

# Filière Systèmes industriels

Orientation Power & Control

## Diplôme 2012

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*Automatisation  
d'un réacteur à plasma*

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Titre / Titel

**Automatisation d'un réacteur à plasma**

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Description et Objectifs / Beschreibung und Ziele

Le laboratoire de physique de la HES-SO Valais dispose d'un réacteur à plasma partiellement équipé. Le but de ce projet est l'instrumentation, l'automatisation et la mise en service du réacteur employé pour des applications médicales ou pour la production de nouveaux matériaux.

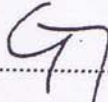
Les objectifs du projet de diplôme peuvent être résumés :


- 1) Conception et réalisation des éléments suivants
  - régulateurs de pression et de température
  - circuits électroniques pour la mesure du courant et de la tension entre le générateur RF et le match-box
  - régulateur d'impédance du réacteur à l'aide des condensateurs variables motorisés du match-box
  - intégration du spectromètre OceanOptics.
- 2) Développement d'une interface d'acquisition de mesures, de commande, de régulation, de supervision et de stockage de données à l'aide du logiciel LabVIEW
- 3) Programmation d'un procédé semi-automatique en implémentant les différentes séquences de démarrage et d'arrêt ainsi que les différentes mesures de sécurité
- 4) Tests et mesures permettant de caractériser le réacteur
- 5) Documentation de l'installation et rédaction d'un mode d'emploi de l'installation complète (Hardware et Software).

Délais / Termine

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## Automatisation d'un Réacteur à Plasma



Diplômant

Davor Volic

### Objectif du projet

Le but de ce projet est l'instrumentation, l'automatisation et la mise en service d'un réacteur à plasma employé pour la production de nouveaux matériaux. Dans un premier temps, l'effet du plasma est étudié sur des échantillons d'amidon placés dans le réacteur.

### Méthodes | Expériences | Résultats

Afin de superviser l'ensemble de l'installation, une interface homme machine est implémentée dans LabVIEW, permettant d'avoir une vue globale de l'installation, d'actionner les différents éléments, de contrôler les différentes grandeurs physiques, de visualiser et de stocker les données.

Les différentes séquences de démarrage et d'arrêt ainsi que les différentes mesures de sécurité sont également implémentées dans LabVIEW.

Afin d'éliminer la puissance réfléchie sur le générateur de haute fréquence, on doit réguler l'impédance interne du réacteur à  $50\Omega$  ainsi que de contrôler le déphasage entre le courant et la tension mesurés sur une matchbox à l'entrée du réacteur.

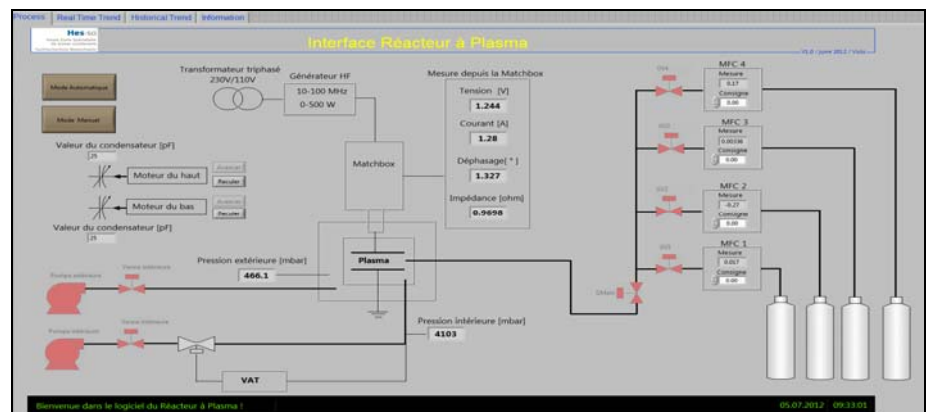
Pour atteindre ce but, deux cartes électroniques sont conçues. La première mesure les valeurs redressées et filtrées des signaux HF de courant et de tension ainsi que leur déphasage. Ces valeurs sont ensuite envoyées vers LabVIEW pour affichage et traitement. La deuxième carte est utilisée pour piloter depuis LabVIEW deux moteurs pas à pas. Ces moteurs sont couplés avec deux condensateurs variables de la matchbox. En variant la capacité des condensateurs, on agit sur l'impédance du réacteur. L'algorithme nécessaire à la régulation de l'impédance n'a pu être implémenté, faute de temps.

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### Interface homme machine

Permet à l'utilisateur d'avoir une vue d'ensemble de l'installation, de commander les différents éléments et de visualiser en temps réel les différentes grandeurs comme débit, pression, tension et courant.

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# 1. Introduction

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Le laboratoire de physique de la HES-SO Valais possède un réacteur à plasma. Le but de ce projet est l'automatisation, l'instrumentation et la mise en service du réacteur à plasma. Le travail est divisé en deux parties distinctes :

La première est le projet de semestre, effectué pendant le sixième semestre à raison de un jour par semaine. À la fin de cette première partie, un programme de base sur Labview a été effectué, celui-ci permet le pilotage des différents éléments composant l'installation.

La deuxième partie est réalisée pendant les 8 semaines du travail de diplôme. L'amélioration de l'interface utilisateur, les réalisations des cartes électroniques de mesure et de commande des moteurs sont les objectifs principaux.

## 2. Cahier des Charges

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Pour le travail de diplôme les tâches suivantes devaient être effectuées :

- Ajout de deux électrovannes et de deux régulateurs de débit, pour pouvoir gérer au total 4 gaz différents.
- Equiper les deux pompes par des relais commandés depuis Labview.
- Remplacer les deux vannes manuelles qui se situent à l'entrée des pompes, par des vannes pneumatique commandées depuis Labview.
- Proposer un éventuel réarrangement de l'armoire électrique.
- Implémenter Labview pour répondre aux critères suivants :
  - ✓ Envoyer la consigne de débit au régulateur.
  - ✓ Afficher la mesure du débit reçu par le régulateur.
  - ✓ Afficher les valeurs de pression extérieure et intérieure des chambres.
  - ✓ Contrôler l'ouverture et la fermeture des cinq électrovannes et des deux vannes pneumatique.
  - ✓ Contrôler l'enclenchement et le déclenchement des pompes.
  - ✓ Programmer une phase d'initialisation.
  - ✓ Programmer une phase de démarrage et d'arrêt de procédé.
  - ✓ Stocker les données et avoir une visualisation graphique des différentes grandeurs.
  - ✓ Proposer une interface utilisateur.
- Effectuer un test d'étanchéité sur l'installation.
- Effectuer un test sur les régulateurs de débit.
- Réaliser et tester un circuit électronique pour la mesure du courant et de la tension entre le générateur HF et le Matchbox.
- Réaliser et tester un circuit de commande des moteurs pas à pas
- Régulation de l'impédance et du déphasage dans la matchbox

## 3. Le Plasma

Un plasma est un milieu gazeux partiellement ionisé. Il est constitué de molécules, d'atomes d'ions et d'électrons. Tout gaz peut atteindre l'état de plasma pourvu qu'une énergie d'excitation suffisante lui soit transmise. Le gaz se transforme en Plasma de la manière suivante :

- Le gaz arrive entre deux électrodes. À pression réduite et stable environ 2 mbar, une tension suffisante pour créer une décharge est appliquée aux électrodes à une fréquence de 13Mhz. À partir de ce moment, les molécules de gaz se fractionnent pour créer des électrons libres, des ions.

La figure 1 montre le diagramme de Paschen. Ce diagramme indique la tension minimale, en fonction du produit entre la pression  $p$  du gaz et de la distance  $d$  entre les électrodes, permettant au courant électrique de se décharger dans le gaz.

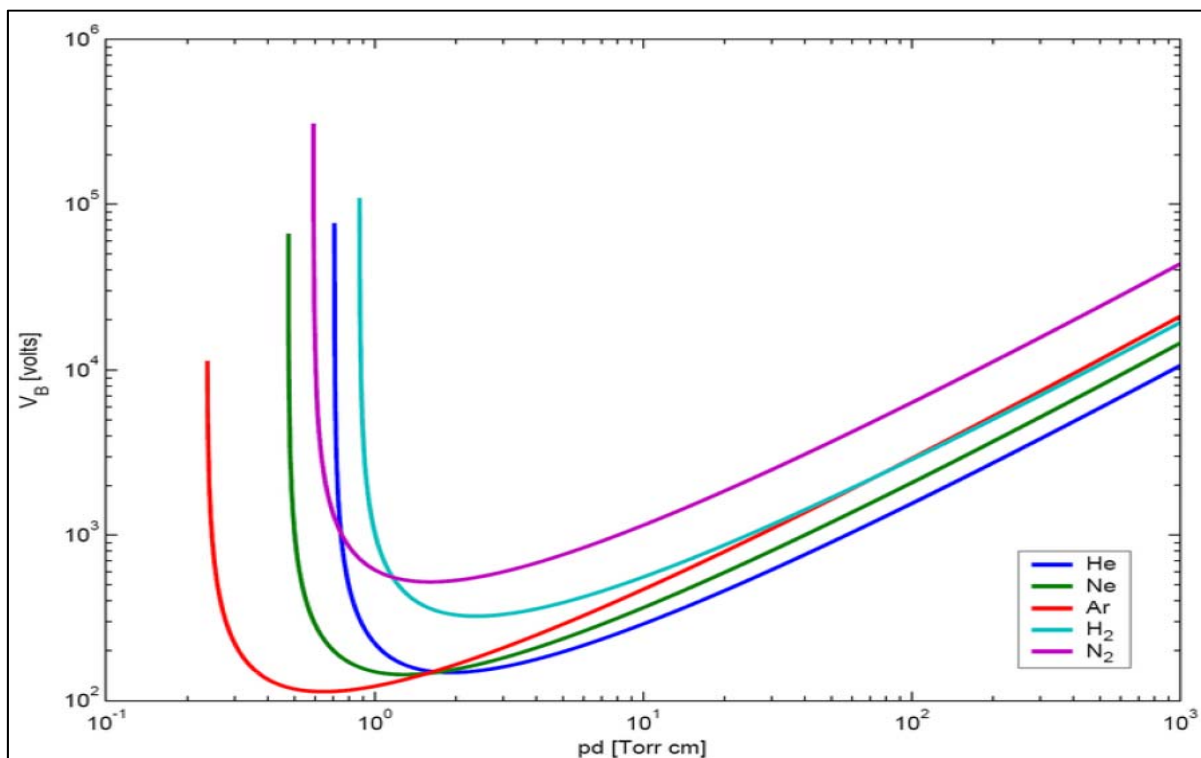


Figure 1: Diagramme de Paschen

## 4. Descriptif de l'Installation

Sur la figure 2, le schéma de principe de notre installation.

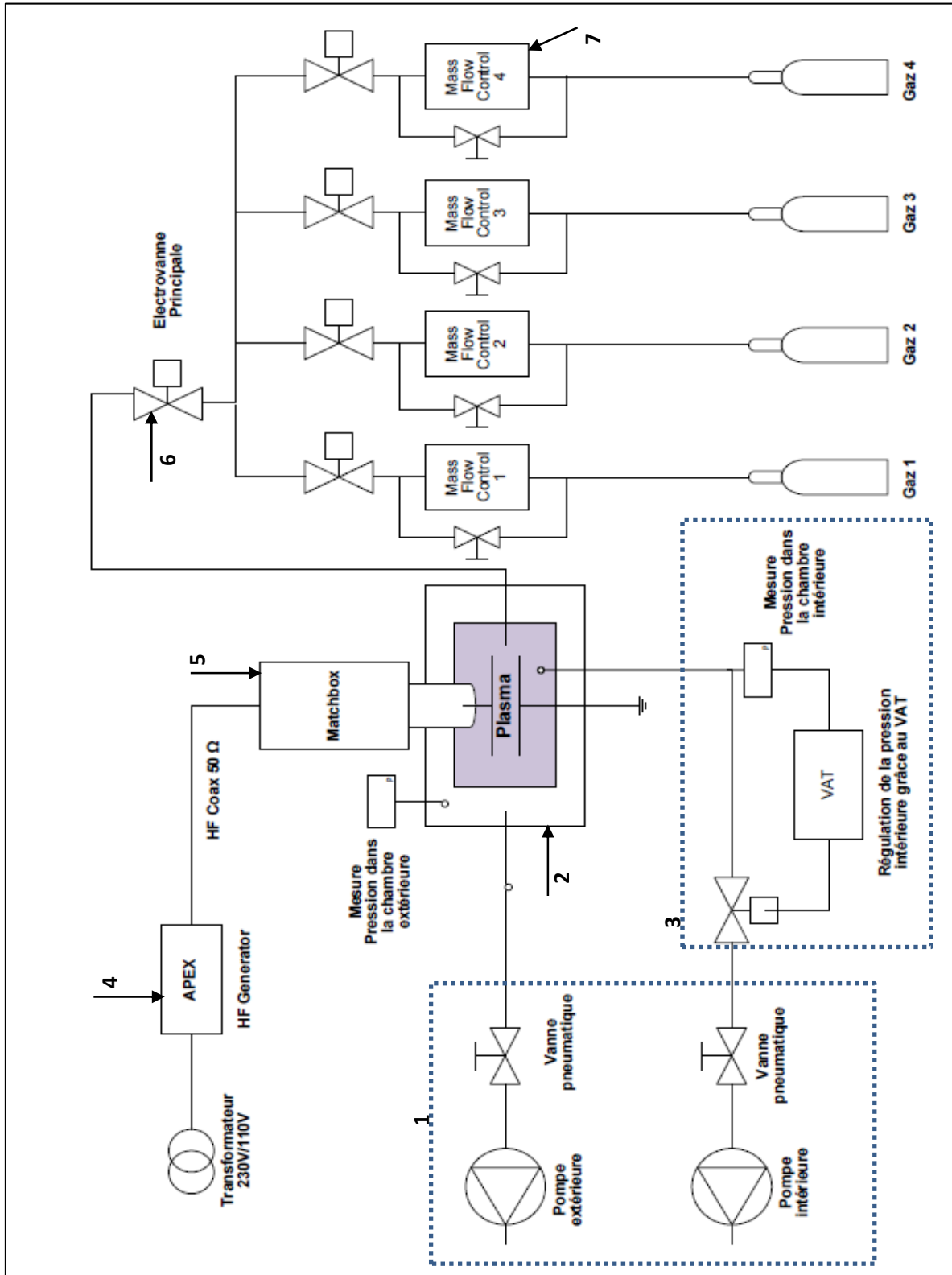


Figure 2: Schéma de principe de l'installation

Le rôle de chacun des éléments selon la figure 2 est expliqué ci-dessous :

- **Nr. 1** : Le système du vide, est composé de deux pompes et de deux vannes pneumatique permettant de faire baisser la pression dans la chambre intérieure et extérieure.

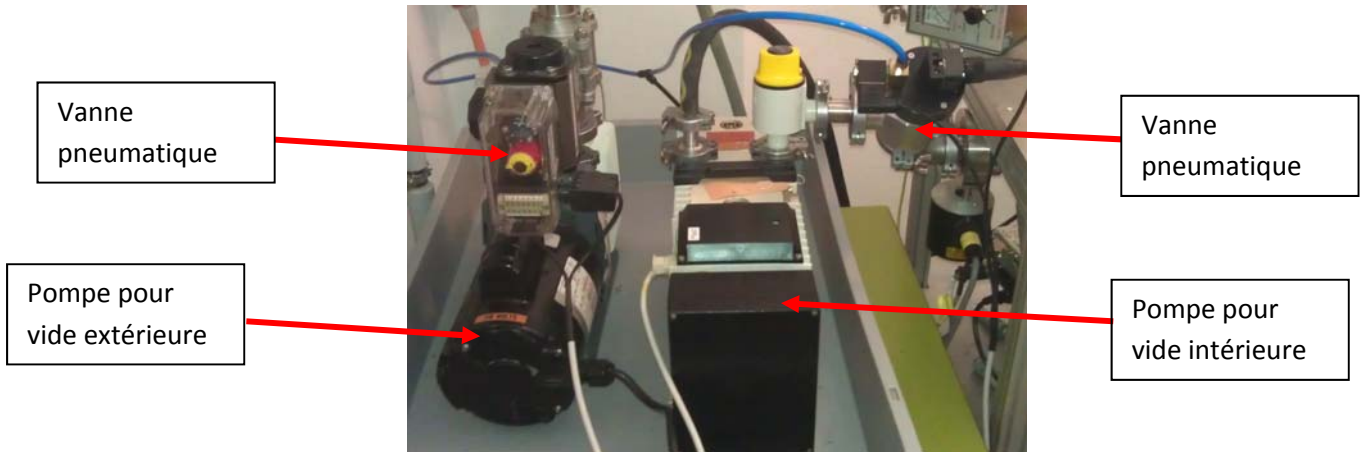


Figure 3: Système de vide

- **Nr. 2** : La chambre intérieure est le compartiment où se situent les électrodes et où le gaz passe à l'état de plasma. La chambre extérieure est utilisée comme sécurité, afin de minimiser les fuites entre la chambre intérieure et la salle.

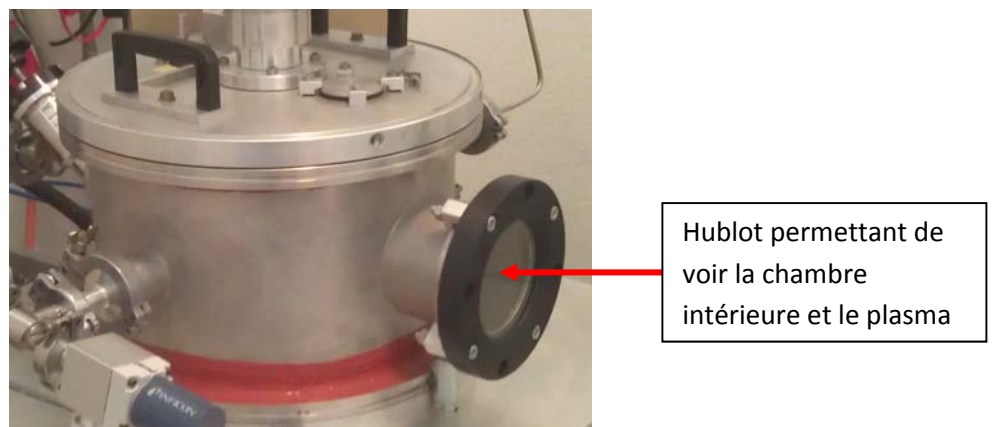


Figure 4: Chambre extérieure

- **Nr. 3** : Régulateur de pression VAT, permettant de contrôler la pression dans la chambre intérieure.



Figure 5: Régulateur de Pression VAT



- **Nr. 4 :** Générateur de fréquence fournissant la puissance nécessaire afin de faire passer le gaz à l'état de plasma.



Figure 6: Générateur de fréquence

- **Nr. 5 :** La matchbox contient les mesures de courant et de tension. Permettant ainsi de définir les valeurs d'impédance et de déphasage nécessaire à la régulation. Les consignes d'impédance et de déphasage sont atteintes grâce à deux condensateurs variables fixés dans la matchbox.

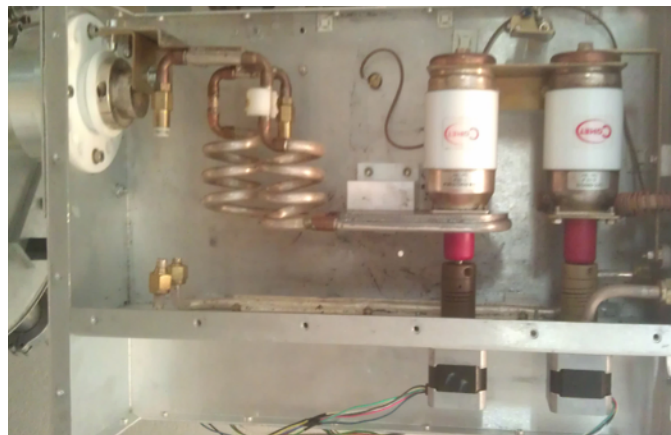


Figure 7: Matchbox

- **Nr. 6 :** Electrovanne commandée depuis Labview pour permettre au gaz d'accéder dans la chambre intérieure.



Figure 8: Electrovanne

- **Nr. 7 :** Le Mass Flow Controller est un régulateur de débit de gaz dont la consigne est fixée depuis Labview.



Figure 9: Mass Flow Controller

Sur notre installation, le gaz passe à l'état de plasma de la manière suivante :

- Premièrement on allume les pompes intérieure et extérieure, une fois les deux pompes enclenchées on ouvre les deux vannes pneumatiques afin de faire baisser la pression dans les chambres extérieure et intérieure.
- Lorsque la pression dans les deux chambres est inférieure à 2 [mbar], l'électrovanne principale ainsi que l'électrovanne correspondante au gaz souhaité peuvent être ouvertes.
- On choisit la consigne de débit de gaz souhaitée puis le gaz est amené dans la chambre intérieure.
- Puis le générateur de fréquence est enclenché manuellement afin d'appliquer une tension à la surface des électrodes et ainsi nous obtenons notre plasma.

### *Schéma électrique*

Le schéma électrique de l'installation se trouve en Annexe 1.

Remarque :

Un des problèmes avec Labview se situe lorsque l'ordinateur est allumé et que le programme Labview n'est pas allumé. Labview mettra automatiquement tous les sorties numériques à 1 et donc les pompes et les vannes seraient enclenchées. Pour éviter ce problème un relais avec des contacts normalement fermés a été ajouté, le rôle de ce relais est de choisir à quel moment les autres relais qui alimentent les vannes et les pompes peuvent être actionnées. Dans le schéma électrique en Annexe 4 le relais à la dénomination "Relais lancer installation". Ainsi lorsque les sorties sont à 1, les contacts de ce relais sont ouverts et donc aucun autre relais n'est alimenté.

### *Conception pièce pour fixation connecteur*

Cette pièce sert de gabarit pour que le connecteur de Type N se fixe dessus.

La pièce sera utilisée lors des tests du générateur haute fréquence et sera placée entre le générateur et la Matchbox Vectronics.

En Annexe 2 les plans de la pièce

## 5. Matchbox

Le rôle de la matchbox est de réguler l'impédance du système et le déphasage entre courant et tension, grâce à deux moteurs pas à pas qui font varier la valeur des condensateurs.

Sur les figures 10 et 11 le schéma équivalent de la matchbox et la photo :

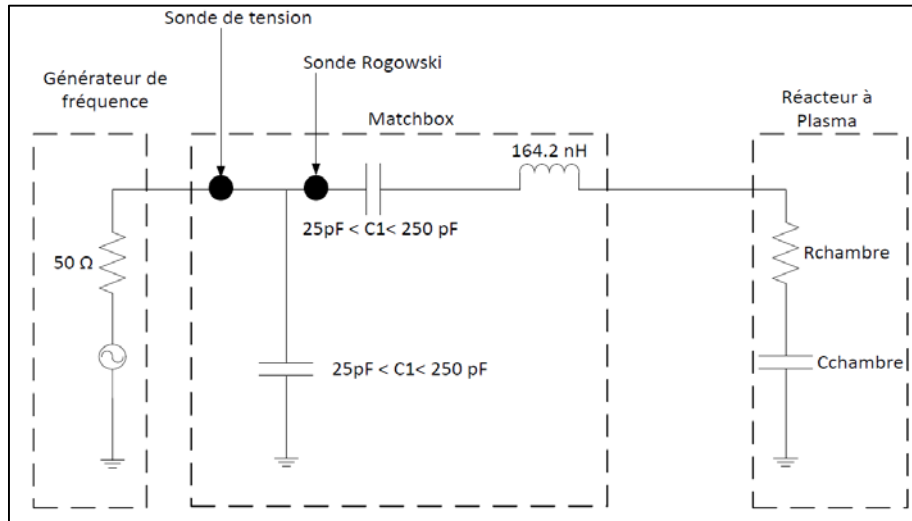


Figure 10: Schéma HF-Système

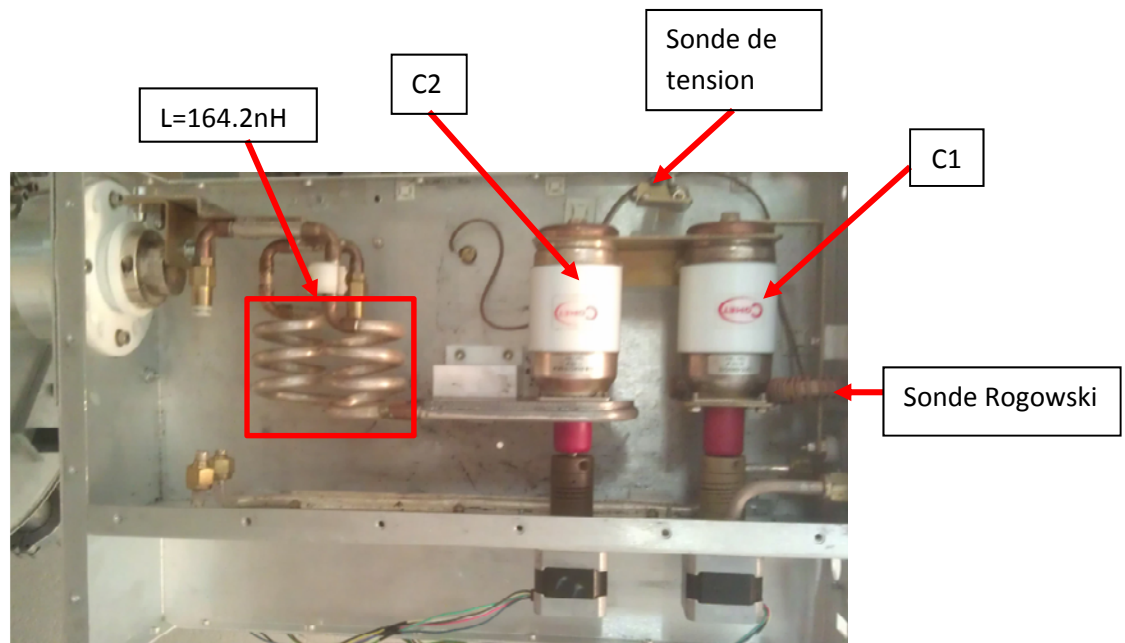


Figure 11: Matchbox

La valeur de l'impédance dans la chambre varie en fonction de la fréquence. Le dessin de la figure 12 qui représente l'intérieure du réacteur explique l'origine de cette impédance.

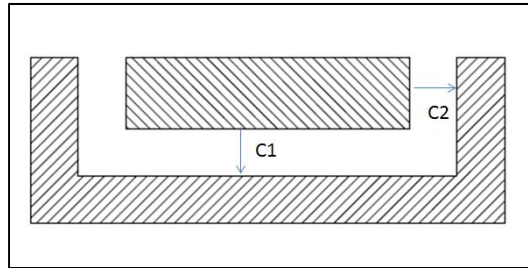


Figure 12: Coupe du Réacteur à Plasma

Le vide qu'il existe entre l'électrode et la terre se comporte comme un condensateur. Un teste a été effectué, par mes collègues lors du PGA, pour déterminer la valeur de cette impédance .Le test a été effectué sans apport de gaz et à pression ambiante. Le résultat est visible sur la figure 13

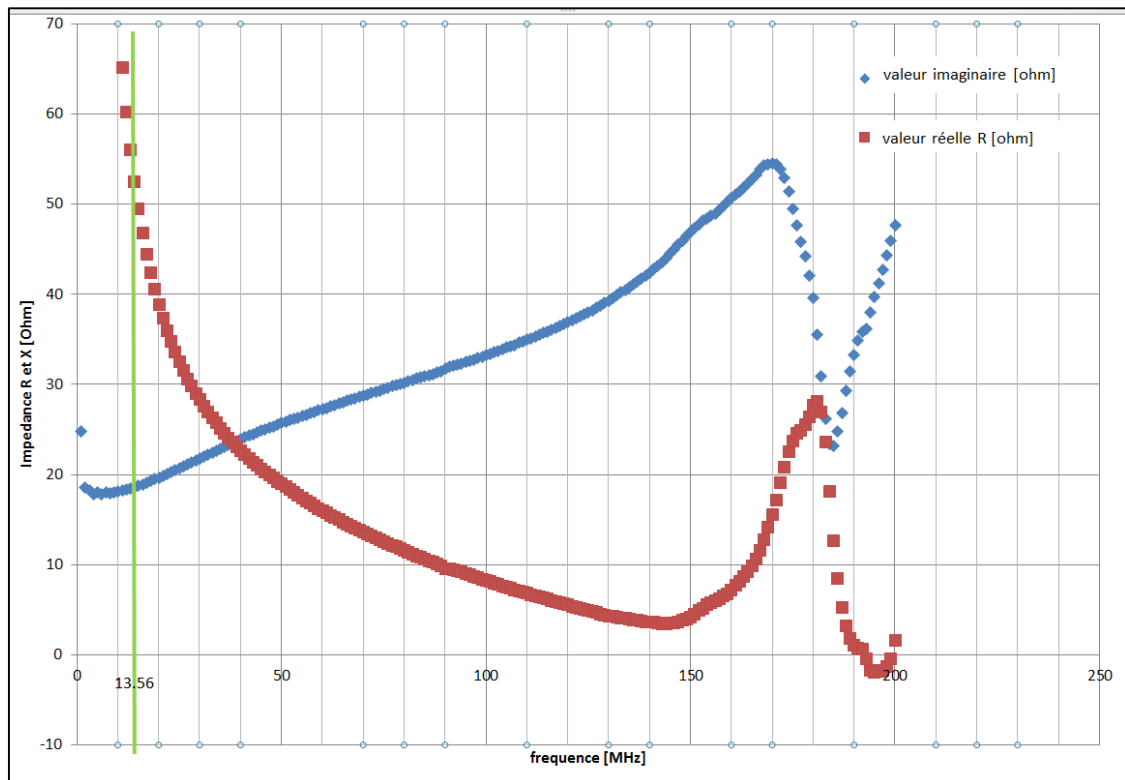


Figure 13: Valeur de l'impédance dans la chambre en fonction de la fréquence

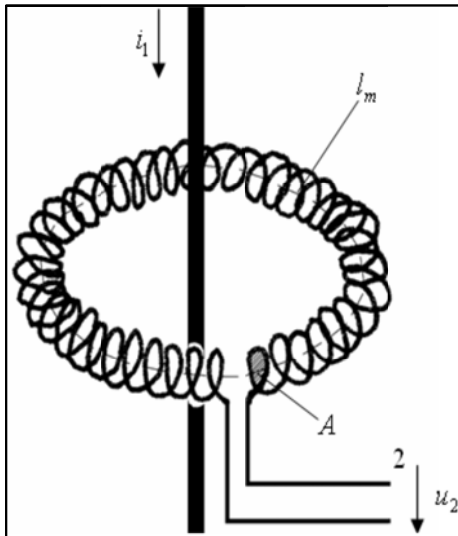
La capacité d'un condensateur est calculée de la manière suivante :

$$C = \varepsilon_0 \cdot \varepsilon_r \cdot \frac{A}{d}$$

Avec  $\varepsilon_0 (8.84 \cdot 10^{-12} \frac{C^2}{Nm^2})$  qui représente la permittivité relative du vide et  $\varepsilon_r$  la permittivité relative du gaz présent dans le réacteur. Donc la valeur de l'impédance dans le réacteur dépend du gaz injecté.

## 5.1 Mesure du courant

Le courant circulant dans la matchbox est mesuré grâce à un enroulement Rogowski.

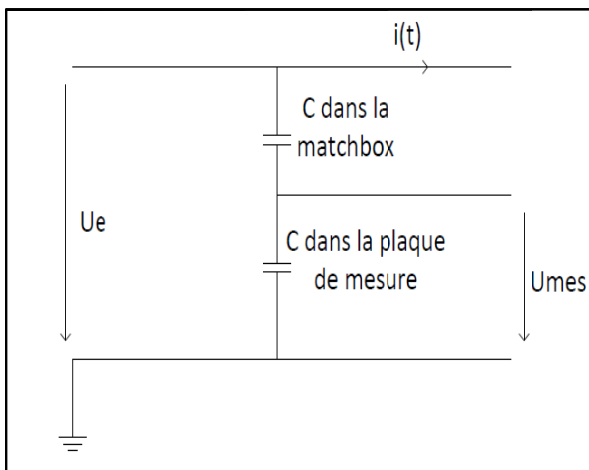


La tension induite  $U_2$  est proportionnel à la dérivée du courant dans le conducteur. Cette tension est ensuite amenée jusqu'à la plaque PCB de mesure qui s'occupe du traitement du signal.

Habituellement l'enroulement Rogowski est relié un circuit intégrateur afin de compenser le déphasage de  $90^\circ$  dû à la tension induite qui est proportionnel à la dérivée du courant.

## 5.2 Mesure de tension

La tension est mesurée grâce à un diviseur capacitif.



La valeur de la capacité dans la Matchbox est définie de la manière suivante :

$$C = \epsilon_0 \cdot \epsilon_r \cdot \frac{A}{d}$$

Avec comme paramètre les valeurs suivantes :

$$S = L \cdot l = 30\text{mm} \cdot 10\text{mm} = 0.00075 \text{ mm}^2$$

$$d = 19\text{mm}$$

$$\varepsilon_0 = 8.86 \cdot 10^{-12} \frac{\text{C}^2}{\text{Nm}^2}$$

Ce qui nous donne comme valeur de capacité  $C=0.35\text{pF}$

Cette tension mesuré va ensuite sur la plaque PCB de mesure qui converti notre tension sinusoïdale en tension efficace.

## 6. Carte Électronique

### 6.1 PCB De Mesure

Comme expliqué dans les chapitres 5.1 et 5.2, une mesure de tension et de courant sinusoïdal à haute fréquence est effectuée grâce à la sonde Rogowski et à la sonde de tension. Le problème est que ces fréquences beaucoup trop élevées (10Mhz – 100Mhz) ne permettent pas de rentrer directement sur les cartes d'acquisition.

Pour remédier à ce problème une électronique de mesure a été conçue. Le rôle de cette carte est d'obtenir les valeurs efficaces courant et tension, ainsi que le déphasage entre les deux signaux. La schématique de l'électronique se trouve en Annexe 3 et le protocole de test se trouve dans le chapitre 8.4.

Ci-dessous le schéma bloc permettant une meilleure compréhension de la solution choisie et la photo de la carte PCB.

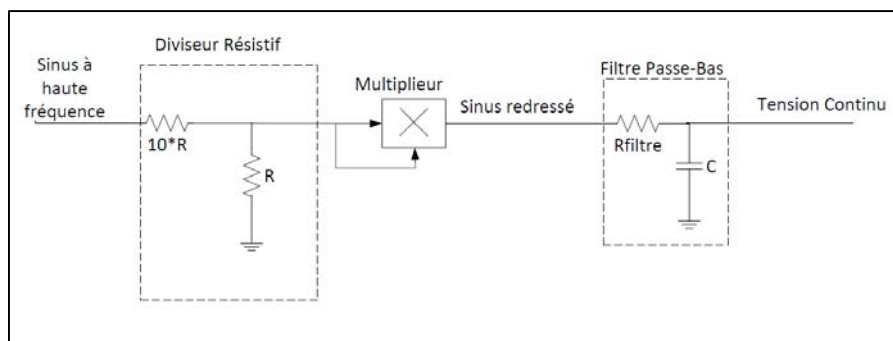


Figure 18: Schéma bloc pour conversion Sinus vers valeurs efficace

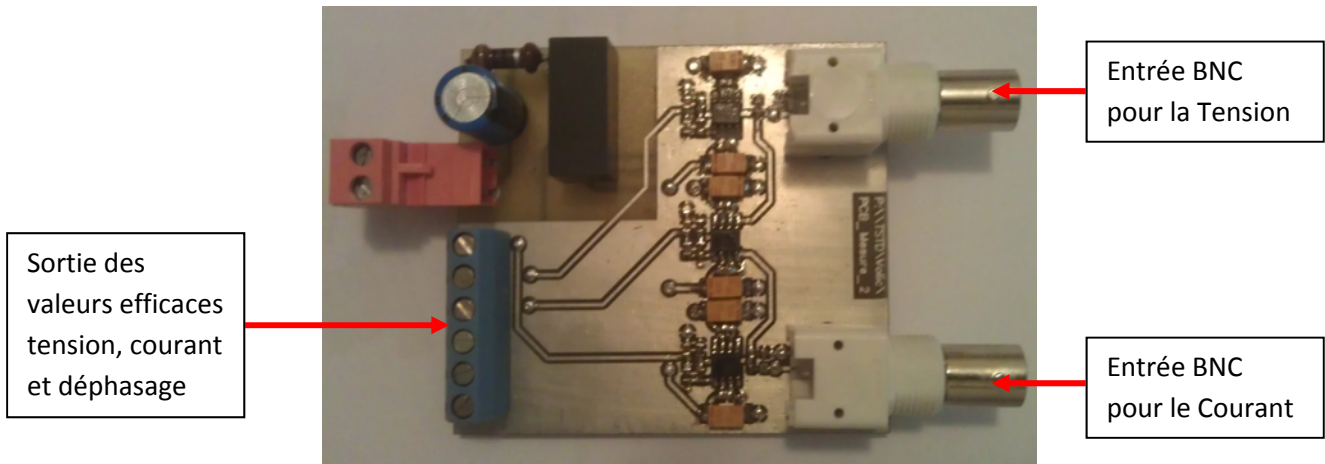


Figure 19: Carte électronique de mesure

### 6.1.1 Conversion Tension et Courant en valeur efficace

Afin de ne pas avoir de perturbation du aux hautes fréquences appliquées (10Mhz – 100Mhz), la liaison entre la matchbox et l'électronique de mesure se fait à l'aide de câbles coaxiaux. De plus tous les composants utilisés sur la carte sont des SMD pouvant travailler aux fréquences désirées.

La Conversion de courant et de tension sinusoïdale en valeur RMS se fait de la manière suivante :

- À l'entrée du PCB un diviseur résistif pour le courant et un diviseur capacitif pour la tension ont été mis en place afin de ne pas faire saturer la sortie du multiplieur.

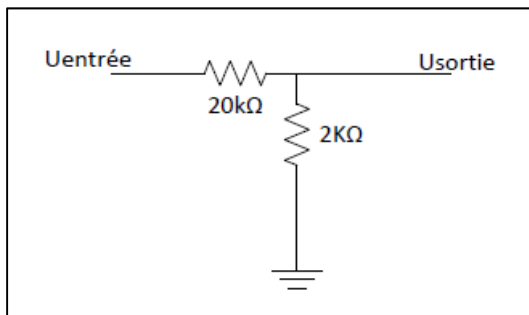


Figure 21 : Diviseur résistif

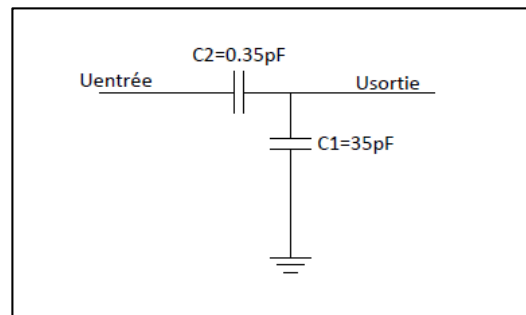


Figure 20 : Diviseur capacitif

Rapport des diviseurs :

- Diviseur résistif :  $U_{sortie} = U_{entrée} \cdot \frac{2k}{2k+20k} \rightarrow \frac{U_{sortie}}{U_{entrée}} = 0.09$
- Diviseur capacitif :  $U_{sortie} = U_{entrée} \frac{\frac{1}{sC1}}{\frac{1}{sC1} + \frac{1}{sC2}} = U_{entrée} \frac{C2}{C2+C1} \rightarrow \frac{U_{sortie}}{U_{entrée}} = 0.009$

- Le multiplieur choisi est l'AD835 (datasheet Annexe 4) car le chip peut travailler jusqu'à des fréquences de 200 MHz. Il multiplie le sinus par lui-même et donc en sortie on obtient un sinus redressé.
- Le sinus redressé est transformé en tension continu grâce au filtre passe bas. Cette valeur est égale au carré de la valeur RMS souhaité. Pour obtenir la valeur correcte une mise sous racine est effectuée dans Labview.

Choix des composants pour le filtre passe-bas.

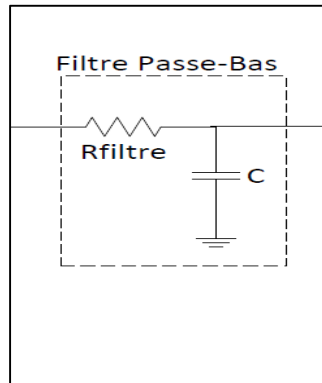


Figure 22: Filtre Passe-Bas

Le choix de la fréquence de coupure est dimensionné par rapport à la plus basse de fréquences fourni par le générateur (10 MHz). Après plusieurs essais avec des valeurs de résistance et de condensateurs différentes, les composants suivant ont été choisi :

- R = 12 KΩ
- C = 100 pF

D'où nous obtenons la fréquence de coupure suivante :

$$f_c = \frac{1}{2 \cdot \pi \cdot R \cdot C} = \frac{1}{2 \cdot \pi \cdot 12 \cdot 10^3 \cdot 100 \cdot 10^{-12}} = 132 \text{ KHz}$$

### 6.1.2 Mesure Déphasage entre U et I

Le déphasage entre le courant et la tension s'obtient grâce au multiplieur AD835. Le schéma de principe est sensiblement le même que pour obtenir la valeur RMS

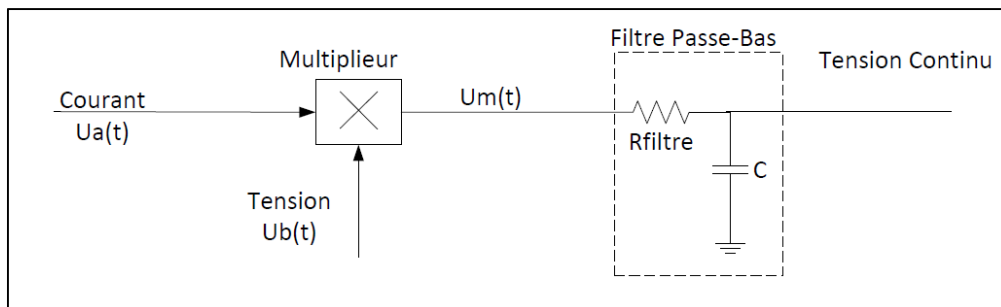


Figure 23: Mesure déphasage entre U et I



La sortie du multiplieur  $U_m(t)$  varie en fonction du temps et est définie par l'équation suivante :

$$U_m(t) = U_a(t) \cdot U_b(t) = (\hat{U}_a \cdot \sin(\omega t + \gamma_i)) \cdot (\hat{U}_b \cdot \sin(\omega t + \gamma_u))$$

$$= \frac{\hat{U}_a \cdot \hat{U}_b}{2} (\sin(\gamma_i - \gamma_u)) + \sin(2\omega t + \gamma_i + \gamma_u)$$

Composante Continue

Composante en fonction de la fréquence

Pour obtenir le déphasage, seul la composante continue nous intéresse, la seconde composante sera supprimée par le filtre. La valeur lu sur la carte d'acquisition pour le déphasage est :

$$Tension\ continu = U = \frac{\hat{U}_a \cdot \hat{U}_b}{2} \sin(\gamma_i - \gamma_u)$$

Ainsi nous obtenons la valeur de déphasage entre le courant et la tension :

$$\gamma_i - \gamma_u = \sin^{-1}\left(\frac{U \cdot 2}{\hat{U}_a \cdot \hat{U}_b}\right)$$

La partie non continue de l'équation est supprimés avec le filtre passe-bas dont la fréquence de coupure est égale à deux fois la plus haute des fréquences du générateur. Dans notre cas, le générateur Appex a une fréquence fixe de 13.6Mhz, et donc la fréquence de coupure du filtre doit être égale à 27.2Mhz. Après plusieurs tests les composants suivants ont été choisis :

- R = 12 KΩ et C = 50pF

## 6.2 Commande moteur

Afin de pouvoir régler l'impédance et le déphasage, deux condensateurs variables sont fixé dans la matchbox. Ces deux condensateurs sont ajustés grâce à deux moteurs qui son pilotés depuis Labview.

Les moteurs utilisés sont des moteurs pas à pas dont le datasheet se trouve en Annexe 5.

|            | Valeur Nominal |
|------------|----------------|
| Résolution | 1.8°           |
| Nbr de pas | 200 pas/tour   |
| Courant    | 1.2A par phase |
| Tension    | 4V             |

Tableau 1: Données du moteur



Figure 24 : Moteur pas à pas

*Mode de commande*

Il existe deux modes de commande différentes pour les moteurs pas à pas. Le mode de commande demi-pas et pas entier. Le mode de commande demi-pas a été choisi. Son principal avantage est qu'il augmente le nombre de pas dans un tour d'un facteur deux et donc la précision de la valeur du condensateur (datasheet Annexe 6). Pour chaque demi-pas effectué la capacité du condensateur varie de 0.0625pF.

|              | Cmin  | Cmax  | Cmin à Cmax | pF/tour      |
|--------------|-------|-------|-------------|--------------|
| Condensateur | 25 pF | 250pF | 10.8 Tours  | 20.83pF/tour |

Tableau 2: Données du condensateur

Le schéma électronique de commande se trouve en Annexe 7 et le protocole de test se trouve au chapitre 8.5 , le schéma bloc suivant facilite la compréhension du système. Le fonctionnement de chacun des éléments est expliqué dans le chapitre 6.2.1.

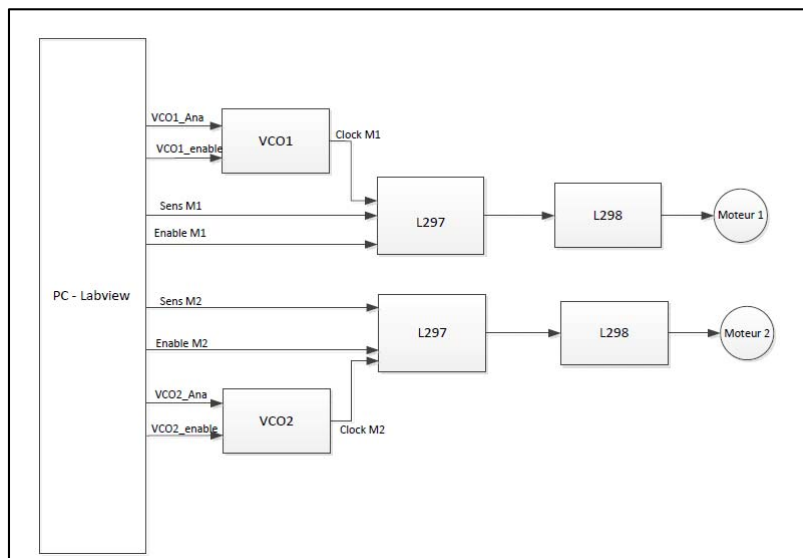


Figure 25: Schéma bloc de commande des moteurs

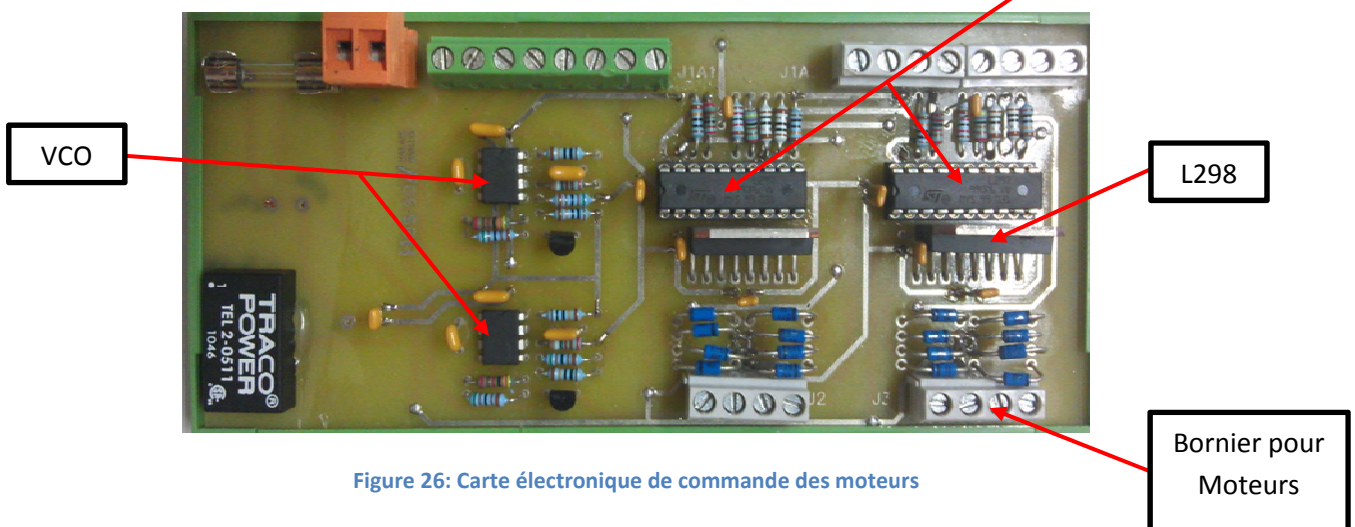


Figure 26: Carte électronique de commande des moteurs

## 6.2.1 Circuit de commande

### Voltage Controlled Oscillator

Un VCO (Voltage Controlled Oscillator) est un oscillateur piloté par une tension continue. Deux VCO sont nécessaire pour piloter la vitesse des deux moteurs séparément. Le VCO est indispensable car les TTL fourni par les cartes d'acquisition, ne sont pas capable d'aller à une fréquence au-dessus de 50Hz. Le datasheet des VCO utilisés se trouve en annexe 8

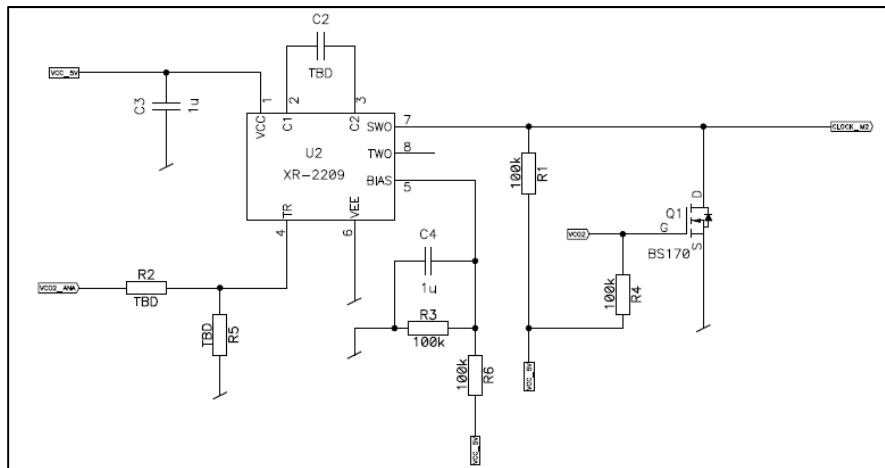


Figure 27: VCO XR-2209

Le VCO est commandé à l'aide de deux signaux, un signal analogique et un signal digital. La fréquence souhaitée est fixé à l'aide de VCO1\_ANA et comme le VCO fournit en tout temps un signal de sortie carré, il est nécessaire de le couper. Pour ce faire un mosfet BS170 a été placé. Un 5 V sur la gate du mosfet permet de stopper le signal de sortie du VCO.

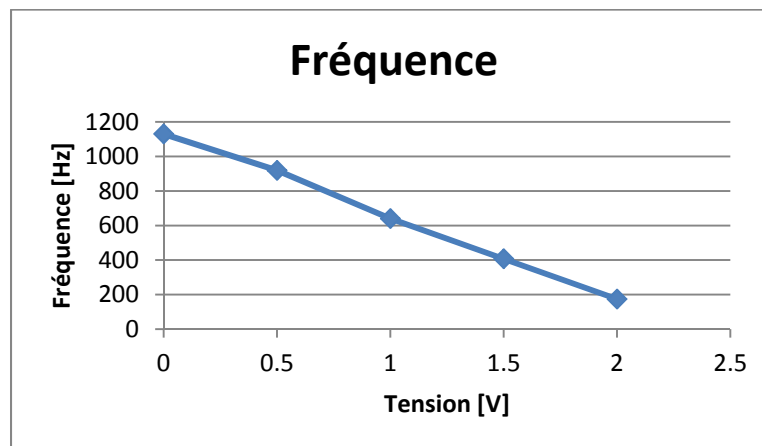


Figure 28: Test Linéarité du VCO

Le VCO est linéaire, et sa plage de fréquence varie entre 1130Hz et 200Hz pour une tension allant de 0V à 2V. En mode demi-pas, 1130Hz représente un vitesse pour le moteur de 2.9 tours/s et pour 200Hz 0.5 tours/s.

## L297

Le chip L297 (datasheet Annexe 9) contient toutes les commandes nécessaires au pilotage d'un moteur pas à pas. Utilisé avec un double pont H, dans notre cas le L298, l'ensemble constitue un pilotage idéal d'un moteur pas à pas depuis Labview.

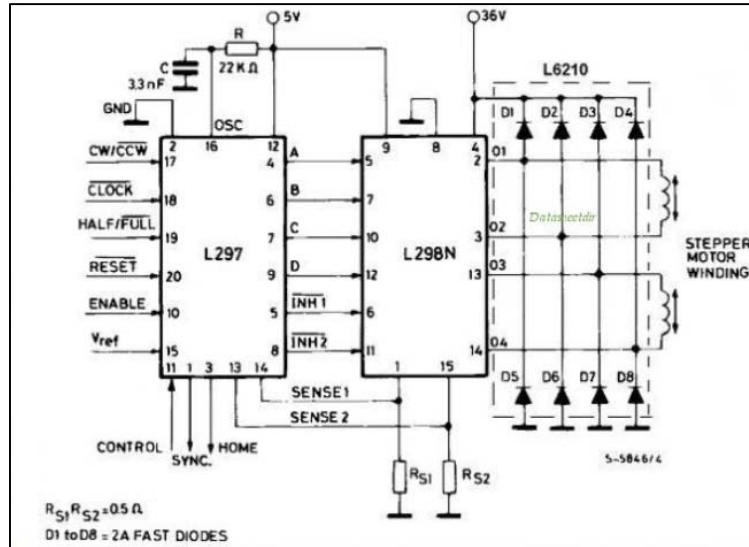


Figure 29: Circuit de commande L297 avec le pont H L298N

Le L297 est capable de générer les TTL des deux phases du moteur en fonction d'un train d'impulsion qu'il reçoit sur son entrée clock.

Voici la description des principaux signaux d'entrées sur le L297 :

- **Clock** : signal d'horloge provenant du VCO, fixant la vitesse du moteur. Chaque flanc montant incrémente le moteur d'un demi-pas.
- **cw/CCW** : sélection du sens de rotation.
- **Enable** : Le niveau logique 0, le moteur est inactif ce qui permet à son axe de tourner librement. Lorsque le niveau passe à 1 le moteur est prêt à être activé.
- **Vref** : tension de référence permettant de fixer la limitation de courant
- **Half/Full** : indique dans quel mode de commande vous pilotez, mode pas entier ou demi-pas.

Voici les signaux des deux phases (phase 1 A-B, phase 2 B-C) dans le mode demi-pas.

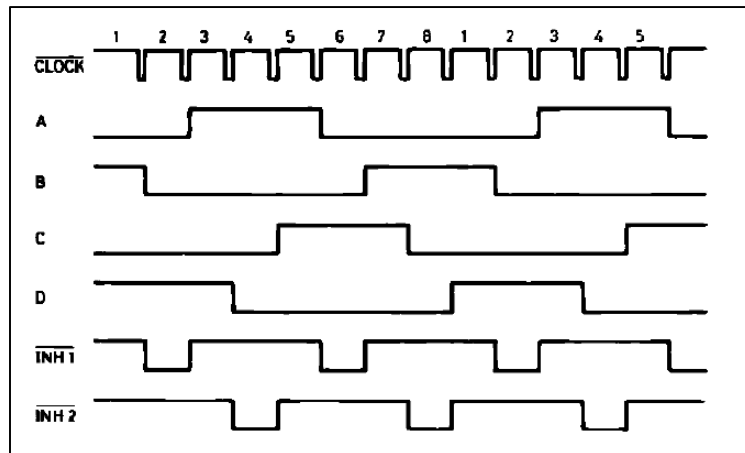


Figure 30: Signaux des du mode demi-pas

La limite supérieure du courant à fixer sur  $V_{ref}$  est choisie au courant nominal du moteur soit 1.2 A plus une marge de 0.2 A donc 1.4 A. Cette valeur doit être fixée en tension. Étant donné que les résistances shunts  $R_{s1}$  et  $R_{s2}$  valent  $1\Omega$ , on obtient 1.4V qui est équivalent à 1.4A.

Cette valeur est définie avec le diviseur de tension suivant :

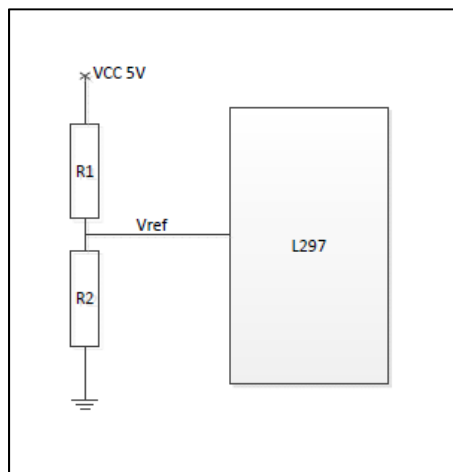


Figure 31: Diviseur de tension

$$V_{ref} = V_{cc} \cdot \frac{R_2}{R_2 + R_1} = 1.4 \text{ avec } R_2 = 4.7 \text{ K}\Omega \text{ et donc } R_1 = 12\text{K}\Omega$$

### L298N

Le L298N (datasheet Annexe 10) est un double pont en H formant ainsi l'étage de puissance permettant de piloter le moteur pas à pas. Il possède un accès à l'émetteur de chaque driver, ainsi l'intensité du courant traversant les bobines est connue par l'intermédiaire des résistances shunts.

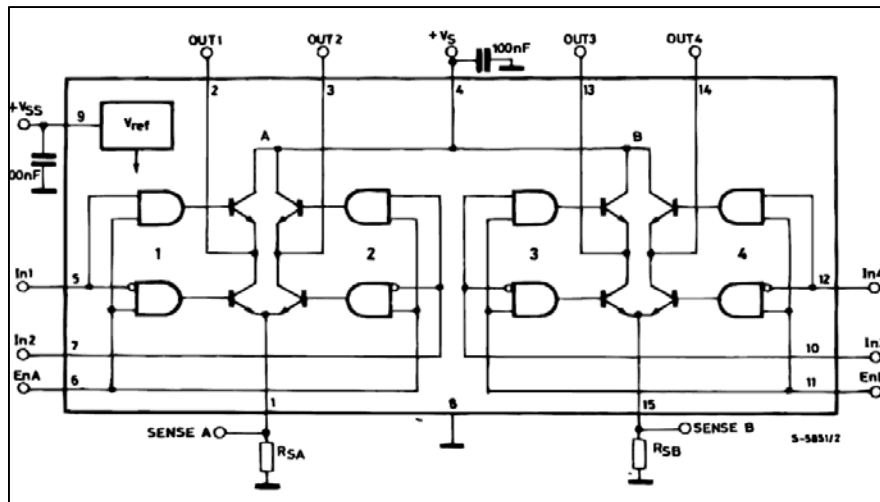


Figure 32: L298N

Une attention particulière a été portée au fait que le circuit L298N ne possède pas de diodes de roues libres. Il est donc nécessaire de les ajouter au montage. Ces diodes sont des BYV 10 qui supportent un courant de 1.5 A. Elles sont utilisées uniquement lorsque le moteur est stoppé, ainsi le moteur qui est composé d'inductances peut se décharger au travers des diodes.

## 7. Labview

### 7.1 Carte d'acquisition

Les modules choisis pour la gestion de l'envoi et de la réception des signaux depuis Labview jusqu'aux cartes électronique et sur la carte des relais se fais à l'aide de :

- Une carte d'acquisition NI USB-6008 dont le datasheet se trouve en Annexe 11
- Deux cartes d'acquisitions NI PCI-MOI-16XE-50 dont le datasheet se trouve en Annexe 12

La liste des entrées sorties des cartes d'acquisition se trouve en Annexe 13.

## 7.2 Interface Homme Machine

Afin d'avoir une interface utilisateur des plus conviviales possible, je me suis basé sur le schéma de principe de la figure 1 pour créer mon interface. Ainsi chaque utilisateur pourra retrouver tous les éléments de l'installation sur l'écran de l'ordinateur, et de cette manière s'y retrouver beaucoup plus facilement. L'interface permet de commander et de visualiser chaque composant de l'installation.

L'interface homme machine est composé de trois panneaux différents. On passe facilement d'un affichage à l'autre grâce aux labels qui se situent en à gauche de l'interface(voir Figure 33). Les 3 affichages possibles sont les suivants :

- **Process** : Interface homme machine permettant de commander et de visualiser chaque composant de l'installation.
- **Real time Trend** : Permet d'afficher sur un graphique les valeurs désirées en temps réel. En annexe 14 un exemple de visualisation des graphiques.
- **Historial Trend** : Permet d'afficher sur un graphique les valeurs désirés en choisissant sur quel durée on veut afficher les données. Toutes les valeurs lues des 365 derniers jours sont enregistrées dans un fichier, et ainsi nous pouvons les afficher à n'importe quel moment. En annexe 15 un exemple de visualisation des graphiques.

L'installation peut être commandée de deux manières différentes :

### *Mode manuel*

Dans ce mode, l'utilisateur a accès à tous les éléments de l'installation. Il peut choisir l'ordre d'enclenchement des pompes et des vannes pneumatiques. Ce mode permet aussi à l'utilisateur de faire varier les capacités des condensateurs en avançant ou en reculant les moteurs.

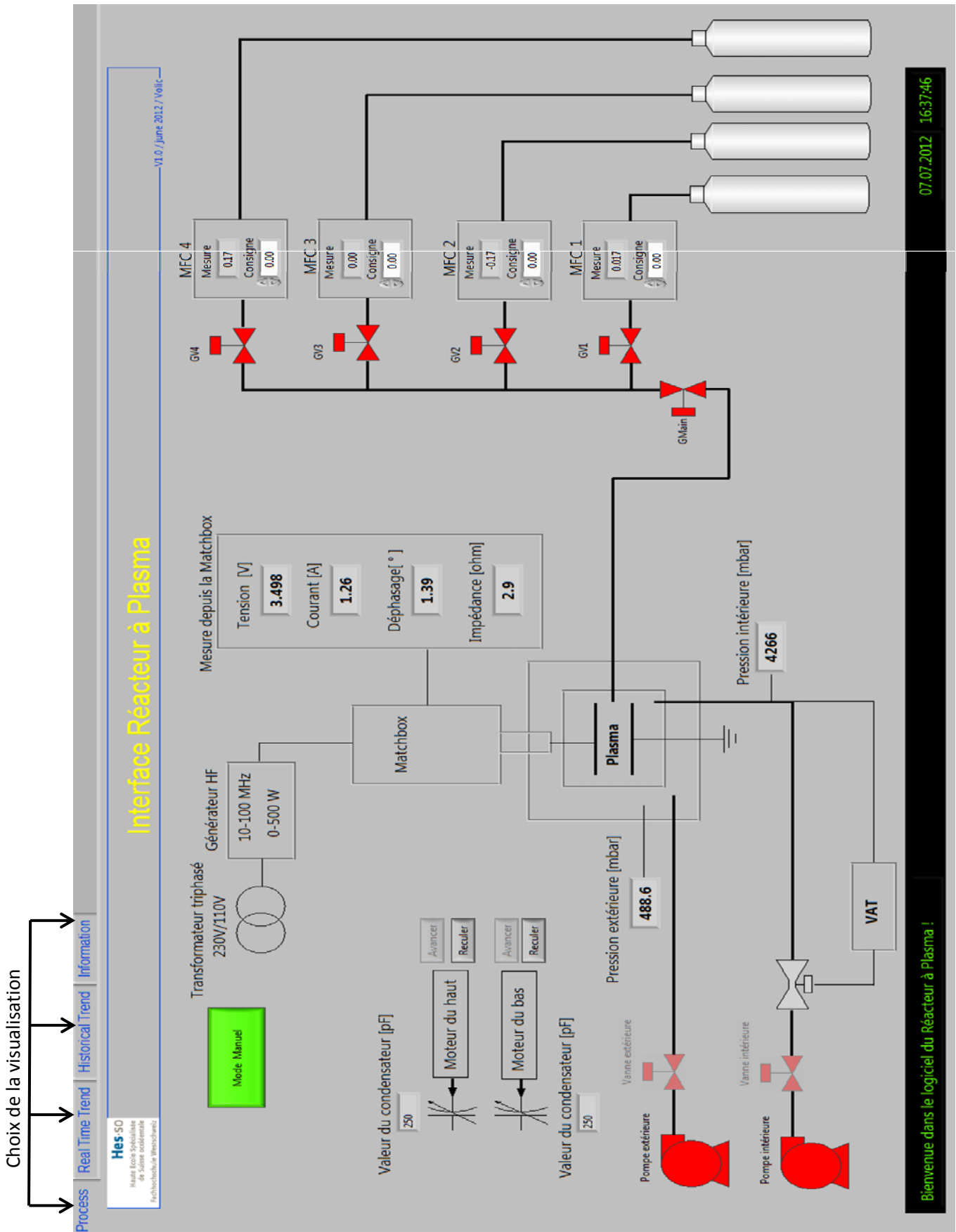


Figure 33 : Interface homme machine en mode manuel



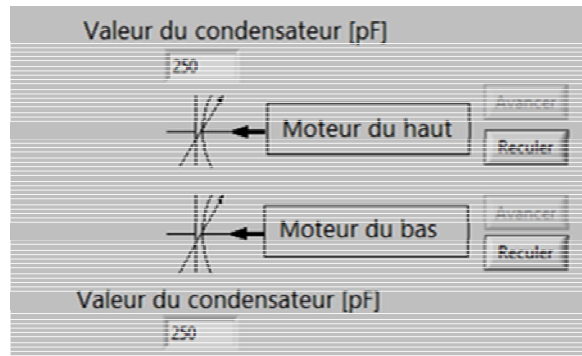


Figure 34: Commande Moteur pas à pas dans le mode manuel

Sur la figure 34, se trouve la commande utilisée pour piloter les deux moteurs pas à pas. Cette commande n'est accessible qu'en mode manuel. La programmation nécessaire pour le pilotage des deux moteurs est traitée au chapitre 7.3.3.

### Mode automatique

Dans ce mode, les vannes pneumatiques et les pompes s'enclenche, dès que l'utilisateur appuie sur le bouton "Mode Automatique". Avec ce mode l'utilisateur n'a pas accès au pilotage des moteurs pas à pas, mais il devra donner des consignes d'impédance et de déphasage, et c'est un régulateur implémenté dans Labview qui contrôlera les moteurs afin d'arriver aux consignes souhaitées.

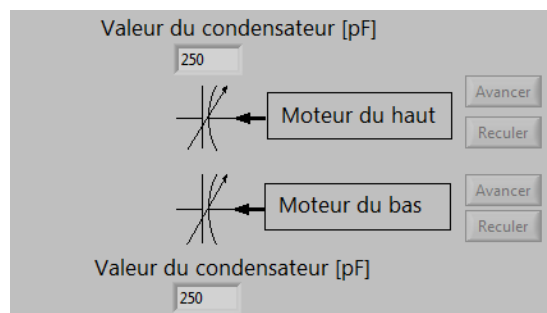


Figure 35: Commande moteur pas à pas inaccessible en mode automatique

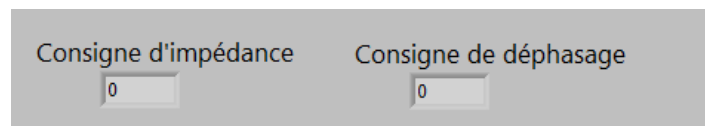


Figure 36: Consignes d'impédance et de déphasage

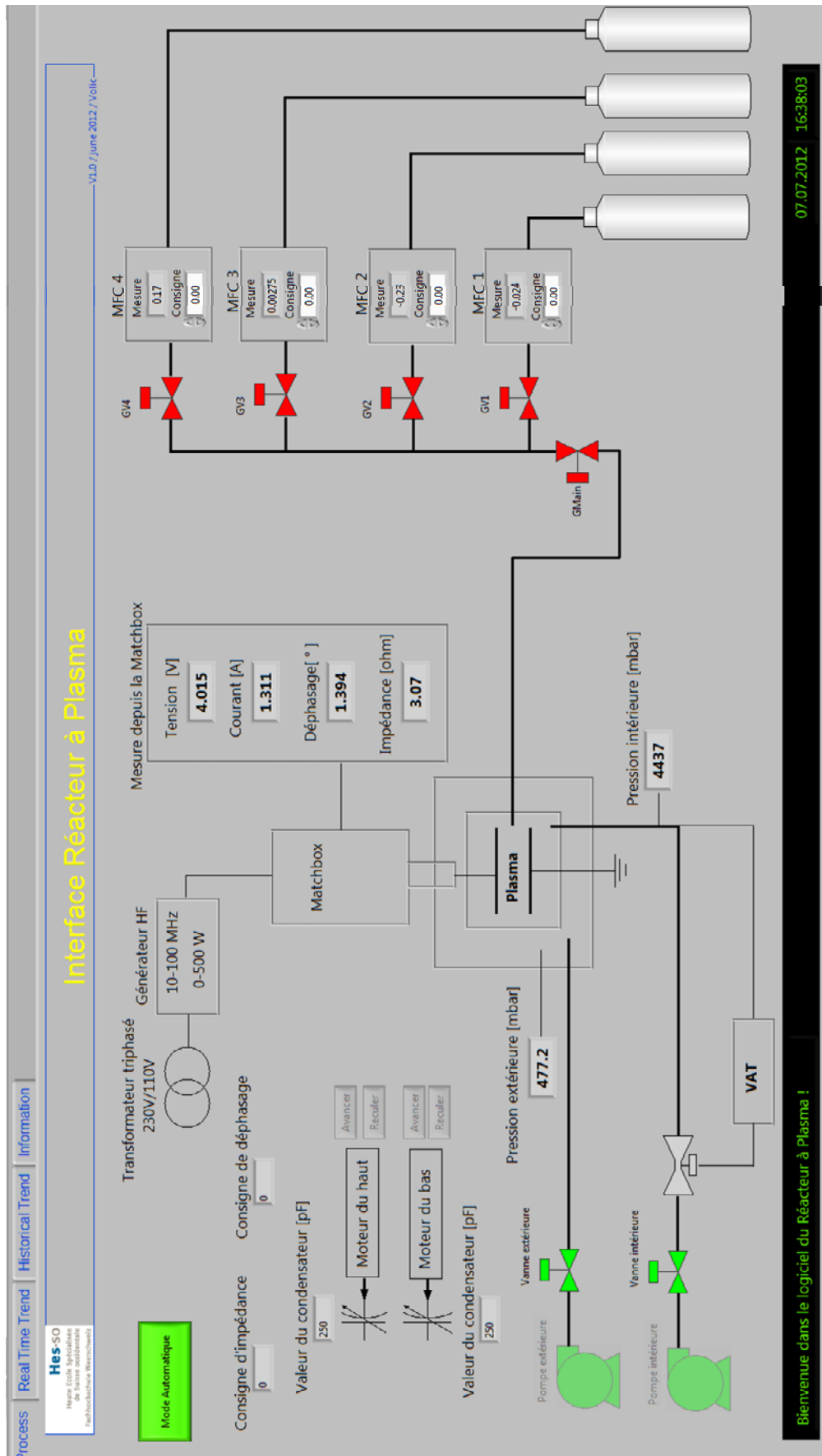


Figure 37 : Interface homme machine mode automatique

## 7.3 Programmation

### 7.3.1 Acquisition

#### Sorties digitales

La figure 38 représente la programmation nécessaire pour changer un bit à la sortie.

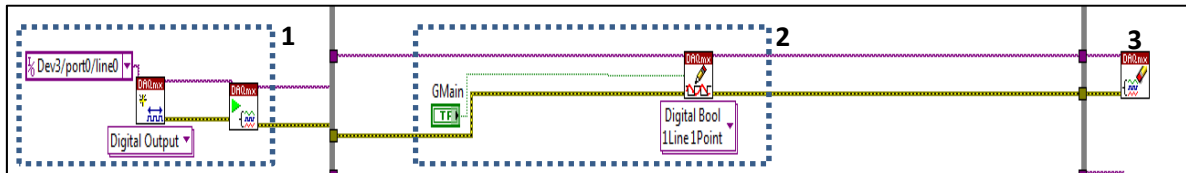


Figure 38: Programmation sortie digital

Cette partie du programme gère la sortie digitale de l'électrovanne principale.

Voici l'explication de l'utilité de chaque bloc qui se trouve sur la figure 38 :

- **1** : Définit dans quelle carte d'acquisitions et sur quelle sortie notre programme va aller écrire. Dans notre cas Device 3 représente le NI USB-6008, et ira écrire sur la sortie port 0 ligne 0 qui est désigné par DO.0
- **2** : Lis la variable Gmain pour savoir si il y a eu un changement d'état
- **3** : Indique la fin du programme.

#### Sorties Analogiques

La figure 39 représente la programmation nécessaire pour gérer une sortie analogique.

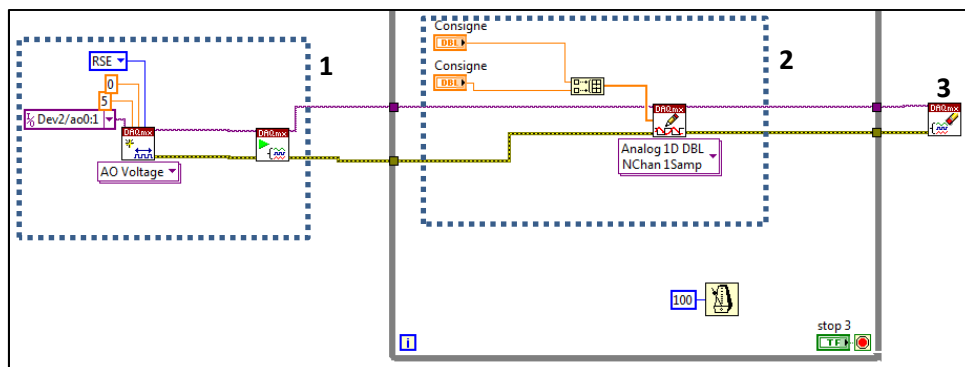


Figure 39: Programmation sorties analogiques

Cette partie du programme gère l'envoi d'une consigne entre 0-5V sur les MFC 1 et 2,

Voici l'explication de l'utilité de chaque bloc:

- **1** : Définit dans quelle carte d'acquisitions et sur quelle sortie notre programme va aller écrire. Dans notre cas Device 3 représente le NI USB-6008, et ira écrire sur les sorties AO.0 et AO.1. La limitation de 0-5V se fixe dans ce bloc.
- **2** : Lecture des valeurs de consignes imposées depuis l'interface utilisateur et ces valeurs sont ensuite enregistrées dans un tableau, puis écrits sur la sortie.
- **3** : Indique la fin du programme.

### Entrées analogiques

La figure 40 représente la programmation nécessaire pour lire les entrées analogiques.

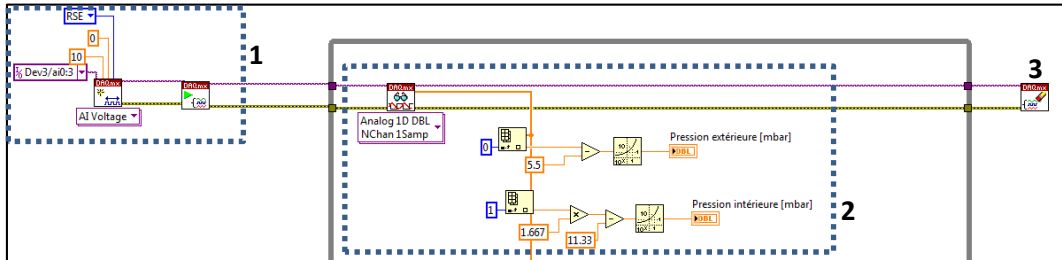


Figure 40: Programmation entrées analogiques

Cette partie du programme est utilisé pour aller lire l'entrée analogique, ce sont les valeurs des pressions des chambres intérieures et extérieures qui sont lues dans cet exemple.

Voici l'explication de l'utilité de chaque bloc:

- **1** : Définit dans quelle carte d'acquisitions et sur quelle sortie notre programme va aller lire. Dans notre cas Device 3 représente le NI USB-6008, et ira lire sur la sortie AI.0 et AI.1. Dans ce bloc nous fixons aussi la limitation à l'entrée.
- **2** : Dans le tableau les valeurs sont en [V], pour transformer ces données en valeurs physique [mbar] je me suis servi des datasheet (Annexe 16 et 17) des capteurs de pression pour faire la conversion. Une fois la conversion réalisée ces valeurs sont enregistrées dans les variables correspondantes et seront automatiquement affichés sur l'interface utilisateur.
- 

|                               |     |       |                                  |  |
|-------------------------------|-----|-------|----------------------------------|--|
| $p = 10^{1.667 \times U - d}$ |     | ⇔     | $U = c + 0.6 \times \log_{10} p$ |  |
| p                             | U   | c     | d                                |  |
| [mbar]                        | [V] | 6.8   | 11.33                            |  |
| [ubar]                        | [V] | 5.0   | 8.333                            |  |
| [Torr]                        | [V] | 6.875 | 11.46                            |  |
| [mTorr]                       | [V] | 5.075 | 8.458                            |  |
| [micron]                      | [V] | 5.075 | 8.458                            |  |
| [Pa]                          | [V] | 5.6   | 9.333                            |  |
| [kPa]                         | [V] | 7.4   | 12.33                            |  |

Figure 42: Conversion pour pression Intérieure

|                  |         |       |     |                       |       |  |
|------------------|---------|-------|-----|-----------------------|-------|--|
| $p = 10^{(U-c)}$ |         |       | ⇔   | $U = c + \log_{10} p$ |       |  |
| U                | p       | c     | U   | p                     | c     |  |
| [V]              | [mbar]  | 5.5   | [V] | [micron]              | 2.625 |  |
| [V]              | [ubar]  | 2.5   | [V] | [Pa]                  | 3.5   |  |
| [V]              | [Torr]  | 5.625 | [V] | [kPa]                 | 6.5   |  |
| [V]              | [mTorr] | 2.625 |     |                       |       |  |

Figure 41: Conversion pour Pression extérieure

- **3** : Indique la fin du programme.

### Affichage du courant, tension et déphasage

Les valeurs de tension, courant et déphasage arrive sur la carte d'acquisition sous forme de tension continue.

Afin de lire les bonnes valeurs une transformation dans Labview doit être effectuée.

Pour le courant et la tension il s'agit de multiplier la valeur obtenu par le facteur du diviseur résistif et capacitif (9.09 pour le courant et 99 pour la tension). Une fois cette multiplication effectuée, une mise sous racine est faite.

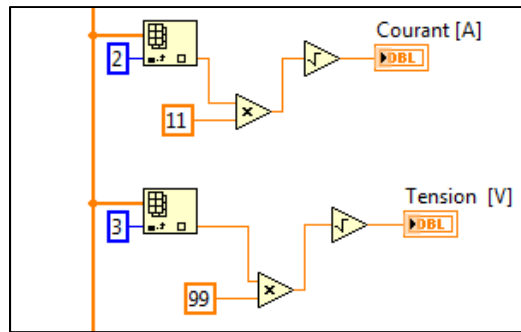


Figure 43: Affichage courant et tension

Pour obtenir la bonne valeur du déphasage entre courant et tension, la formule montrée au chapitre 6.1.2 est utilisée.

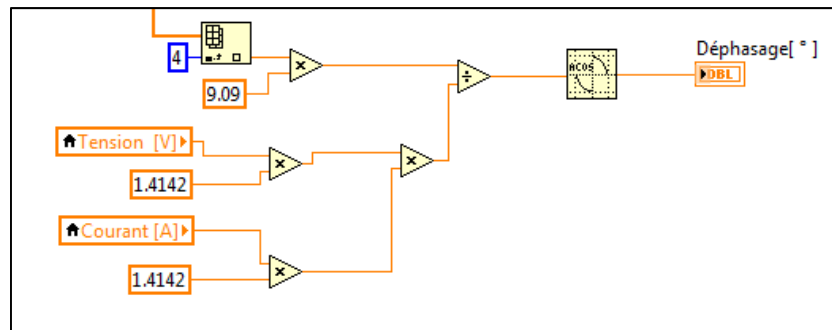


Figure 44: Affichage du déphasage

### 7.3.2 Phase de démarrage et d'arrêt

Pour assurer une sécurité optimale de l'installation et du matériel, une première boucle doit obliger l'utilisateur à allumer et éteindre le réacteur dans un certain ordre.

Pour la phase de démarrage l'ordre est le suivant :

- Choix du mode (automatique ou manuel) → allumer les deux pompes → ouvrir les deux vannes pneumatiques

Pour la phase d'arrêt la procédure est la suivante :

- Fermer les deux vannes → Eteindre les deux pompes → Eteindre l'installation

Pour assurer ces procédures de démarrage et d'arrêt, l'utilisation de Structure Case était la manière la plus simple d'y parvenir.

Remarque : Structure Case en Labview = if en C

Dans les figures 45 et 46 la programmation pour réaliser ces deux procédures.

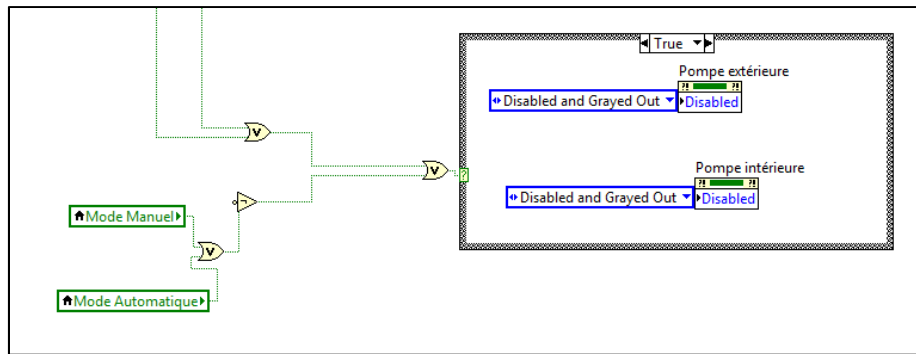


Figure 45: Programmation pour l'utilisation des pompes

Les pompes sont grisées et inaccessible si l'installation n'est pas enclenché ou si une des deux vannes pneumatiques est ouverte.

Les pompes sont accessible si l'installation est enclenché et si les des deux vannes pneumatiques sont ouvertes.

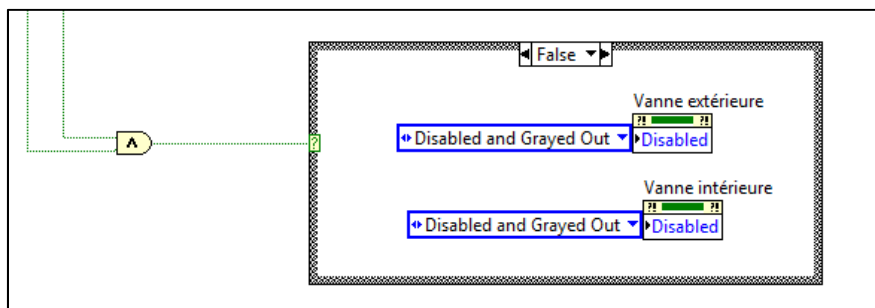


Figure 46: programmation pour l'utilisation des vannes

Les vannes sont grisées est inaccessible tant que les deux pompes ne sont pas enclenchées.

### 7.3.3 Programmation commande moteurs pas à pas

Dans le mode manuel, chaque moteur peut être commandé séparément, comme montré dans le chapitre 7.2.

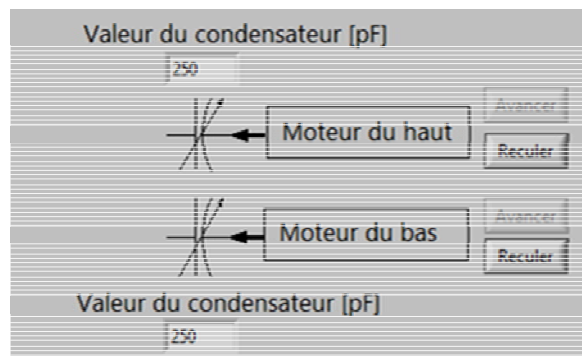


Figure 47: Commande moteur

Sur la figure 48 la programmation nécessaire pour le pilotage d'un moteur :

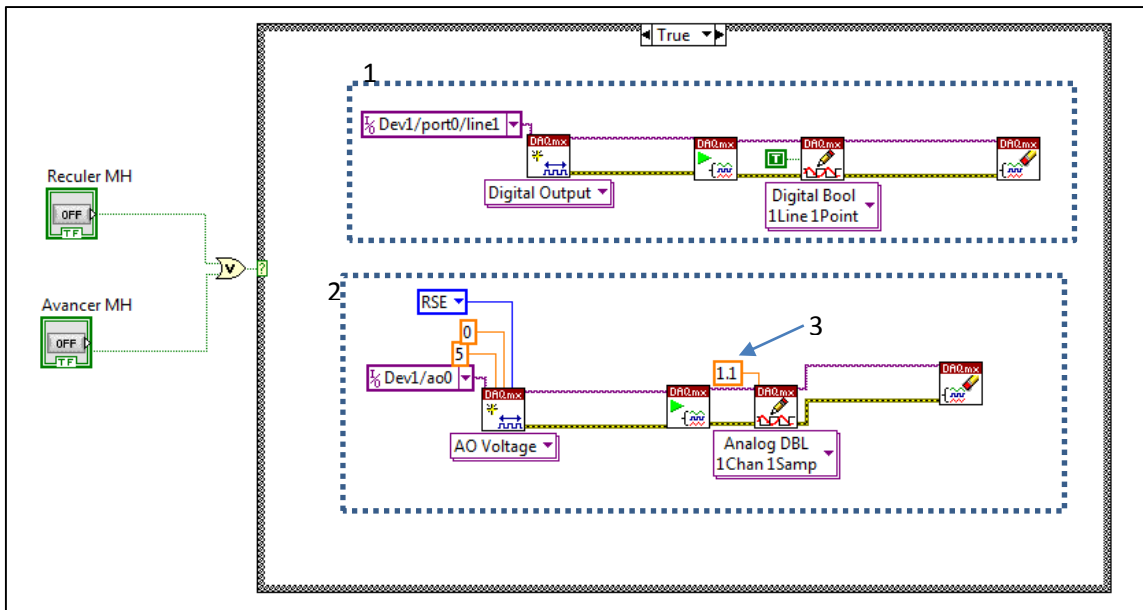


Figure 48: Sortie pour pilotage du moteur pas à pas

Cette partie du code est utilisé pour piloter le moteur du haut. On rentre dans le structure case si un des boutons avancer ou reculer moteur a été actionné. Voici l'explication des blocs utilisés :

- **Bloc 1** : Lorsqu'un des boutons est enclenché, la sortie digitale est activée. Cette sortie est ensuite connectée à l'entrée du PCB de commande des moteurs (entrée enable\_M1). Ainsi le driver du moteur haut est activé.
- **Bloc 2** : Ce bloc est utilisé pour définir la tension d'entrée du VCO. En variant la valeur de sortie au point 3 fait varier la fréquence de sortie des TTL. Ici une consigne de 1.1v est imposée sur le VCO pour avoir en sortie des TTL à une fréquence de 600Hz se qui représente une vitesse pour le moteur de 1.5tours/s.

Pour définir le sens de rotation le code suivant est utilisé :

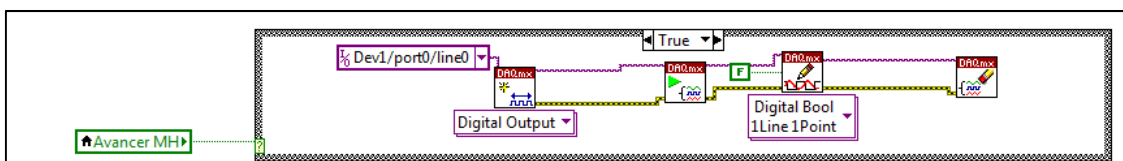


Figure 49: Choix du sens du moteur

Si le bouton "avancer moteur" est enclenché, la sortie digitale qui est connecté sur l'entrée Sens\_M1 de la carte PCB, est désactivée. Donc un 5 V sur l'entrée Sens\_M1 fais tourner le moteur dans un sens et un signal 0V le fait tourner dans l'autre sens.

Une sécurité a été rajouté pour que les boutons avancer moteurs et reculer moteur ne puisse pas être enclenché simultanément.

Comme expliqué dans le chapitre 6.2.2, pour couper le signal TTL venant du VCO, un signal 5V doit être mis sur le gate du mosfet. Il doit y avoir 5V sur le mosfet si aucun des boutons avancer ou reculer n'est activé. Le code suivant réalise cette fonction :

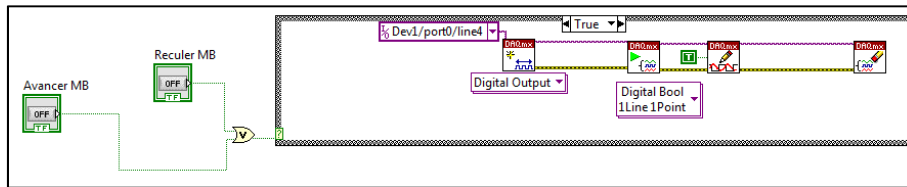


Figure 50: Signal de sortie pour couper le TTL

### Initialisation de la position zéro de condensateurs

À chaque nouveau lancement du programme Labview une fenêtre apparaît, demandant à l'utilisateur de lancer la phase de repositionnement des condensateurs. Lorsque l'utilisateur clique sur "lancer initialisation" les moteurs sont activés et retournent à leurs positions zéro. Cette position zéro correspond à une valeur de condensateurs égale à 250pF.

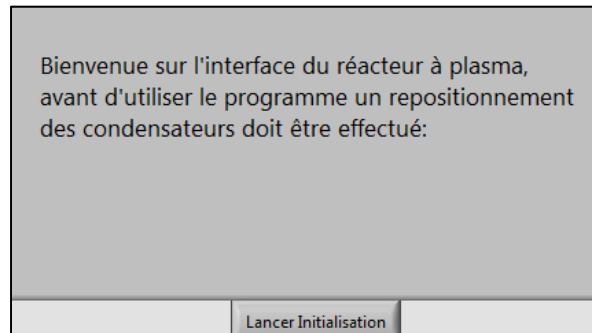


Figure 51: Repositionnement des moteurs

La position zéro et la plage de déplacement est définie de la manière suivante :

- Les deux condensateurs ont été mis à leurs valeurs maximum (250pF) manuellement une première fois.
- Cette position correspond à une valeur zéro dans un compteur.
- Par rapport au datasheet des condensateurs (annexe 6), il faut 10.8 tours pour passer de la capacité maximum à minimum (250pF → 25pF).
- Sachant que la fréquence de sortie du VCO est de 600 Hz, et que les moteurs sont pilotés en mode demi-pas. Alors le moteur effectue 1.5 tours/s et pour faire les 10.8 tours il lui faut 7.2 s.
- Lorsque le condensateur avance on incrémente le compteur toutes les 100ms. Pour arriver à la valeur minimal du condensateur (25pF) il faut que le compteur atteigne la valeur 72 = 7200ms = 7.2s.
- La valeur du condensateur est ainsi connue en fonction du compteur.
  - Si le compteur = 0 → condensateur = 250pF
  - Si le compteur = 72 → condensateur = 25pF
- Une sécurité programmée empêche le condensateur de dépasser ces valeurs limite (25pF et 250pF)



À noter que cette méthode est imprécise, car le moteur peut sauter des pas, notamment lors de l'arrêt à cause de son inertie.

Voici les différents blocs utilisés pour contrôler la course des moteurs :

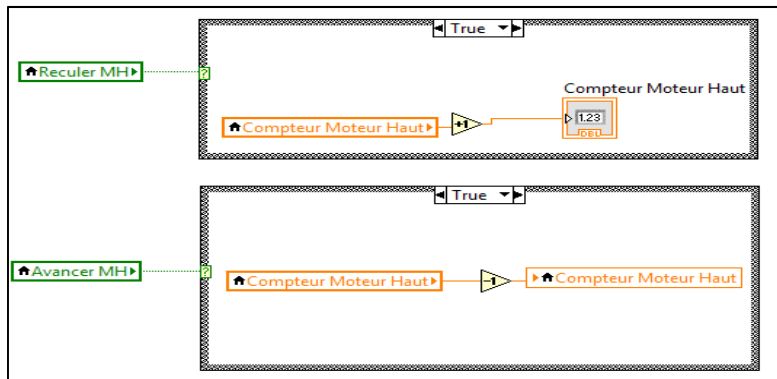


Figure 52: Implémentation du compteur

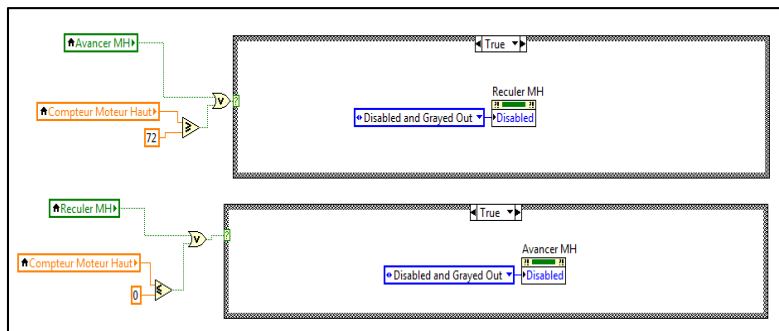


Figure 53: Implémentation des fins de course

## 8. Tests

### 8.1 Test d'étanchéité

Un test d'étanchéité a été effectué sur toute l'installation.

Le principe est le suivant :

- Les deux pompes sont enclenchées et les deux vannes pneumatiques sont ouvertes.
- Puis à tour de rôle nous ouvrons les électrovannes et regardons si la pression reste suffisamment basse.
- Si la pression augmente, nous utilisons de l'éthanol sur les raccords entre les tuyaux et les MFC pour voir à quel endroit se trouve la fuite.
- Si la pression restait suffisamment basse nous passons à l'étape suivante.
- Après plusieurs essais et plusieurs réglages sur l'installation, nous avons effectué un test concluant dont les résultats se trouvent dans le tableau 3.

| Date/Heure | Quoi         | Mesure              |            |                     |                | Qui         |
|------------|--------------|---------------------|------------|---------------------|----------------|-------------|
|            |              | Pression intérieure |            | Pression extérieure |                |             |
| 26.04.2012 |              | Labview [V]         | VAT [mbar] | Labview [V]         | Edwards [mbar] | Volic Davor |
| 11:30      | GMain fermé  | 5.78                | -0.01      | 3.92                | 0.052          |             |
| 11:35      | GMain ouvert | 6.2                 | 0.08       | 3.98                | 0.055          |             |
| 11:36      | GV 1 ouvert  | 6.29                | 0.1        | 3.98                | 0.055          |             |
| 11:44      | GV 2 ouvert  | 6.05                | 0.03       | 3.92                | 0.052          |             |
| 11:48      | GV 3 ouvert  | 6.03                | 0.03       | 3.94                | 0.055          |             |
| 11:50      | GV 4 ouvert  | 6.02                | 0.03       | 3.91                | 0.52           |             |

Tableau 3: Test d'étanchéité

Remarque :

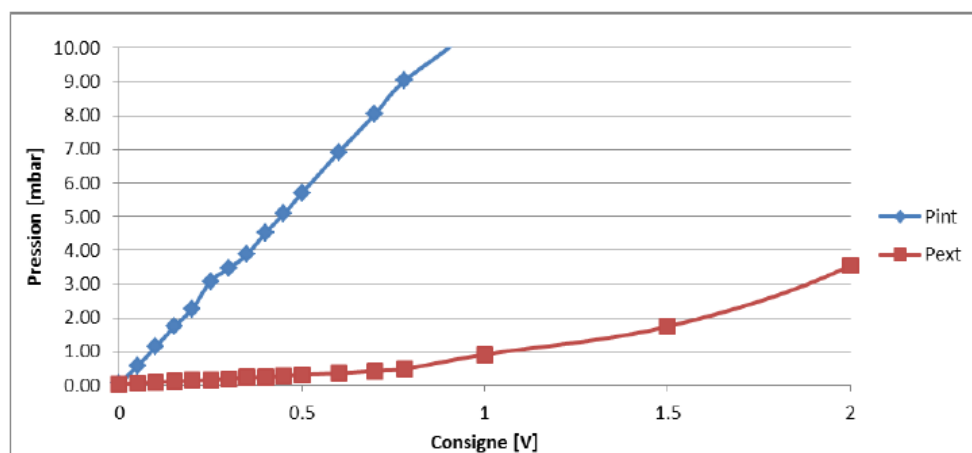
La pression de -0.01 [mbar] s'explique par le faite, que la pression est tellement basse, que les valeurs ne sont pas dans les plages de mesure de l'appareil.

## 8.2 Test Mesure MFC

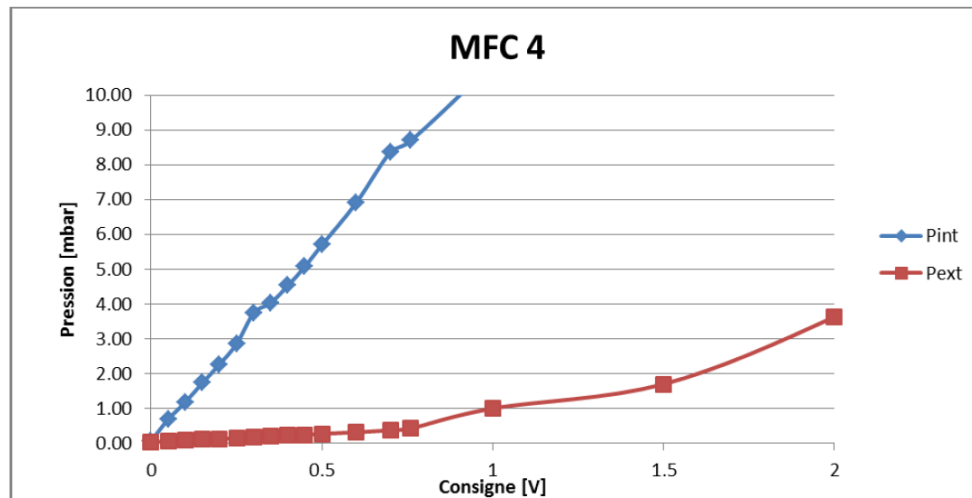
Pour vérifier le bon fonctionnement des régulateurs de débit, là aussi un test a été mis en place, dont le principe et le suivant :

- Lorsque l'installation est enclenchée, nous augmentons la consigne de débit du gaz, pas à pas et regardons comment réagis la pression intérieur et extérieur de nos chambres.
- Ensuite nous réalisons un graphique ou l'on affiche la pression intérieure et extérieure en fonction de la consigne. Si notre installation est correcte, nous devons obtenir une droite de la pression intérieure linéaire et sans offset.

### MFC 3

Figure 54: Test MFC 3  $P=f(\text{consigne})$

## MFC 4

Figure 55: Test MFC 4  $P=f(\text{consigne})$ 

Remarque :

- On constate que sur les figures 54 et 55 la droite Pint est bien linéaire et il n'y a pas d'offset.
- On remarque que sur les figures 54 et 55 qu'à partir d'une consigne de 0.5 [V] sur le débit, la pression de la chambre extérieure augmente. Cela est sûrement dû au fait que l'étanchéité entre les deux chambres n'est pas optimale.

### 8.3 Test de linéarité des condensateurs

Les tests de linéarité sur les deux condensateurs ont été effectués de la manière suivante :

- Les deux condensateurs sont mis à leur position zéro et ont comme capacité 250pF. Puis des pas de un tour et demi sont effectués et la nouvelle valeur de capacité est lue.

Sur les figures 52 et 53 les tests de linéarité des condensateurs.

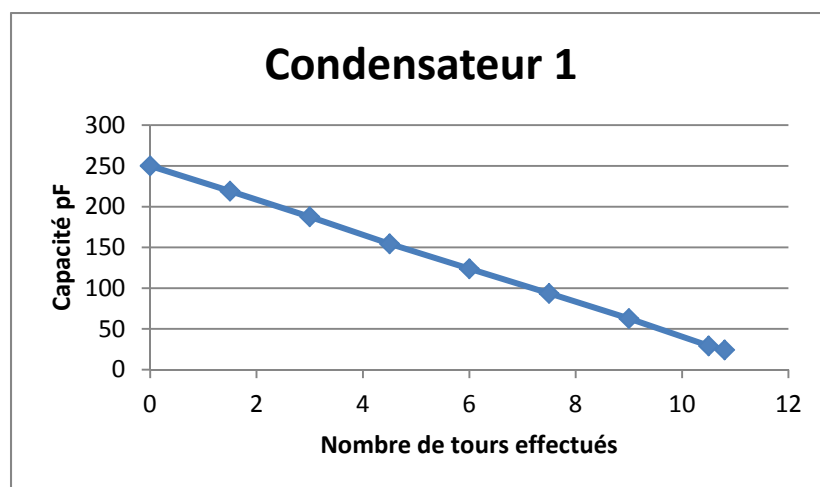


Figure 56; Valeurs du condensateur 1 en fonction du nombre de tour effectués

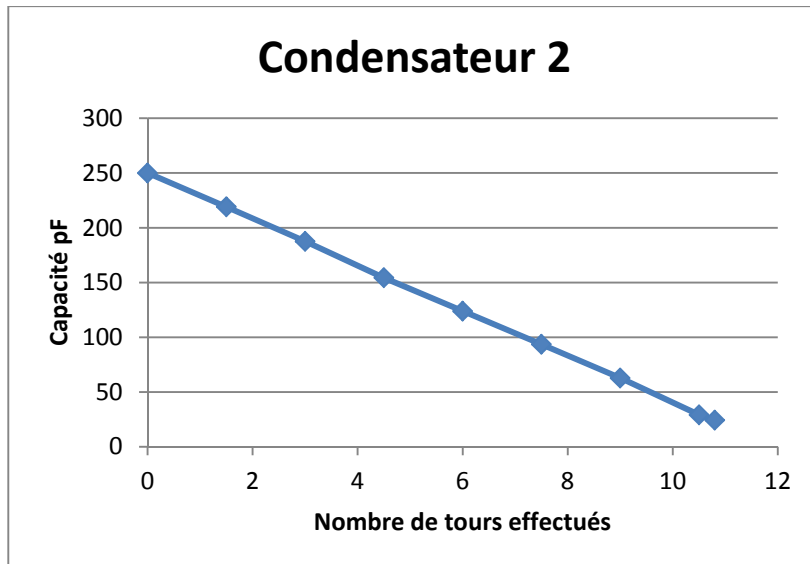


Figure 57. Valeurs du condensateur 2 en fonction du nombre de tour effectués

Les deux condensateurs ont un comportement linéaire.

## 8.4 Protocole de test de la carte de mesure

Afin de vérifier le bon fonctionnement de la carte de mesure un Protocole de test a été effectué.

| Mesures           | Condition   | Point de Mesure         | Résultats attendus   | Résultats obtenus | Ok |
|-------------------|---|-------------------------|--|-------------------|----|
| Alimentation      | Alimentation 9[V] à l'entrée de la plaque                                   | J1                      | 9[V]   | 9[V]              | ok |
|                   | Alimentation 9[V] à l'entrée du traco Power TMR 0521                        | U1 (1:2)                | 9[V]   | 9[V]              | ok |
|                   | Tension +5 [V] à la sortie du TMR 0521                                      | U1 (6:7)                | 5[V]   | 5[V]              | ok |
|                   | Tension -5 [V] à la sortie du TMR 0521                                      | U1 (8:7)                | -5[V]  | -5[V]             | ok |
|                   | Alimentation 5[V] sur les 3 multiplieurs AD835                              | U2 (6)                  | 5[V]   | 5[V]              | ok |
|                   |   | U3 (6)                  | 5[V]   | 5[V]              | ok |
|                   |   | U4 (6)                  | 5[V]   | 5[V]              | ok |
|                   | Alimentation -5[V] sur les 3 multiplieurs AD835                             | U2 (3)                  | -5[V]  | -5[V]             | ok |
|                   |   | U3 (3)                  | -5[V]  | -5[V]             | ok |
|                   |   | U4 (3)                  | -5[V]  | -5[V]             | ok |
| Diviseur résistif | Envoi sinus $f=13.6\text{Mhz}$<br>$U=1\text{Vpp}$                           | Après diviseur résistif | Sinus: $F=13.6\text{Mhz}$<br>$U=0.09*1\text{Vpp}=0.09\text{Vpp}$ | Voir figure 59    | ok |
| AD835             | Verifier si sinus redressé au double de la fréquence à la sortie de l'AD835 | U2 (5)                  | Sinus redressé avec $F=27.2\text{ Mhz}$                          | Voir figure 60    | Ok |
| Tension Continu   | lecture de la tension Continu   | J4 (1)                  | -  | Voir figure 61    | ok |

Figure 58: Protocole de test carte de mesure

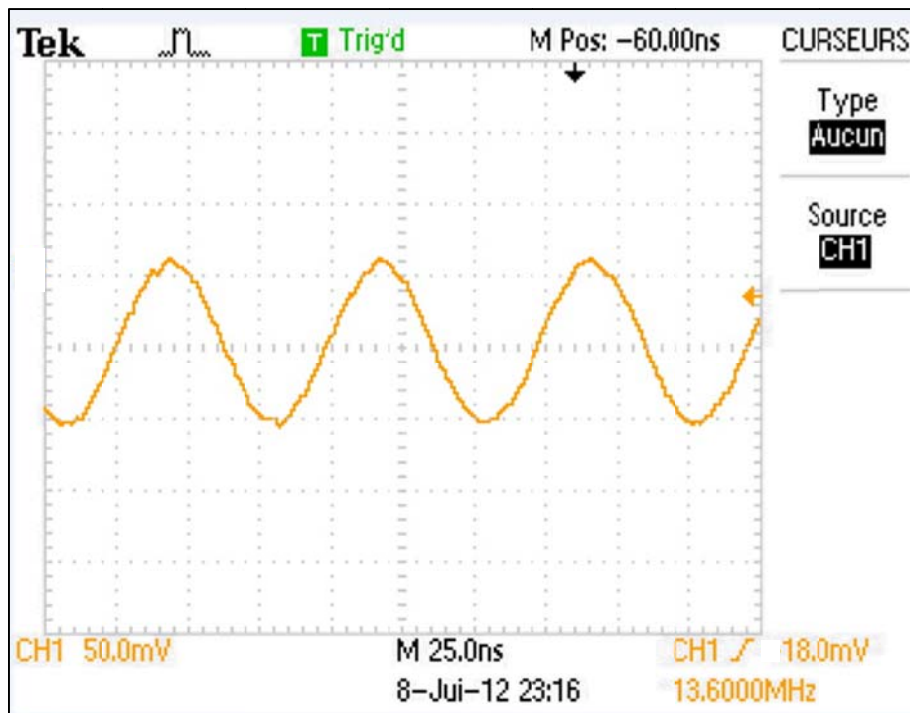


Figure 59: Sinus après diviseur résistif

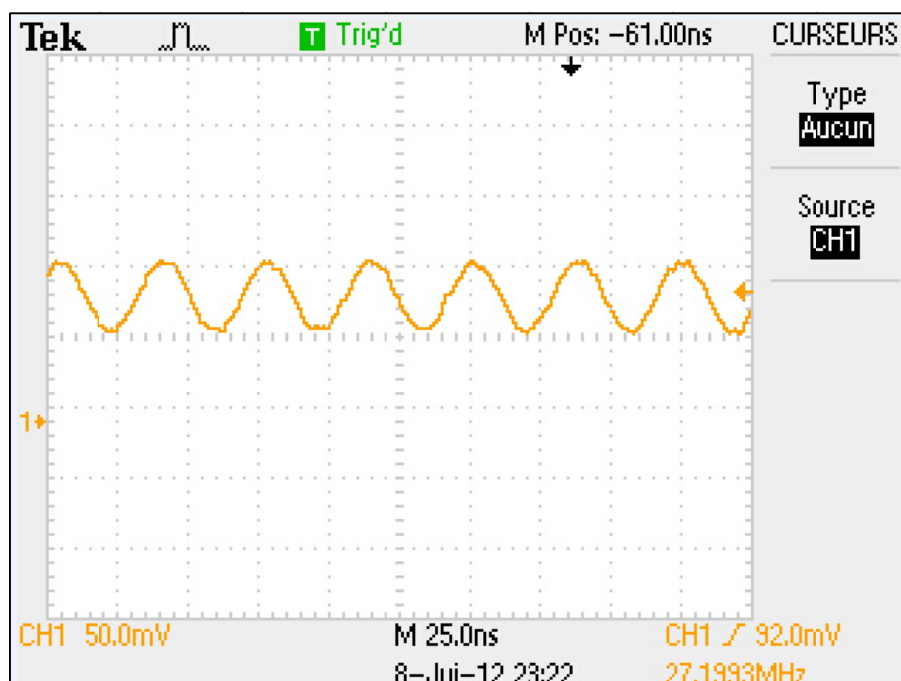


Figure 60: Sinus redressé après le multiplieur AD835

Le signal est redressé et est au double de la fréquence. Par contre un offset de 50mV vient influencer la mesure.

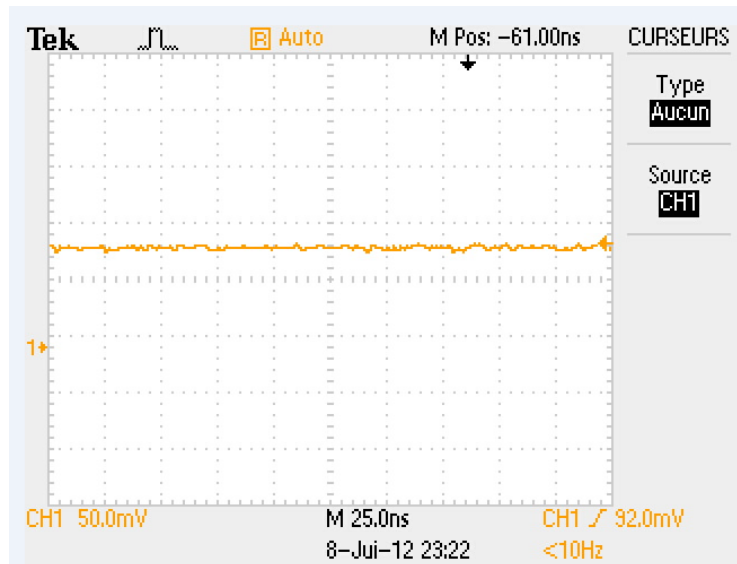


Figure 61: Tension continu en sortie de la carte de mesure

La tension en sortie de la carte est égale à 90mV. Si on multiplie cette valeur par le facteur du diviseur résistif, nous obtenons  $\rightarrow \sqrt{90\text{mV}^2} = 1\text{Vrms}$ . Durant mon test, un sinus avec une amplitude 1Vpp a été envoyé, cela veut dire que la valeur efficace doit être égale à 353mV.

Cette différence entre les deux valeurs s'explique par l'offset lors de la multiplication (Figure 60).

Si cette carte sera utilisé dans un travail future, il sera nécessaire de calibrer les mesures dans Labview, afin d'avoir les bonnes valeurs efficaces pour compenser l'offset dans la mesure.

## 8.5 Protocole de test de la carte de commande

Le bon fonctionnement de la carte de commande des moteurs a été effectué grâce à un Protocole de test.

| Mesures      | Condition  | Point de Mesure                        | Résultats attendus                                      | Résultats obtenus | Ok |
|--------------|--|--|---|-------------------|----|
| Alimentation | Alimentation 7[V] à l'entrée de la plaque                            | J1                                     | 7[V]  | 7[V]              | ok |
|              | Alimentation 7[V] à l'entrée du traco Power TMR 2-0511               | U1 (1:2)                               | 7[V]  | 7[V]              | ok |
|              | Tension +5 [V] à la sortie du TMR 2-0511                             | U1 (3:5)                               | 5[V]  | 5[V]              | ok |
|              | Alimentation 5[V] sur les 2 VCO XR-2209                              | U2 (1)                                 | 5[V]  | 5[V]              | ok |
|              |  | U3 (1)                                 | 5[V]  | 5[V]              | ok |
|              | Alimentation 5[V] sur les 2 drivers L297                             | U4 (12)                                | 5[V]  | 5[V]              | ok |
|              |  | U6 (12)                                | 5[V]  | 5[V]              | ok |
|              | Alimentation 5[V] sur les 2 ponts H L298                             | U5 (9)                                 | 5[V]  | 5[V]              | ok |
| U7 (9)       |  | 5[V]                                   | 5[V]  | ok                |    |
| VCO          | test de linéarité des VCO  | U2 (7)                                 | Fréquence qui varie en fonction de la tension appliquée | Voir figure 60    | ok |
| L297         | Vérifier que le signal de sortie des VCO arrive sur l'entrée du L297 | U6(18) et U4(16)                       | -   | -                 | ok |
| L298         | Vérifier on retrouve le signal pour les deux phases                  | U5 (2, 3, 13, 14)<br>U7 (2, 3, 13, 14) | -   | Voir figure 61    | ok |

Figure 62: Protocole de test de la carte de commande des moteurs



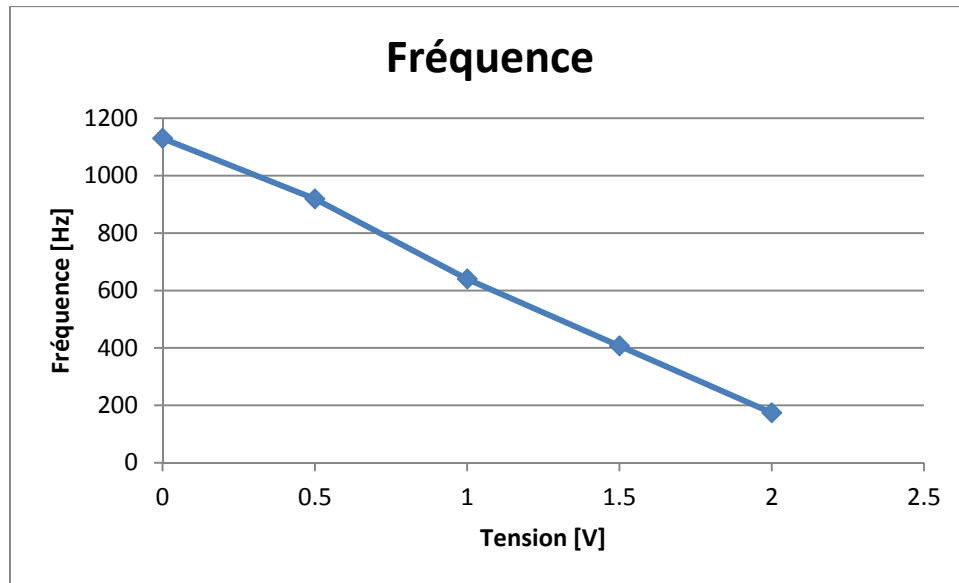


Figure 63: test de linéarité des VCO

Le VCO est linéaire, et la plage de fréquence varie entre 1130Hz et 200Hz pour une tension allant de 0V à 2V. En mode demi-pas, 1130Hz représente un vitesse pour le moteur de 2.9 tours/s et pour 200Hz 0.5 tours/s.

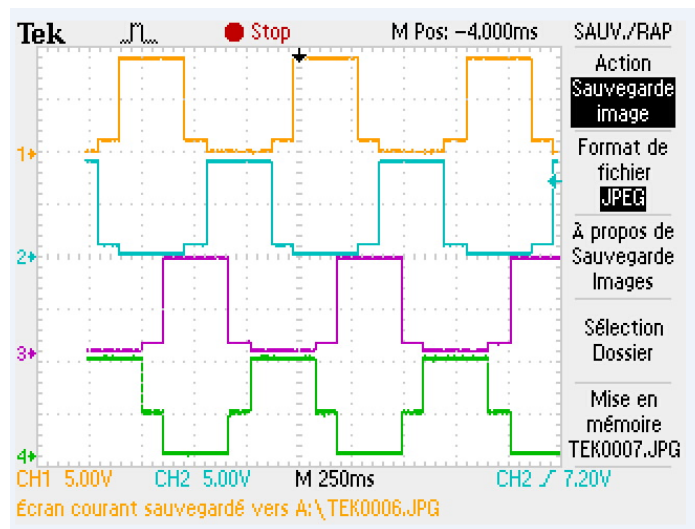


Figure 64: Signaux des deux phases en mode demi pas

Sur la figure 64, les signaux pour les deux phases du moteur pas à pas provenant du driver L297 sont corrects car ils correspondent à la figure 30 provenant du datasheet.

## 9. Remarques et amélioration

### *Court-circuit du générateur*

Durant la journée du 26 juin le générateur fut utilisé afin de faire des tests sur des échantillons d'amidon. De plus une analyse de spectre a été faite et pour garantir une mesure optimale un rideau noir fut posé et la porte fut fermée durant toute la journée.

Le problème est que la température extérieure était déjà très élevée, et la température dans la salle grimpait à cause des deux pompes qui fonctionnaient. Au bout d'un certain temps la différence de température entre la salle et le circuit de refroidissement du générateur créa de la condensation dans le générateur de fréquence, d'où le court-circuit.

Depuis nous n'avons plus de générateur, et tous les tests sur l'installation ont dû être stoppés. Si le générateur nous revient avant la présentation orale, je pourrais faire une série de mesure pour caractériser l'installation. Malheureusement aucune mesure n'est faite pour l'instant.

### *Amélioration à apporter*

- Suite au problème rencontré avec le générateur, il serait nécessaire d'installer une climatisation afin d'assurer une température ambiante acceptable pour le générateur.
- Étant donné la taille de l'installation, déplacer l'ensemble dans une salle plus grande, afin d'avoir un certain confort de travail.
- Les 4 MFC à disposition sont tous calibrés pour contrôler le débit de gaz de l'azote. Étant donné que l'on travail avec différents gaz, il est nécessaire de faire une calibration pour chaque gaz.
- Fixer un support sur la Matchbox pour assurer une bonne stabilité
- Durant ce projet les mesures de courant et tension sont effectuées à l'aide d'une sonde Rogowski et d'une tension capacitive. Cependant la matchbox possède à la base une partie d'électronique qui mesure le courant et la tension. Il s'agirait de reprendre sur cette électronique les valeurs de tension et de courant.

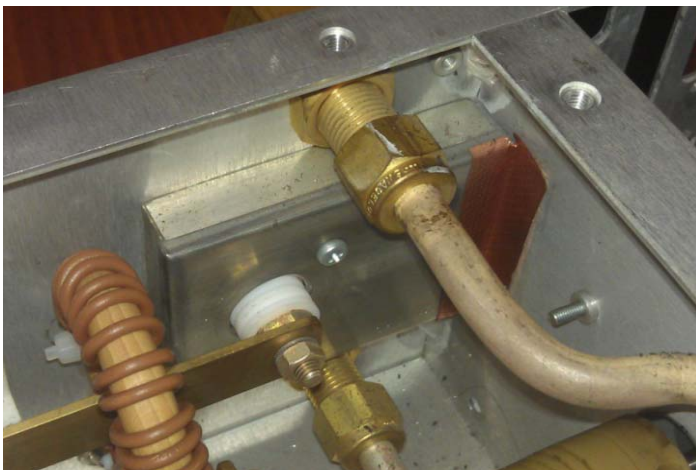


Figure 66: Boîtier contenant l'électronique de mesure



65: Sortie du boîtier

## 10. Conclusion

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Le développement des trois parties principales soit la partie mise en route de l'installation, informatique et électronique ont été réalisés correctement. Cependant le cahier des charges a été modifié durant le travail de diplôme, et c'est pour cette raison que la régulation de l'impédance est reportée.

La partie informatique permet à l'utilisateur d'avoir une vue d'ensemble de l'installation et permet de visualiser en temps réel les différentes données. La carte électronique de commande des moteurs, permet de piloter les moteurs pas à pas et ainsi de faire varier la valeur des condensateurs.

La carte de mesure a uniquement été testée sur un générateur de fonction et n'a pas pu être testée sur l'installation.

La multidisciplinarité du projet et sa complexité ont rendu ce travail particulièrement intéressant. Notamment l'apprentissage du logiciel Labview ainsi que la conception des cartes PCB.

Le temps passé sur ce projet m'a permis d'acquérir une grande expérience dans le développement d'un projet et m'offre ainsi une parfaite préparation à l'insertion dans le monde professionnel.

## 11. Remerciement

---

Je tiens à remercier :

Madame Fariba Moghaddam et Monsieur Christoph Ellert, qui m'ont suivi tout au long du projet et qui par leurs nombreux conseils m'ont permis d'avancer au mieux durant toute la phase du projet.

Aldo Vaccari, pour sa disponibilité lors de ma programmation sur Labview.

Steve Gallay, pour son aide lors de la conception des cartes électroniques.

## 12. Bibliographie

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- Forum National Instrument
- Rapport PGA (Eberhardt Joahnn, Schaller Philipp, Borter Angelo)
- Cours d'Electronique Industriel, 3<sup>ème</sup> années HES-So Valais.

## 13. Annexe

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Annexe 1 : Schéma électrique

Annexe 2 : Pièce pour fixation connecteur

Annexe 3 : Schéma électronique de la carte de mesure

Annexe 4 : Datasheet multiplieur AD835

Annexe 5 : Datasheet Moteur pas à pas

Annexe 6 : Datasheet Condensateur

Annexe 7 : Schéma électronique de la carte de commande des moteurs pas à pas

Annexe 8 : Datasheet des VCO

Annexe 9 : Datasheet L297

Annexe 10 : Datasheet L298

Annexe 11 : Datasheet Ni-USB

Annexe 12 : Datasheet NI-PCI

Annexe 13 : Liste Entrées/Sorties

Annexe 14 : Exemple Real Time Trend Labview

Annexe 15 : Exemple Historical Trend Labview

Annexe 16 : Datasheet capteur pression intérieure

Annexe 17 : Datasheet capteur pression extérieure

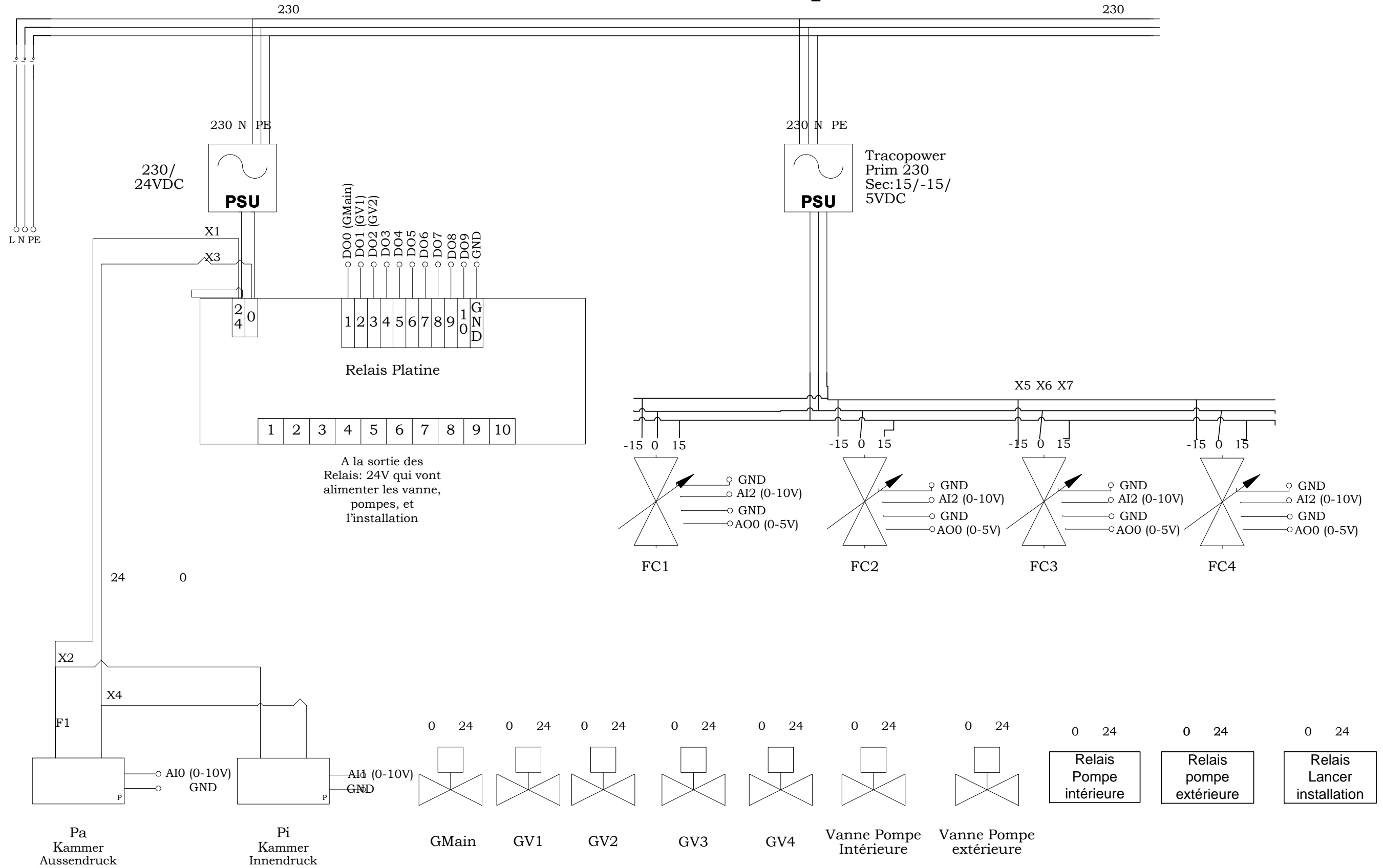
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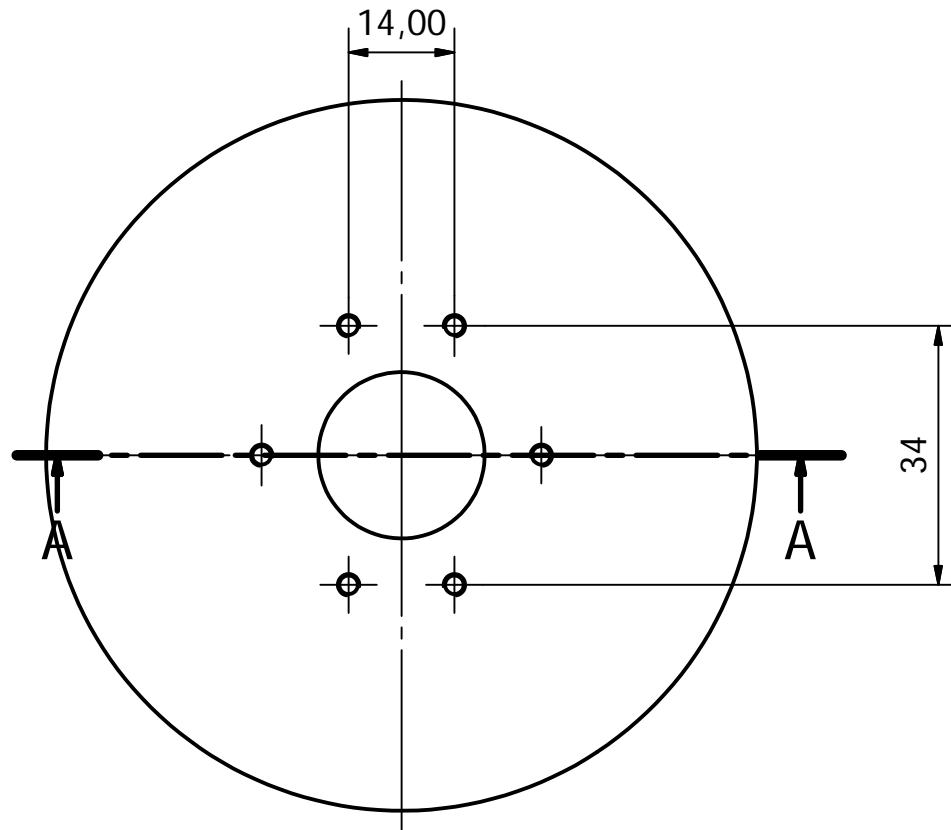
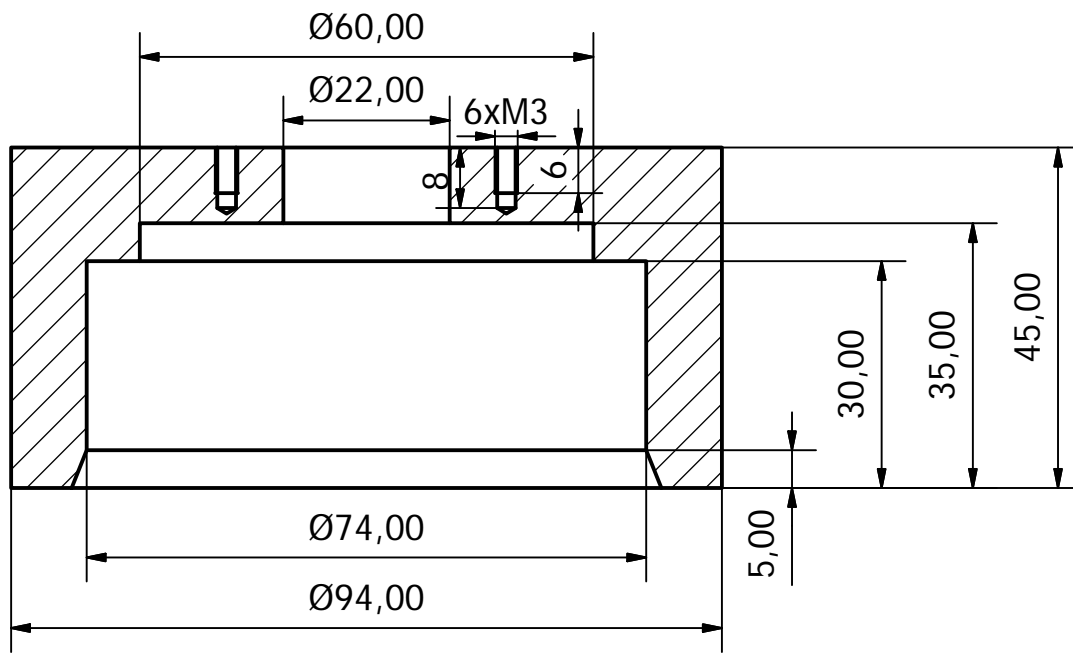
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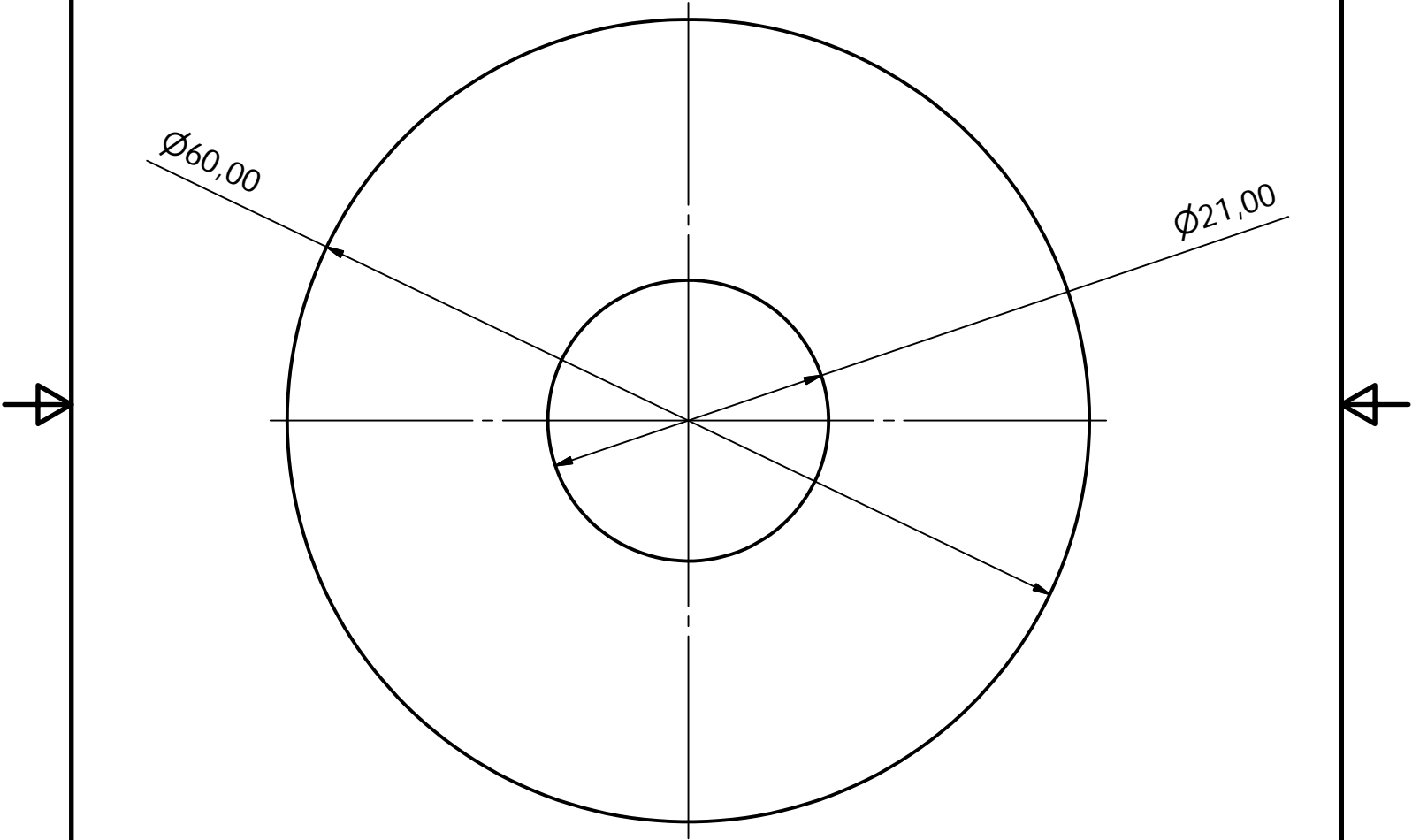
Sion, le 9 juillet 2012

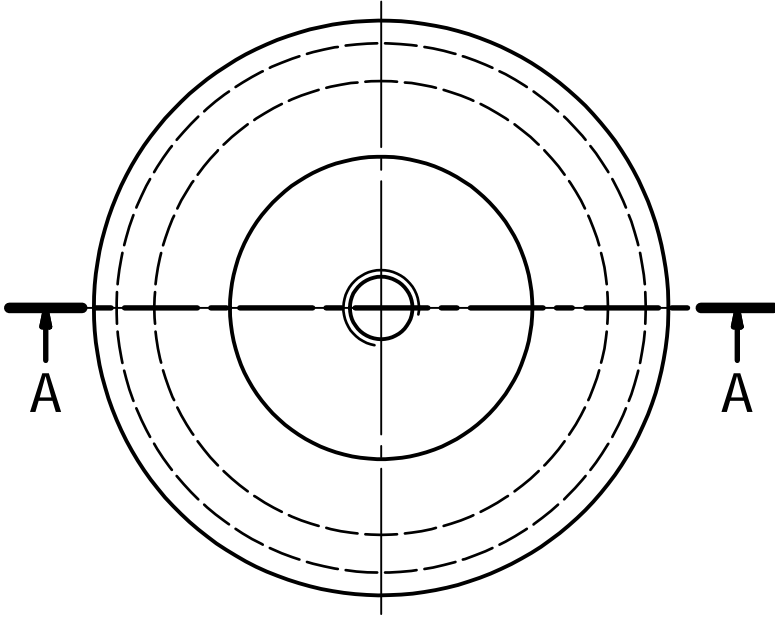
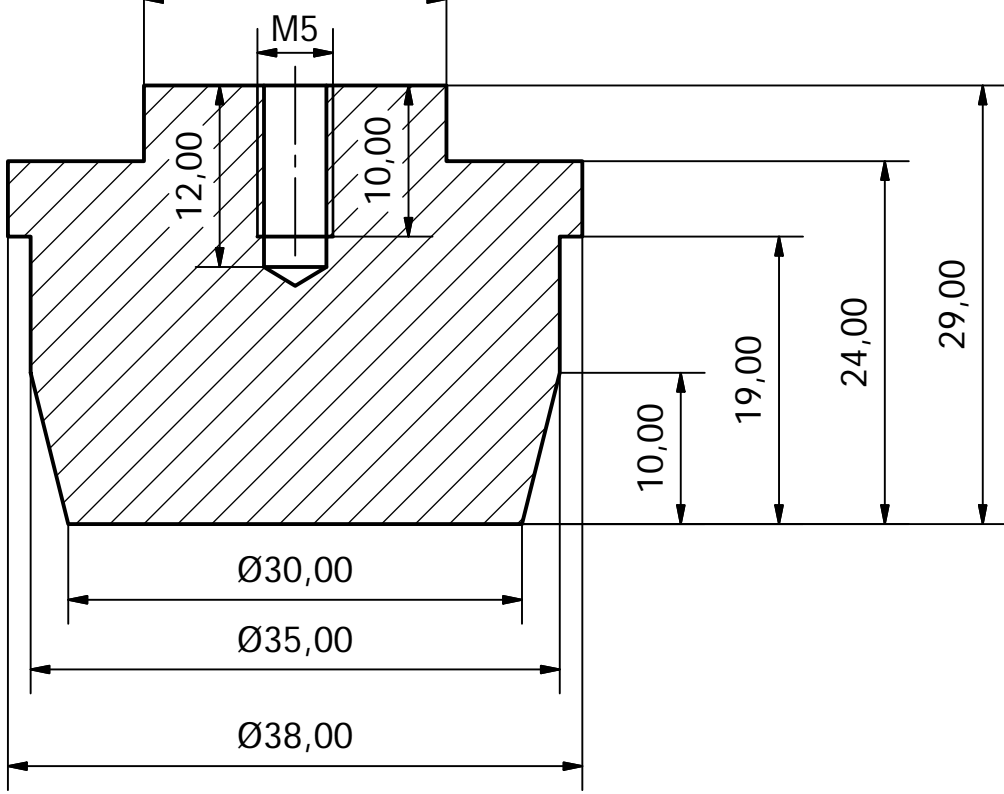
Davor Volic

# Schéma électrique

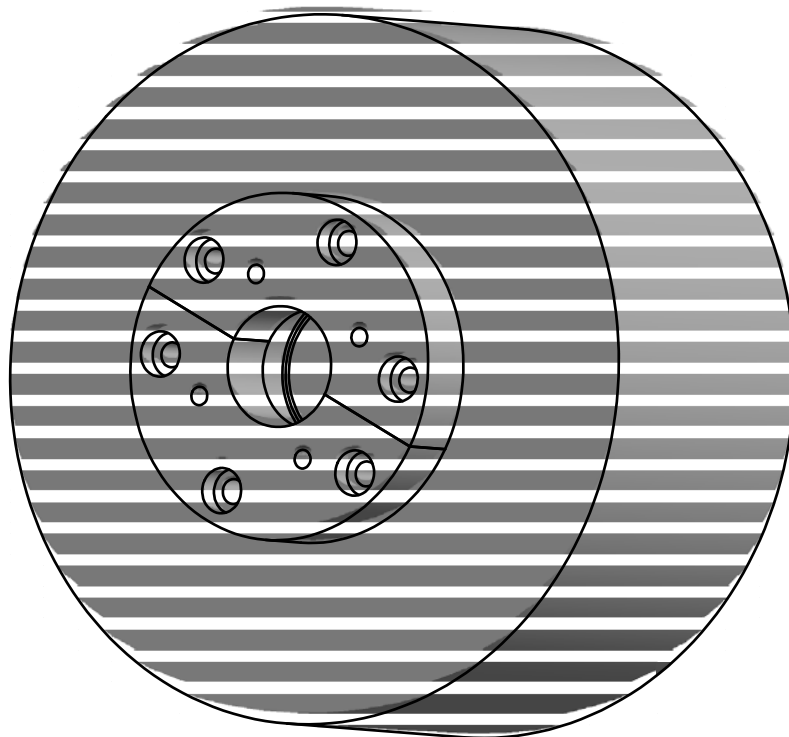
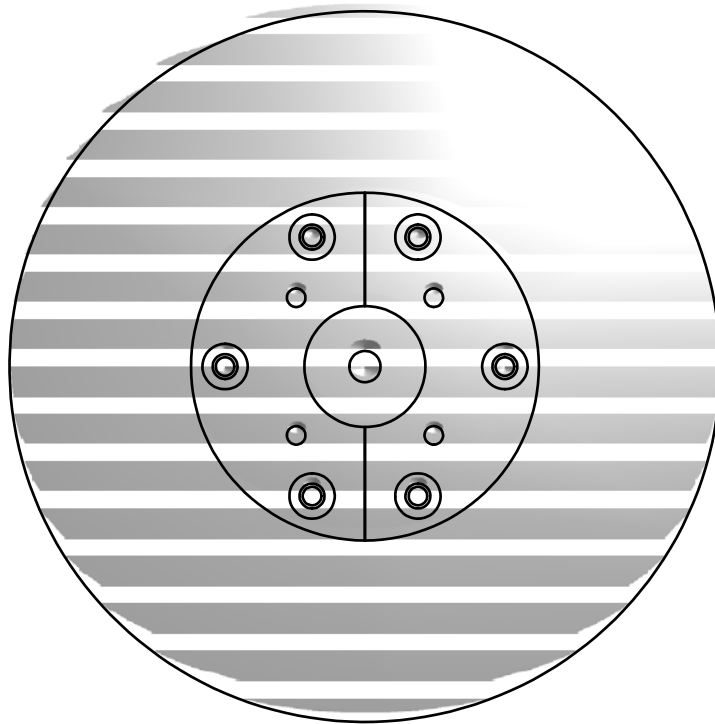












Montage assemblé

Dessiné  
Gezeichnet

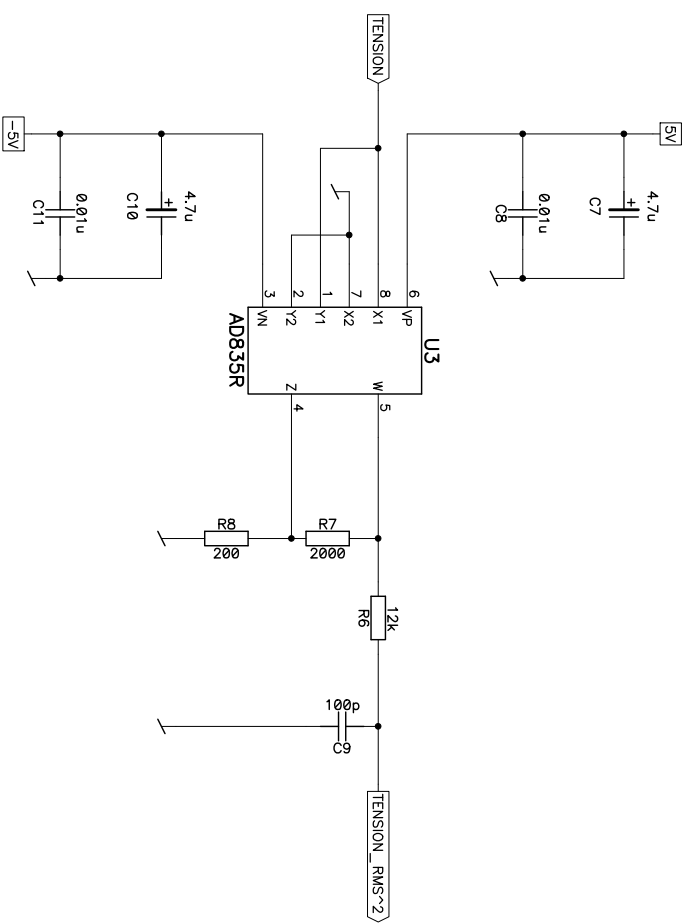
09.07.2012

Echelle  
Massstab

Contrôlé  
Geprüft

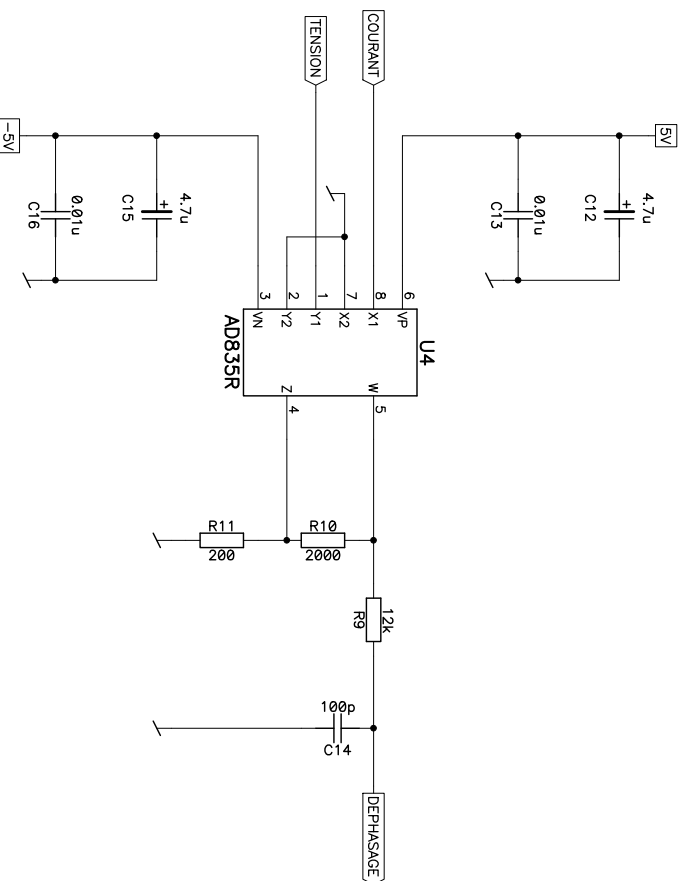
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Datei



|                        |  |     |                  |             |
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| PCB de mesure          |  | DES | 06.2012          | Davor Volic |
| HAUTE ECOLE VALAISANNE |  | REV | V1.0             |             |
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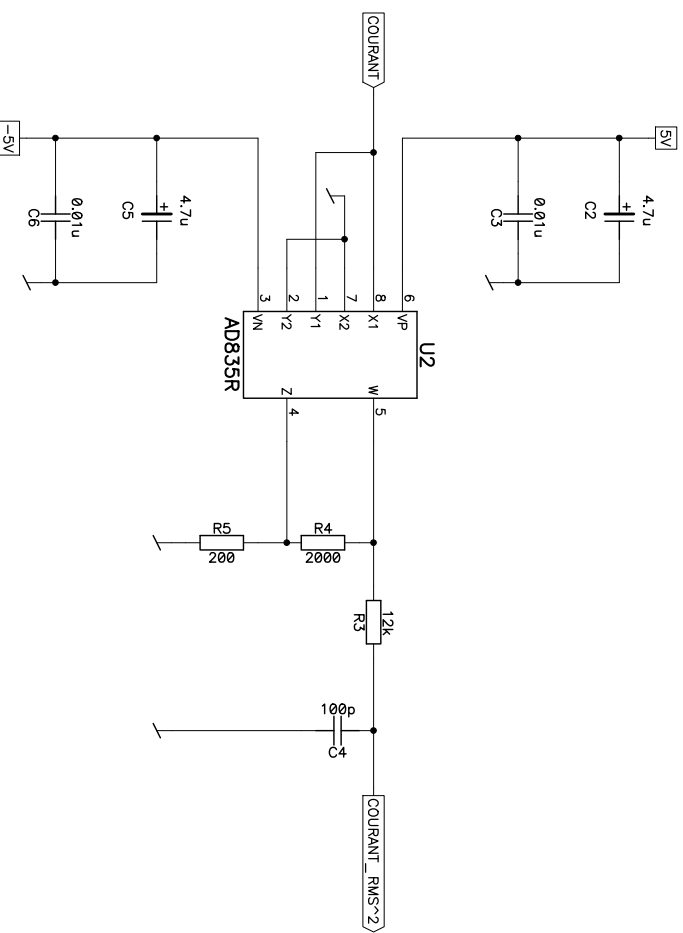
Tension



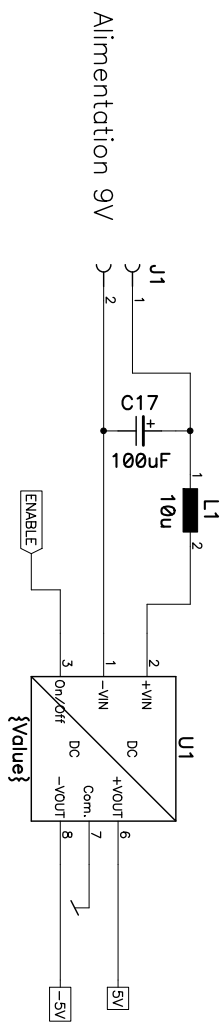
PCB de mesure  
 HAUTE ECOLE VALAISANNE

Déphasage

|     |         |                  |
|-----|---------|------------------|
| DES | 06.2012 | Davor Volic      |
| REV | V1.0    |                  |
| 5/5 | {Path}  | PCB_Mesure_2.sch |



|                        |                  |             |
|------------------------|------------------|-------------|
| PCB de mesure          |                  |             |
| HAUTE ECOLE VALAISANNE |                  |             |
| Courant                |                  |             |
| DES                    | 06.2012          | Davor Volic |
| REV                    | V1.0             |             |
| 3/5                    | {Path}           |             |
|                        | PCB_Mesure_2.sch |             |



|               |         |                  |  |
|---------------|---------|------------------|--|
| PCB de mesure |         | Alimentation     |  |
| DES           | 06.2012 | Davor Volic      |  |
| REV           | V1.0    |                  |  |
| 2/5           | {Path}  | PCB_Mesure_2.sch |  |

HAUTE ECOLE VALAISANNE

### FEATURES

- Simple:** basic function is  $W = XY + Z$
- Complete:** minimal external components required
- Very fast:** Settles to 0.1% of full scale (FS) in 20 ns
- DC-coupled voltage output** simplifies use
- High differential input impedance** X, Y, and Z inputs
- Low multiplier noise:** 50 nV/ $\sqrt{\text{Hz}}$

### APPLICATIONS

- Very fast multiplication, division, squaring**
- Wideband modulation and demodulation**
- Phase detection and measurement**
- Sinusoidal frequency doubling**
- Video gain control and keying**
- Voltage-controlled amplifiers and filters**

### GENERAL DESCRIPTION

The AD835 is a complete four-quadrant, voltage output analog multiplier, fabricated on an advanced dielectrically isolated complementary bipolar process. It generates the linear product of its X and Y voltage inputs with a -3 dB output bandwidth of 250 MHz (a small signal rise time of 1 ns). Full-scale (-1 V to +1 V) rise to fall times are 2.5 ns (with a standard  $R_L$  of 150  $\Omega$ ), and the settling time to 0.1% under the same conditions is typically 20 ns.

Its differential multiplication inputs (X, Y) and its summing input (Z) are at high impedance. The low impedance output voltage (W) can provide up to  $\pm 2.5$  V and drive loads as low as 25  $\Omega$ . Normal operation is from  $\pm 5$  V supplies.

Though providing state-of-the-art speed, the AD835 is simple to use and versatile. For example, as well as permitting the addition of a signal at the output, the Z input provides the means to operate the AD835 with voltage gains up to about  $\times 10$ . In this capacity, the very low product noise of this multiplier (50 nV/ $\sqrt{\text{Hz}}$ ) makes it much more useful than earlier products.

The AD835 is available in an 8-lead PDIP package (N) and an 8-lead SOIC package (R) and is specified to operate over the -40°C to +85°C industrial temperature range.

### FUNCTIONAL BLOCK DIAGRAM

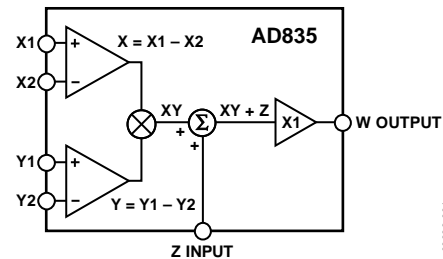


Figure 1.

### PRODUCT HIGHLIGHTS

1. The AD835 is the first monolithic 250 MHz, four-quadrant voltage output multiplier.
2. Minimal external components are required to apply the AD835 to a variety of signal processing applications.
3. High input impedances (100 k $\Omega$ ||2 pF) make signal source loading negligible.
4. High output current capability allows low impedance loads to be driven.
5. State-of-the-art noise levels achieved through careful device optimization and the use of a special low noise, band gap voltage reference.
6. Designed to be easy to use and cost effective in applications that require the use of hybrid or board-level solutions.

#### Rev. D

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**REVISION HISTORY****12/10—Rev. C to Rev. D**

|  |    |
|--|----|
| Changes to Figure 1 .....                            | 1  |
| Changes to Absolute Maximum Ratings and Table 2..... | 5  |
| Added Figure 19, Renumbered Subsequent Tables.....   | 10 |
| Added Figure 23.....                                 | 11 |

**10/09—Rev. B to Rev. C**

|                                  |           |
|----------------------------------|-----------|
| Updated Format .....             | Universal |
| Changes to Figure 22.....        | 11        |
| Updated Outline Dimensions ..... | 13        |
| Changes to Ordering Guide .....  | 14        |

**6/03—Rev. A to Rev. B**

|                                  |           |
|----------------------------------|-----------|
| Updated Format .....             | Universal |
| Updated Outline Dimensions ..... | 10        |

## SPECIFICATIONS

$T_A = 25^\circ\text{C}$ ,  $V_S = \pm 5\text{ V}$ ,  $R_L = 150\ \Omega$ ,  $C_L \leq 5\text{ pF}$ , unless otherwise noted.

Table 1.

| Parameter                       | Conditions  | Min                                    | Typ       | Max        | Unit                   |
|---------------------------------|---|--|-----------|------------|------------------------|
| TRANSFER FUNCTION               |   | $W = \frac{(X1 - X2)(Y1 - Y2)}{U} + Z$ |           |            |                        |
| INPUT CHARACTERISTICS (X, Y)    |   |  |           |            |                        |
| Differential Voltage Range      | $V_{CM} = 0\text{ V}$   |  | $\pm 1$   |            | V                      |
| Differential Clipping Level     |   | $\pm 1.2^1$                            | $\pm 1.4$ |            | V                      |
| Low Frequency Nonlinearity      | $X = \pm 1\text{ V}, Y = 1\text{ V}$                                    |  | 0.3       | $0.5^1$    | % FS                   |
|                                 | $Y = \pm 1\text{ V}, X = 1\text{ V}$                                    |  | 0.1       | $0.3^1$    | % FS                   |
| vs. Temperature                 | $T_{MIN}$ to $T_{MAX}^2$  |  |           |            |                        |
|                                 | $X = \pm 1\text{ V}, Y = 1\text{ V}$                                    |  |           | 0.7        | % FS                   |
|                                 | $Y = \pm 1\text{ V}, X = 1\text{ V}$                                    |  |           | 0.5        | % FS                   |
| Common-Mode Voltage Range       |   | $-2.5$                                 |           | $+3$       | V                      |
| Offset Voltage                  |   |  | $\pm 3$   | $\pm 20^1$ | mV                     |
| vs. Temperature                 | $T_{MIN}$ to $T_{MAX}^2$  |  |           | $\pm 25$   | mV                     |
| CMRR                            | $f \leq 100\text{ kHz}; \pm 1\text{ V p-p}$                             | $70^1$                                 |           |            | dB                     |
| Bias Current                    |   |  | 10        | $20^1$     | $\mu\text{A}$          |
| vs. Temperature                 | $T_{MIN}$ to $T_{MAX}^2$  |  |           | 27         | $\mu\text{A}$          |
| Offset Bias Current             |   |  | 2         |            | $\mu\text{A}$          |
| Differential Resistance         |   |  | 100       |            | $\text{k}\Omega$       |
| Single-Sided Capacitance        |   |  | 2         |            | pF                     |
| Feedthrough, X                  | $X = \pm 1\text{ V}, Y = 0\text{ V}$                                    |  |           | $-46^1$    | dB                     |
| Feedthrough, Y                  | $Y = \pm 1\text{ V}, X = 0\text{ V}$                                    |  |           | $-60^1$    | dB                     |
| DYNAMIC CHARACTERISTICS         |   |  |           |            |                        |
| -3 dB Small Signal Bandwidth    |   | 150                                    | 250       |            | MHz                    |
| -0.1 dB Gain Flatness Frequency |   |  | 15        |            | MHz                    |
| Slew Rate                       | $W = -2.5\text{ V to }+2.5\text{ V}$                                    |  | 1000      |            | $\text{V}/\mu\text{s}$ |
| Differential Gain Error, X      | $f = 3.58\text{ MHz}$   |  | 0.3       |            | %                      |
| Differential Phase Error, X     | $f = 3.58\text{ MHz}$   |  | 0.2       |            | Degrees                |
| Differential Gain Error, Y      | $f = 3.58\text{ MHz}$   |  | 0.1       |            | %                      |
| Differential Phase Error, Y     | $f = 3.58\text{ MHz}$   |  | 0.1       |            | Degrees                |
| Harmonic Distortion             | $X$ or $Y = 10\text{ dBm}$ , second and third harmonic<br>Fund = 10 MHz |  |           | $-70$      | dB                     |
|                                 | Fund = 50 MHz   |  |           | $-40$      | dB                     |
| Settling Time, X or Y           | To 0.1%, $W = 2\text{ V p-p}$   |  | 20        |            | ns                     |
| SUMMING INPUT (Z)               |   |  |           |            |                        |
| Gain                            | From Z to W, $f \leq 10\text{ MHz}$                                     | 0.990                                  | 0.995     |            |                        |
| -3 dB Small Signal Bandwidth    |   |  | 250       |            | MHz                    |
| Differential Input Resistance   |   |  | 60        |            | $\text{k}\Omega$       |
| Single-Sided Capacitance        |   |  | 2         |            | pF                     |
| Maximum Gain                    | $X, Y$ to W, Z shorted to W, $f = 1\text{ kHz}$                         |  | 50        |            | dB                     |
| Bias Current                    |   |  | 50        |            | $\mu\text{A}$          |



# AD835

| Parameter                               | Conditions  | Min  | Typ  | Max               | Unit   |
|---|---|------|------|-------------------|--------|
| <b>OUTPUT CHARACTERISTICS</b>           |   |      |      |                   |        |
| Voltage Swing                           | $T_{MIN}$ to $T_{MAX}$ <sup>2</sup><br>$X = Y = 0\text{ V}$ , $f < 10\text{ MHz}$ | ±2.2 | ±2.5 |                   | V      |
| vs. Temperature                         |   | ±2.0 |      |                   | V      |
| Voltage Noise Spectral Density          | $T_{MIN}$ to $T_{MAX}$ <sup>2</sup>   |      | 50   |                   | nV/√Hz |
| Offset Voltage                          |   |      | ±25  | ±75 <sup>1</sup>  | mV     |
| vs. Temperature <sup>3</sup>            |   |      |      | ±10               | mV     |
| Short-Circuit Current                   |   |      | 75   |                   | mA     |
| Scale Factor Error                      | $T_{MIN}$ to $T_{MAX}$ <sup>2</sup>   |      | ±5   | ±8 <sup>1</sup>   | % FS   |
| vs. Temperature                         |   |      |      |                   | ±9     |
| Linearity (Relative Error) <sup>4</sup> | $T_{MIN}$ to $T_{MAX}$ <sup>2</sup>   |      | ±0.5 | ±1.0 <sup>1</sup> | % FS   |
| vs. Temperature                         |   |      |      |                   | ±1.25  |
| <b>POWER SUPPLIES</b>                   |   |      |      |                   |        |
| Supply Voltage                          |   | ±4.5 | ±5   | ±5.5              | V      |
| For Specified Performance               |   |      |      |                   |        |
| Quiescent Supply Current                | $T_{MIN}$ to $T_{MAX}$ <sup>2</sup>   |      | 16   | 25 <sup>1</sup>   | mA     |
| vs. Temperature                         |   |      |      |                   | 26     |
| PSRR at Output vs. VP                   | +4.5 V to +5.5 V  |      |      | 0.5 <sup>1</sup>  | %/V    |
| PSRR at Output vs. VN                   | -4.5 V to -5.5 V  |      |      | 0.5               | %/V    |

<sup>1</sup> All minimum and maximum specifications are guaranteed. These specifications are tested on all production units at final electrical test.

<sup>2</sup>  $T_{MIN} = -40^{\circ}\text{C}$ ,  $T_{MAX} = 85^{\circ}\text{C}$ .

<sup>3</sup> Normalized to zero at  $25^{\circ}\text{C}$ .

<sup>4</sup> Linearity is defined as residual error after compensating for input offset, output voltage offset, and scale factor errors.

## ABSOLUTE MAXIMUM RATINGS

Table 2.

| Parameter                          | Rating  |
|------------------------------------|---|
| Supply Voltage                     | $\pm 6$ V                                       |
| Internal Power Dissipation         | 300 mW  |
| Operating Temperature Range        | $-40^{\circ}\text{C}$ to $+85^{\circ}\text{C}$  |
| Storage Temperature Range          | $-65^{\circ}\text{C}$ to $+150^{\circ}\text{C}$ |
| Lead Temperature, Soldering 60 sec | $300^{\circ}\text{C}$                           |
| ESD Rating                         |   |
| HBM                                | 1500 V  |
| CDM                                | 250 V   |

Stresses above those listed under Absolute Maximum Ratings may cause permanent damage to the device. This is a stress rating only; functional operation of the device at these or any other conditions above those indicated in the operational section of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

For more information, see the Analog Devices, Inc., [Tutorial MT-092, Electrostatic Discharge](#).

## THERMAL RESISTANCE

Table 3.

| Package Type    | $\theta_{JA}$ | $\theta_{JC}$ | Unit                        |
|-----------------|---------------|---------------|-----------------------------|
| 8-Lead PDIP (N) | 90            | 35            | $^{\circ}\text{C}/\text{W}$ |
| 8-Lead SOIC (R) | 115           | 45            | $^{\circ}\text{C}/\text{W}$ |

## ESD CAUTION



**ESD (electrostatic discharge) sensitive device.** Charged devices and circuit boards can discharge without detection. Although this product features patented or proprietary protection circuitry, damage may occur on devices subjected to high energy ESD. Therefore, proper ESD precautions should be taken to avoid performance degradation or loss of functionality.

# AD835

## PIN CONFIGURATION AND FUNCTION DESCRIPTIONS

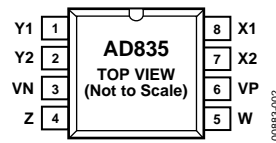


Figure 2. Pin Configuration

Table 4. Pin Function Descriptions

| Pin No. | Mnemonic | Description                       |
|---------|----------|-----------------------------------|
| 1       | Y1       | Noninverting Y Multiplicand Input |
| 2       | Y2       | Inverting Y Multiplicand Input    |
| 3       | VN       | Negative Supply Voltage           |
| 4       | Z        | Summing Input                     |
| 5       | W        | Product                           |
| 6       | VP       | Positive Supply Voltage           |
| 7       | X2       | Inverting X Multiplicand Input    |
| 8       | X1       | Noninverting X Multiplicand Input |

# TYPICAL PERFORMANCE CHARACTERISTICS

DG DP (NTSC) FIELD = 1 LINE = 18 Wfm → FCC COMPOSITE

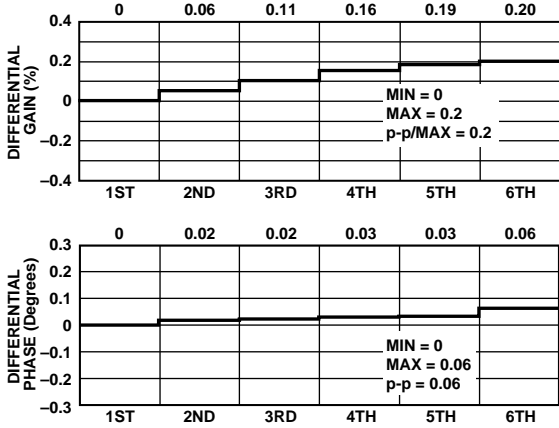


Figure 3. Typical Composite Output Differential Gain and Phase, NTSC for X Channel;  $f = 3.58$  MHz,  $R_L = 150 \Omega$

DG DP (NTSC) FIELD = 1 LINE = 18 Wfm → FCC COMPOSITE

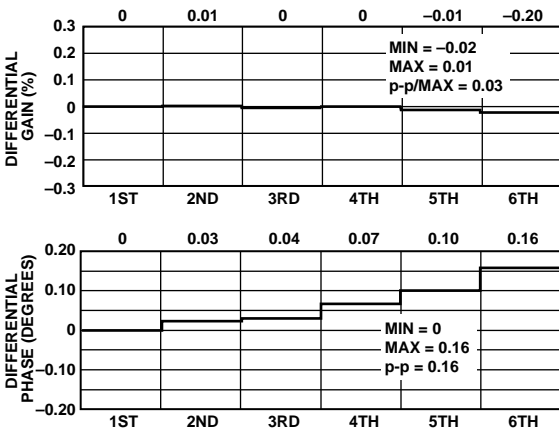


Figure 4. Typical Composite Output Differential Gain and Phase, NTSC for Y Channel;  $f = 3.58$  MHz,  $R_L = 150 \Omega$

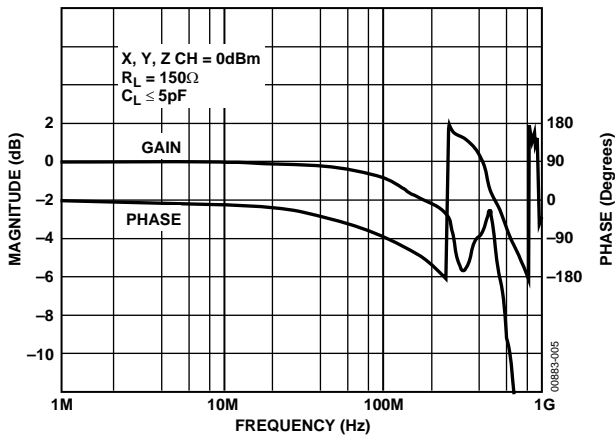


Figure 5. Gain and Phase vs. Frequency of X, Y, Z Inputs

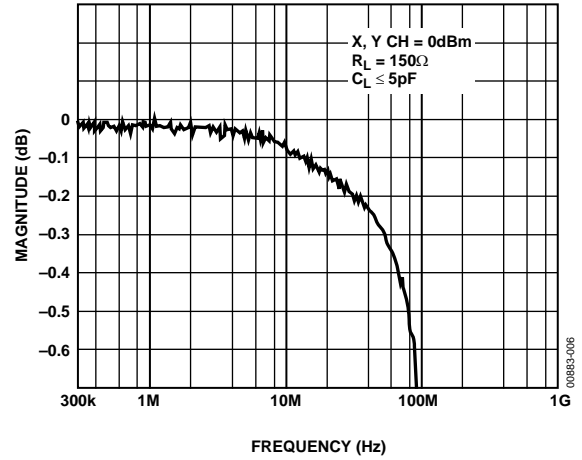


Figure 6. Gain Flatness to 0.1 dB

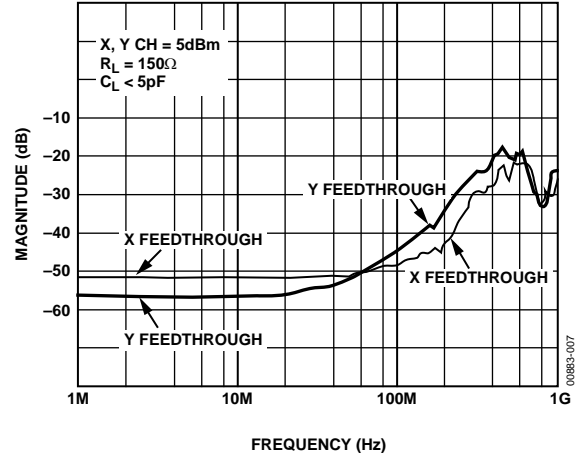


Figure 7. X and Y Feedthrough vs. Frequency

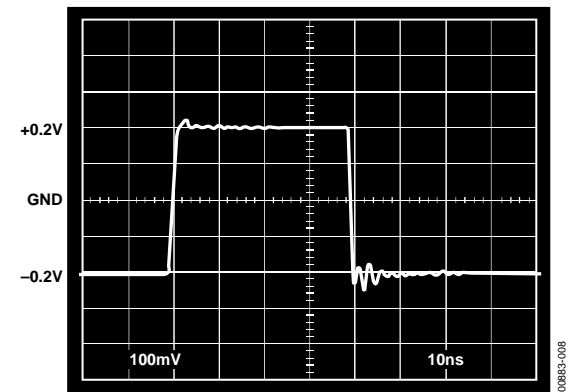


Figure 8. Small Signal Pulse Response at W Output,  $R_L = 150 \Omega$ ,  $C_L \leq 5$  pF, X Channel =  $\pm 0.2$  V, Y Channel =  $\pm 1.0$  V

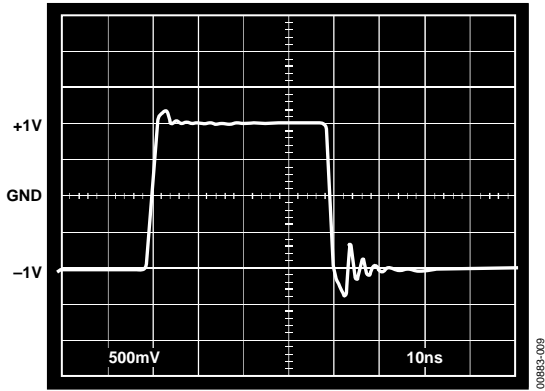


Figure 9. Large Signal Pulse Response at W Output,  $R_L = 150 \Omega$ ,  $C_L \leq 5 \text{ pF}$ , X Channel =  $\pm 1.0 \text{ V}$ , Y Channel =  $\pm 1.0 \text{ V}$

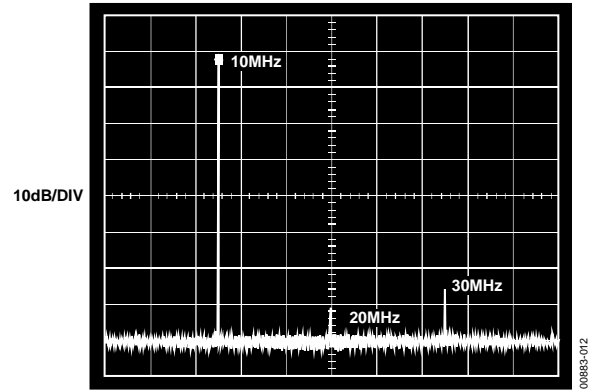


Figure 12. Harmonic Distortion at 10 MHz; 10 dBm Input to X or Y Channels,  $R_L = 150 \Omega$ ,  $C_L \leq 5 \text{ pF}$

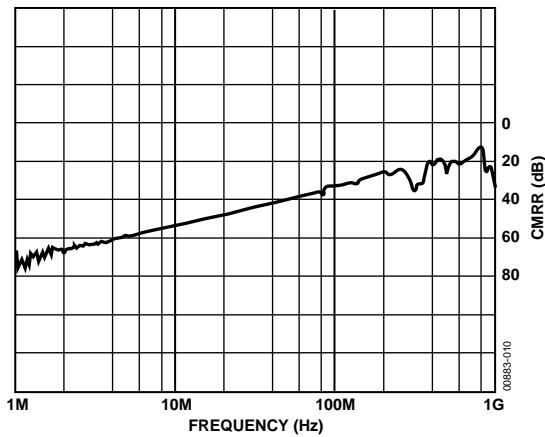


Figure 10. CMRR vs. Frequency for X or Y Channel,  $R_L = 150 \Omega$ ,  $C_L \leq 5 \text{ pF}$

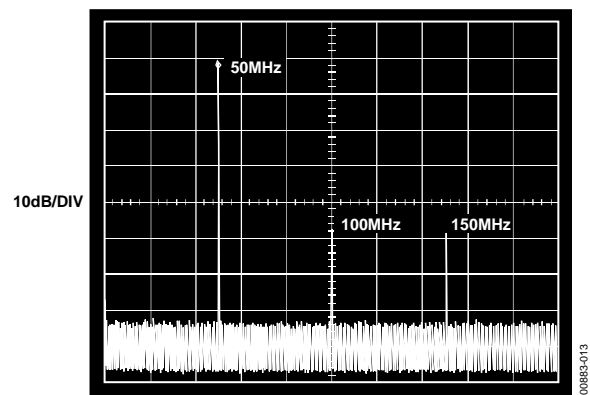


Figure 13. Harmonic Distortion at 50 MHz, 10 dBm Input to X or Y Channel,  $R_L = 150 \Omega$ ,  $C_L \leq 5 \text{ pF}$

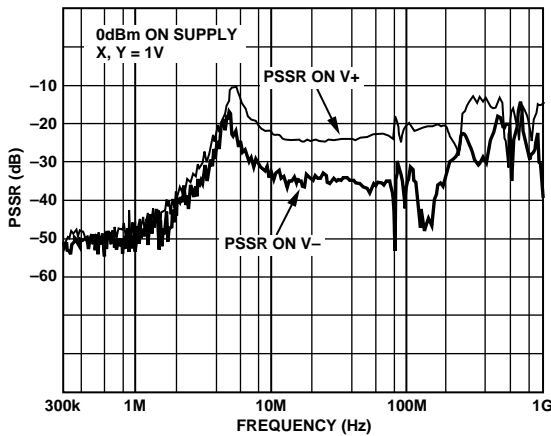


Figure 11. PSRR vs. Frequency for V+ and V- Supply

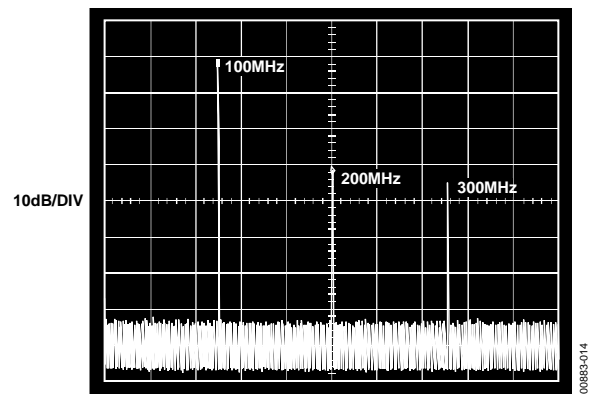


Figure 14. Harmonic Distortion at 100 MHz, 10 dBm Input to X or Y Channel,  $R_L = 150 \Omega$ ,  $C_L \leq 5 \text{ pF}$

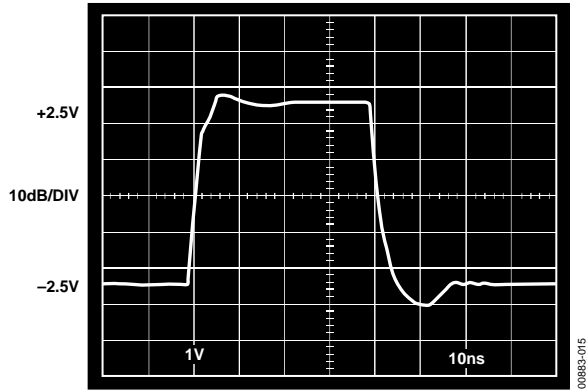


Figure 15. Maximum Output Voltage Swing,  $R_L = 50\ \Omega$ ,  $C_L \leq 5\ \text{pF}$

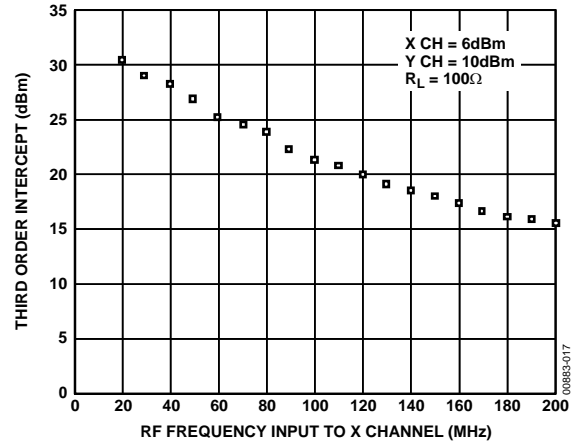


Figure 17. Fixed LO on Y Channel vs. RF Frequency Input to X Channel

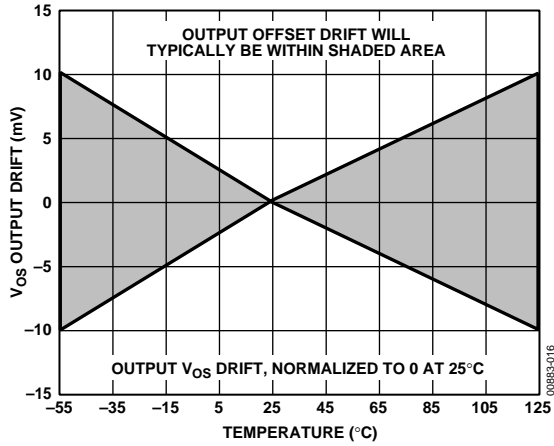


Figure 16.  $V_{OS}$  Output Drift vs. Temperature

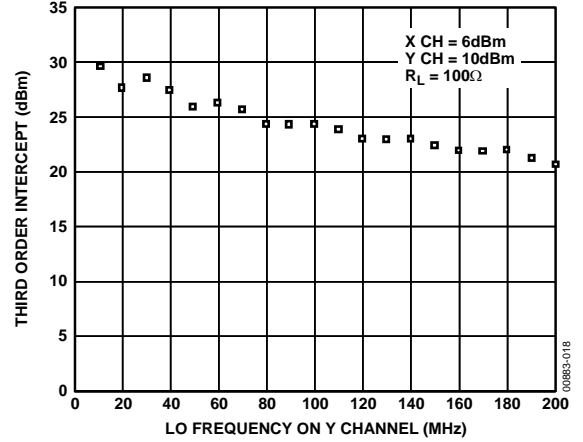


Figure 18. Fixed IF vs. LO Frequency on Y Channel

## THEORY OF OPERATION

The AD835 is a four-quadrant, voltage output analog multiplier, fabricated on an advanced dielectrically isolated complementary bipolar process. In its basic mode, it provides the linear product of its X and Y voltage inputs. In this mode, the -3 dB output voltage bandwidth is 250 MHz (with small signal rise time of 1 ns). Full-scale (-1 V to +1 V) rise to fall times are 2.5 ns (with a standard  $R_L$  of 150  $\Omega$ ), and the settling time to 0.1% under the same conditions is typically 20 ns.

As in earlier multipliers from Analog Devices a unique summing feature is provided at the Z input. As well as providing independent ground references for the input and the output and enhanced versatility, this feature allows the AD835 to operate with voltage gain. Its X-, Y-, and Z-input voltages are all nominally  $\pm 1$  V FS, with an overrange of at least 20%. The inputs are fully differential at high impedance (100 k $\Omega$ ||2 pF) and provide a 70 dB CMRR ( $f \leq 1$  MHz).

The low impedance output is capable of driving loads as small as 25  $\Omega$ . The peak output can be as large as  $\pm 2.2$  V minimum for  $R_L = 150 \Omega$ , or  $\pm 2.0$  V minimum into  $R_L = 50 \Omega$ . The AD835 has much lower noise than the AD534 or AD734, making it attractive in low level, signal processing applications, for example, as a wideband gain control element or modulator.

### BASIC THEORY

The multiplier is based on a classic form, having a translinear core, supported by three (X, Y, and Z) linearized voltage-to-current converters, and the load driving output amplifier. The scaling voltage (the denominator U in the equations) is provided by a band gap reference of novel design, optimized for ultralow noise. Figure 19 shows the functional block diagram.

In general terms, the AD835 provides the function

$$W = \frac{(X_1 - X_2)(Y_1 - Y_2)}{U} + Z \quad (1)$$

where the variables W, U, X, Y, and Z are all voltages. Connected as a simple multiplier, with  $X = X_1 - X_2$ ,  $Y = Y_1 - Y_2$ , and  $Z = 0$  and with a scale factor adjustment (see Figure 19) that sets  $U = 1$  V, the output can be expressed as

$$W = XY \quad (2)$$

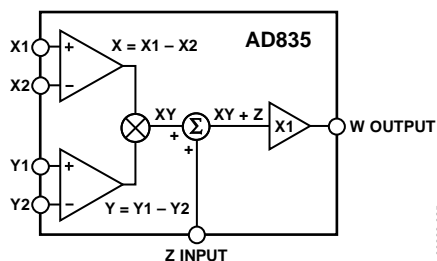


Figure 19. Functional Block Diagram

Simplified representations of this sort, where all signals are presumed expressed in V, are used throughout this data sheet to

avoid the needless use of less intuitive subscripted variables (such as,  $V_{X1}$ ). All variables are being normalized to 1 V.

For example, the input X can either be stated as being in the -1 V to +1 V range or simply -1 to +1. The latter representation is found to facilitate the development of new functions using the AD835. The explicit inclusion of the denominator, U, is also less helpful, as in the case of the AD835, if it is not an electrical input variable.

### SCALING ADJUSTMENT

The basic value of U in Equation 1 is nominally 1.05 V. Figure 20, which shows the basic multiplier connections, also shows how the effective value of U can be adjusted to have any lower voltage (usually 1 V) through the use of a resistive divider between W (Pin 5) and Z (Pin 4). Using the general resistor values shown, Equation 1 can be rewritten as

$$W = \frac{XY}{U} + kW + (1-k)Z' \quad (3)$$

where  $Z'$  is distinguished from the signal Z at Pin 4. It follows that

$$W = \frac{XY}{(1-k)U} + Z' \quad (4)$$

In this way, the effective value of U can be modified to

$$U' = (1-k)U \quad (5)$$

without altering the scaling of the  $Z'$  input, which is expected because the only ground reference for the output is through the  $Z'$  input.

Therefore, to set  $U'$  to 1 V, remembering that the basic value of U is 1.05 V,  $R_1$  must have a nominal value of  $20 \times R_2$ . The values shown allow U to be adjusted through the nominal range of 0.95 V to 1.05 V. That is,  $R_2$  provides a 5% gain adjustment.

In many applications, the exact gain of the multiplier may not be very important; in which case, this network may be omitted entirely, or  $R_2$  fixed at 100  $\Omega$ .

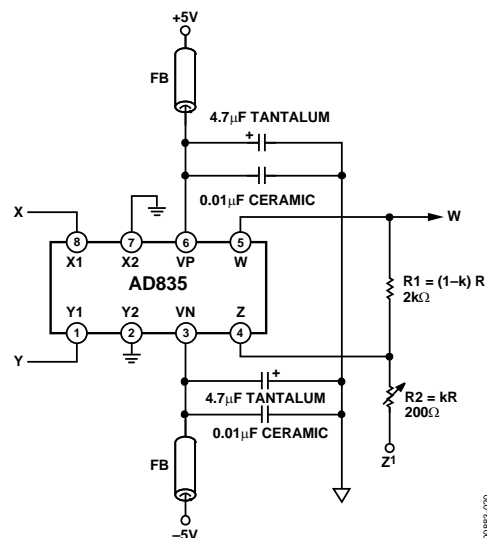


Figure 20. Multiplier Connections

## APPLICATIONS INFORMATION

The AD835 is easy to use and versatile. The capability for adding another signal to the output at the Z input is frequently valuable. Three applications of this feature are presented here: a wideband voltage-controlled amplifier, an amplitude modulator, and a frequency doubler. Of course, the AD835 may also be used as a square law detector (with its X inputs and Y inputs connected in parallel). In this mode, it is useful at input frequencies to well over 250 MHz because that is the bandwidth limitation of the output amplifier only.

### MULTIPLIER CONNECTIONS

Figure 20 shows the basic connections for multiplication. The inputs are often single sided, in which case the X2 and Y2 inputs are normally grounded. Note that by assigning Pin 7 (X2) and Pin 2 (Y2), respectively, to these (inverting) inputs, an extra measure of isolation between inputs and output is provided. The X and Y inputs may be reversed to achieve some desired overall sign with inputs of a particular polarity, or they may be driven fully differentially.

Power supply decoupling and careful board layout are always important in applying wideband circuits. The decoupling recommendations shown in Figure 20 should be followed closely. In Figure 21, Figure 23, and Figure 24, these power supply decoupling components are omitted for clarity but should be used wherever optimal performance with high speed inputs is required. However, if the full, high frequency capabilities of the AD835 are not being exploited, these components can be omitted.

### WIDEBAND VOLTAGE-CONTROLLED AMPLIFIER

Figure 21 shows the AD835 configured to provide a gain of nominally 0 dB to 12 dB. (In fact, the control range extends from well under -12 dB to about +14 dB.) R1 and R2 set the gain to be nominally  $\times 4$ . The attendant bandwidth reduction that comes with this increased gain can be partially offset by the addition of the peaking capacitor C1. Although this circuit shows the use of dual supplies, the AD835 can operate from a single 9 V supply with a slight revision.

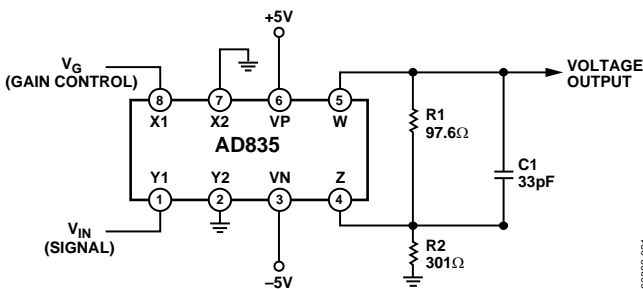


Figure 21. Voltage-Controlled 50 MHz Amplifier Using the AD835

The ac response of this amplifier for gains of 0 dB ( $V_G = 0.25$  V), 6 dB ( $V_G = 0.5$  V), and 12 dB ( $V_G = 1$  V) is shown in Figure 22. In this application, the resistor values have been slightly adjusted to reflect the nominal value of  $U = 1.05$  V. The overall sign of the gain may be controlled by the sign of  $V_G$ .

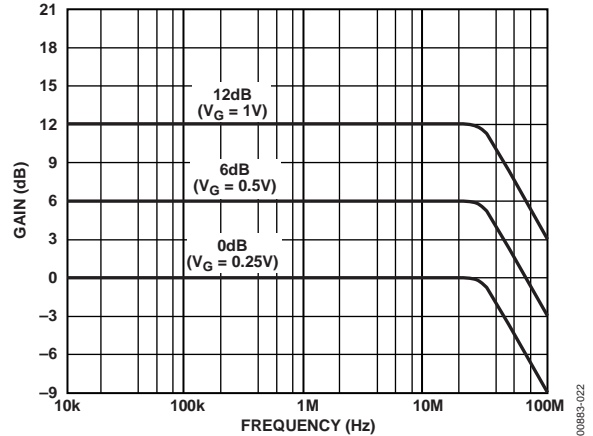


Figure 22. AC Response of VCA

### AMPLITUDE MODULATOR

Figure 23 shows a simple modulator. The carrier is applied to the Y input and the Z input, while the modulating signal is applied to the X input. For zero modulation, there is no product term so the carrier input is simply replicated at unity gain by the voltage follower action from the Z input. At  $X = 1$  V, the RF output is doubled, while for  $X = -1$  V, it is fully suppressed. That is, an X input of approximately  $\pm 1$  V (actually  $\pm U$  or about 1.05 V) corresponds to a modulation index of 100%. Carrier and modulation frequencies can be up to 300 MHz, somewhat beyond the nominal -3 dB bandwidth.

Of course, a suppressed carrier modulator can be implemented by omitting the feedforward to the Z input, grounding that pin instead.

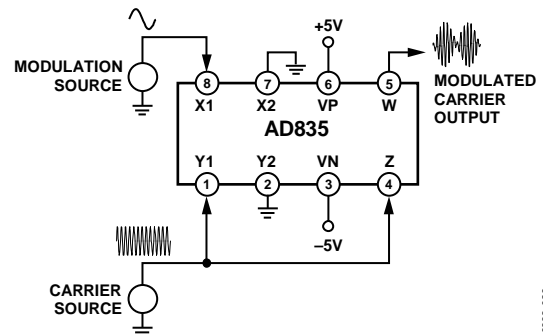


Figure 23. Simple Amplitude Modulator Using the AD835



## SQUARING AND FREQUENCY DOUBLING

Amplitude domain squaring of an input signal,  $E$ , is achieved simply by connecting the X and Y inputs in parallel to produce an output of  $E^2/U$ . The input can have either polarity, but the output in this case is always positive. The output polarity can be reversed by interchanging either the X or Y inputs.

When the input is a sine wave  $E \sin \omega t$ , a signal squarer behaves as a frequency doubler because

$$\frac{(E \sin \omega t)^2}{U} = \frac{E^2}{2U} (1 - \cos 2\omega t) \quad (6)$$

While useful, Equation 6 shows a dc term at the output, which varies strongly with the amplitude of the input,  $E$ .

Figure 24 shows a frequency doubler that overcomes this limitation and provides a relatively constant output over a moderately wide frequency range, determined by the time constant  $R1C1$ . The voltage applied to the X and Y inputs is exactly in quadrature at a frequency  $f = \frac{1}{2\pi C1R1}$ , and their amplitudes are equal. At higher frequencies, the X input becomes smaller while the Y input increases in amplitude; the opposite happens at lower frequencies. The result is a double frequency output centered on ground whose amplitude of 1 V for a 1 V input varies by only 0.5% over a frequency range of  $\pm 10\%$ . Because there is no squared dc component at the output, sudden changes in the input amplitude do not cause a bounce in the dc level.

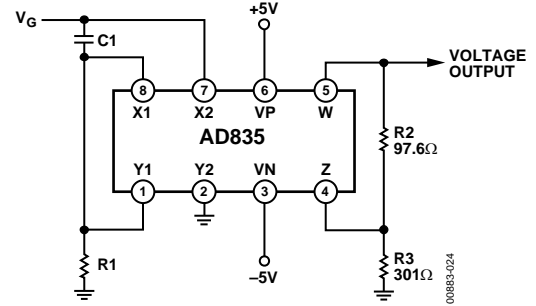


Figure 24. Broadband Zero-Bounce Frequency Doubler

This circuit is based on the identity

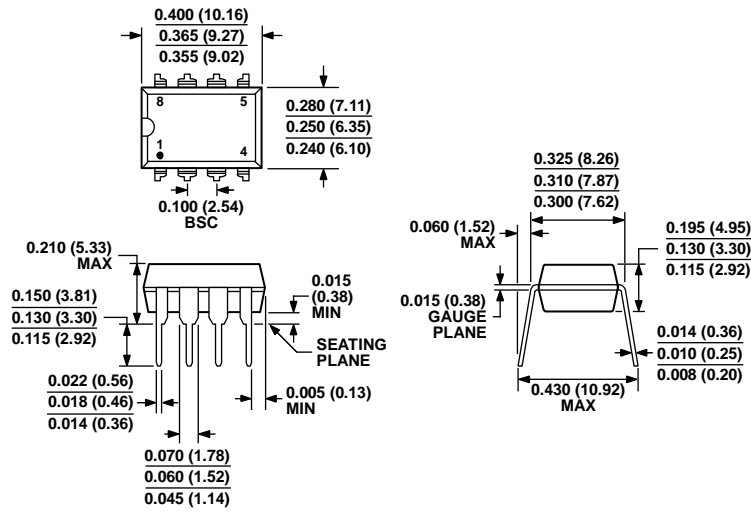
$$\cos \theta \sin \theta = \frac{1}{2} \sin 2\theta \quad (7)$$

At  $\omega_0 = 1/C1R1$ , the X input leads the input signal by  $45^\circ$  (and is attenuated by  $\sqrt{2}$ ), while the Y input lags the input signal by  $45^\circ$  and is also attenuated by  $\sqrt{2}$ . Because the X and Y inputs are  $90^\circ$  out of phase, the response of the circuit is

$$W = \frac{1}{U} \frac{E}{\sqrt{2}} (\sin \omega t - 45^\circ) \frac{E}{\sqrt{2}} (\sin \omega t + 45^\circ) = \frac{E^2}{2U} (\sin 2\omega t) \quad (8)$$

which has no dc component, R2 and R3 are included to restore the output to 1 V for an input amplitude of 1 V (the same gain adjustment as previously mentioned). Because the voltage across the capacitor (C1) decreases with frequency, while that across the resistor (R1) increases, the amplitude of the output varies only slightly with frequency. In fact, it is only 0.5% below its full value (at its center frequency  $\omega_0 = 1/C1R1$ ) at 90% and 110% of this frequency.

OUTLINE DIMENSIONS

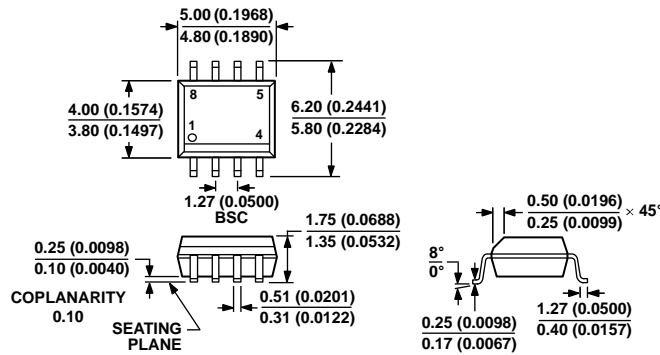


COMPLIANT TO JEDEC STANDARDS MS-001  
 CONTROLLING DIMENSIONS ARE IN INCHES; MILLIMETER DIMENSIONS (IN PARENTHESES) ARE ROUNDED-OFF INCH EQUIVALENTS FOR REFERENCE ONLY AND ARE NOT APPROPRIATE FOR USE IN DESIGN. CORNER LEADS MAY BE CONFIGURED AS WHOLE OR HALF LEADS.

Figure 25. 8-Lead Plastic Dual In-Line Package [PDIP] Narrow Body (N-8)

Dimensions shown in inches and (millimeters)

070606-A



COMPLIANT TO JEDEC STANDARDS MS-012-AA  
 CONTROLLING DIMENSIONS ARE IN MILLIMETERS; INCH DIMENSIONS (IN PARENTHESES) ARE ROUNDED-OFF MILLIMETER EQUIVALENTS FOR REFERENCE ONLY AND ARE NOT APPROPRIATE FOR USE IN DESIGN.

Figure 26. 8-Lead Standard Small Outline Package [SOIC\_N] Narrow Body (R-8)

Dimensions shown in millimeters and (inches)

012407-A

# AD835

## ORDERING GUIDE

| Model <sup>1</sup> | Temperature Range | Package Description                            | Package Option |
|--------------------|-------------------|--|----------------|
| AD835AN            | -40°C to +85°C    | 8-Lead Plastic Dual In-Line Package [PDIP]     | N-8            |
| AD835ANZ           | -40°C to +85°C    | 8-Lead Plastic Dual In-Line Package [PDIP]     | N-8            |
| AD835AR            | -40°C to +85°C    | 8-Lead Standard Small Outline Package [SOIC_N] | R-8            |
| AD835AR-REEL       | -40°C to +85°C    | 8-Lead Standard Small Outline Package [SOIC_N] | R-8            |
| AD835AR-REEL7      | -40°C to +85°C    | 8-Lead Standard Small Outline Package [SOIC_N] | R-8            |
| AD835ARZ           | -40°C to +85°C    | 8-Lead Standard Small Outline Package [SOIC_N] | R-8            |
| AD835ARZ-REEL      | -40°C to +85°C    | 8-Lead Standard Small Outline Package [SOIC_N] | R-8            |
| AD835ARZ-REEL7     | -40°C to +85°C    | 8-Lead Standard Small Outline Package [SOIC_N] | R-8            |

<sup>1</sup> Z = RoHS Compliant Part.

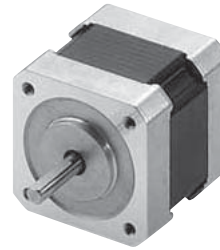
**NOTES**

**AD835**

**NOTES**

# 42 mm

Step Angle 1.8°  
Standard Type



## Specifications (RoHS)

| Model<br>Single Shaft<br>Double Shaft | Connection<br>Type | Holding<br>Torque<br>N·m | Current<br>per Phase<br>A/phase | Voltage<br>V | Resistance<br>per Phase<br>Ω/phase | Inductance<br>mH/phase | Rotor<br>Inertia<br>J: kg·m <sup>2</sup> | Lead<br>Wires | Wirings and<br>Connections<br>(See Page 76) | Corresponding Motor &<br>Driver Package |      |
|---------------------------------------|--------------------|--------------------------|---------------------------------|--------------|------------------------------------|------------------------|--|---------------|---|---|------|
|                                       |                    |                          |                                 |              |                                    |                        |  |               |   | Model                                   | Page |
| <b>PK243DA</b><br><b>PK243DB</b>      | Bipolar            | 0.2                      | 1.5                             | 2.4          | 1.6                                | 1.75                   | $35 \times 10^{-7}$                      | 4             | [1]   | -                                       | -    |
| <b>PK243-01A</b><br><b>PK243-01B</b>  | Bipolar (Series)   | 0.2                      | 0.67                            | 5.6          | 8.4                                | 10                     | $35 \times 10^{-7}$                      | 6             | [3]   | -                                       | -    |
|                                       | Unipolar           | 0.16                     | 0.95                            | 4            | 4.2                                | 2.5                    |  |               | [2]   | <b>CMK243AP</b><br><b>CMK243BP</b>      | P.82 |
| <b>PK243-02A</b><br><b>PK243-02B</b>  | Bipolar (Series)   | 0.2                      | 0.28                            | 13           | 48                                 | 60                     | $35 \times 10^{-7}$                      | 6             | [3]   | -                                       | -    |
|                                       | Unipolar           | 0.16                     | 0.4                             | 9.6          | 24                                 | 15                     |  |               | [2]   | -                                       | -    |
| <b>PK243-03A</b><br><b>PK243-03B</b>  | Bipolar (Series)   | 0.2                      | 0.22                            | 17           | 77                                 | 84                     | $35 \times 10^{-7}$                      | 6             | [3]   | -                                       | -    |
|                                       | Unipolar           | 0.16                     | 0.31                            | 12           | 38.5                               | 21                     |  |               | [2]   | -                                       | -    |
| <b>PK244DA</b><br><b>PK244DB</b>      | Bipolar            | 0.33                     | 1.5                             | 3.45         | 2.3                                | 3.9                    | $54 \times 10^{-7}$                      | 4             | [1]   | -                                       | -    |
| <b>PK244-01A</b><br><b>PK244-01B</b>  | Bipolar (Series)   | 0.33                     | 0.85                            | 5.6          | 6.6                                | 12.8                   | $54 \times 10^{-7}$                      | 6             | [3]   | -                                       | -    |
|                                       | Unipolar           | 0.26                     | 1.2                             | 4            | 3.3                                | 3.2                    |  |               | [2]   | <b>CMK244AP</b><br><b>CMK244BP</b>      | P.82 |
| <b>PK244-02A</b><br><b>PK244-02B</b>  | Bipolar (Series)   | 0.33                     | 0.57                            | 8.6          | 15                                 | 26.8                   | $54 \times 10^{-7}$                      | 6             | [3]   | -                                       | -    |
|                                       | Unipolar           | 0.26                     | 0.8                             | 6            | 7.5                                | 6.7                    |  |               | [2]   | -                                       | -    |
| <b>PK244-03A</b><br><b>PK244-03B</b>  | Bipolar (Series)   | 0.33                     | 0.28                            | 17           | 60                                 | 120                    | $54 \times 10^{-7}$                      | 6             | [3]   | -                                       | -    |
|                                       | Unipolar           | 0.26                     | 0.4                             | 12           | 30                                 | 30                     |  |               | [2]   | -                                       | -    |
| <b>PK245DA</b><br><b>PK245DB</b>      | Bipolar            | 0.43                     | 1.5                             | 3.15         | 2.1                                | 3.1                    | $68 \times 10^{-7}$                      | 4             | [1]   | -                                       | -    |
| <b>PK245-01A</b><br><b>PK245-01B</b>  | Bipolar (Series)   | 0.43                     | 0.85                            | 5.6          | 6.6                                | 11.2                   | $68 \times 10^{-7}$                      | 6             | [3]   | -                                       | -    |
|                                       | Unipolar           | 0.32                     | 1.2                             | 4            | 3.3                                | 2.8                    |  |               | [2]   | <b>CMK245AP</b><br><b>CMK245BP</b>      | P.82 |
| <b>PK245-02A</b><br><b>PK245-02B</b>  | Bipolar (Series)   | 0.43                     | 0.57                            | 8.6          | 15                                 | 28.4                   | $68 \times 10^{-7}$                      | 6             | [3]   | -                                       | -    |
|                                       | Unipolar           | 0.32                     | 0.8                             | 6            | 7.5                                | 7.1                    |  |               | [2]   | -                                       | -    |
| <b>PK245-03A</b><br><b>PK245-03B</b>  | Bipolar (Series)   | 0.43                     | 0.28                            | 17           | 60                                 | 100                    | $68 \times 10^{-7}$                      | 6             | [3]   | -                                       | -    |
|                                       | Unipolar           | 0.32                     | 0.4                             | 12           | 30                                 | 25                     |  |               | [2]   | -                                       | -    |

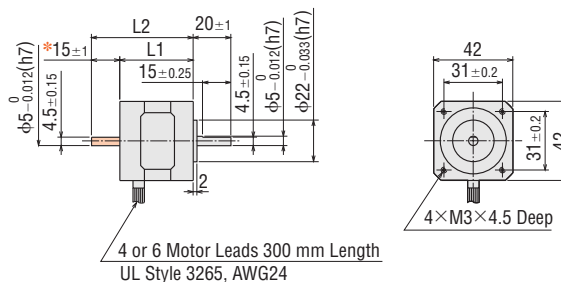
How to read specifications table → Page 78

● Degree of Protection: IP30

## Dimensions (Unit = mm)

| Model                              | L1 | L2 | Mass<br>kg |
|------------------------------------|----|----|------------|
| <b>PK243DA</b><br><b>PK243-0□A</b> | 33 | -  | 0.21       |
| <b>PK243DB</b><br><b>PK243-0□B</b> |    | 48 |            |
| <b>PK244DA</b><br><b>PK244-0□A</b> | 39 | -  | 0.27       |
| <b>PK244DB</b><br><b>PK244-0□B</b> |    | 54 |            |
| <b>PK245DA</b><br><b>PK245-0□A</b> | 47 | -  | 0.35       |
| <b>PK245DB</b><br><b>PK245-0□B</b> |    | 62 |            |

● Enter the winding specifications in the box (□) within the model name.



\*The length of machining on double shaft model is 15±0.25.

● These dimensions are for double shaft models. For single shaft models, ignore the orange (□) areas.

|                     |                        |
|---------------------|------------------------|
| High-Efficiency     | 28 mm                  |
| High-Torque         | 35 mm                  |
| Standard            | 42 mm                  |
| Cable Type          | IP54                   |
| Terminal Box        | IP55                   |
| High-Resolution     | 56.4 mm                |
| PL Geared           | 60 mm                  |
| TH Geared           | 85 mm                  |
| SH Geared           | 90 mm                  |
| 2-Phase             | Motor & Driver Package |
| 5-Phase             | Motor & Driver Package |
| Lead Wire/Connector | Accessories            |
| Coupling            | Accessories            |
| Damper              | Accessories            |
| Mounting Bracket    | Accessories            |

# Uni-Con Series

Variable Vacuum Capacitor

- High Power
- Small Size
- Long Life



Optimized bellows design for high power operation – Identical mounting for all types allows easy switching of capacitors for slightly different applications – Series with highest current capability relative to size – Drive system optimized for high speed tuning and over 3 millions cycles.

- 100 pF / 15 kV
- 250 pF / 15 kV
- 500 pF / 8 kV
- 1000 pF / 5 kV
- 1500 pF / 4 kV

#### Features:

|                                 |                    |
|---------------------------------|--------------------|
| <b>Current (rms max)</b>        | <b>95 A</b>        |
| <b>Voltage (peak test)</b>      | <b>15 kV</b>       |
| <b>Body size (dia x length)</b> | <b>54 x 91 mm</b>  |
| <b>Overall length</b>           | <b>&lt; 134 mm</b> |
| <b>Low torque</b>               | <b>0.20 Nm</b>     |
| <b>High tuning speed</b>        |                    |

Your local representative

COMET AG  
Herrngasse 10 • CH-3175 Flamatt • Switzerland  
Tel. +41 31 744 95 00 • Fax +41 31 744 95 90  
www.comet.ch

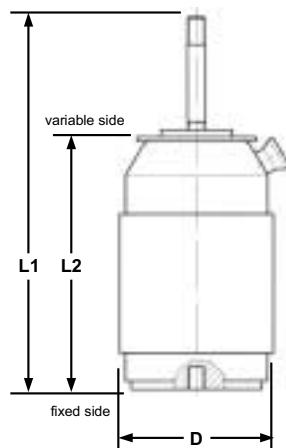
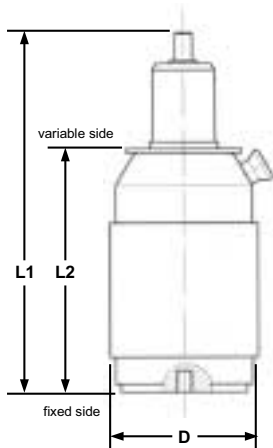


# Uni-Con Series

| Type            | Electrical Parameters  |                        |                                      |  | Dimensions     |                 |                 |      | Drive System     |   |                                |   |                            | Mounting   |               |                          |
|-----------------|------------------------|------------------------|--------------------------------------|--|----------------|-----------------|-----------------|------|------------------|---|--------------------------------|---|----------------------------|------------|---------------|--------------------------|
|                 | C <sub>min</sub><br>pF | C <sub>max</sub><br>pF | V <sub>max</sub><br>kV <sub>pt</sub> | I <sub>max</sub> at<br>13.56 MHz<br>A <sub>rms</sub> | D<br>mm (inch) | L1<br>mm (inch) | L2<br>mm (inch) | Fig. | Tuning<br>Method | Head/Rod<br>Shape<br>Dim.<br>mm (inch)          | Max<br>Torque or<br>Pull Force | C-range<br>C <sub>min</sub> -C <sub>max</sub><br>Turns/Stroke | Slope*<br>pF/turn<br>pF/mm | Fixed Side | Variable Side |                          |
| CV03C-1500 UC/4 | 150                    | 1500                   | 4                                    | 85   | 54.00 (2.13)   | 133.50 (5.26)   | 90.60 (3.57)    | 1    | Screw Drive      | R   | 6.35 (0.25)                    | 0.20 Nm   | 10.9 turns                 | 123.85     | CT M6 x 8 mm  | MF 4 x M4 on 50.8 mm dia |
| CV03C-1500UCG/4 | 150                    | 1500                   | 4                                    | 85   | 54.00 (2.13)   | 134.60 (5.30)   | 90.60 (3.57)    | 1    | Screw Drive      | RFFS  | 6.35 (0.25)                    | 0.20 Nm   | 13.9 turns                 | 97.12      | CT M6 x 8 mm  | MF 4 x M4 on 50.8 mm dia |
| CV05C-500UC/8   | 50                     | 500                    | 8                                    | 90   | 54.00 (2.13)   | 133.50 (5.26)   | 90.60 (3.57)    | 1    | Screw Drive      | R   | 6.35 (0.25)                    | 0.20 Nm   | 11.0 turns                 | 40.91      | CT M6 x 8 mm  | MF 4 x M4 on 50.8 mm dia |
| CV05C-500UCD/8  | 50                     | 500                    | 8                                    | 90   | 54.00 (2.13)   | 134.10 (5.28)   | 90.60 (3.57)    | 1    | Screw Drive      | RFFS  | 6.35 (0.25)                    | 0.20 Nm   | 11.0 turns                 | 40.91      | CT M6 x 8 mm  | MF 4 x M4 on 50.8 mm dia |
| CV05C-1000UC/5  | 100                    | 1000                   | 5                                    | 87   | 54.00 (2.13)   | 133.50 (5.26)   | 90.60 (3.57)    | 1    | Screw Drive      | R   | 6.35 (0.25)                    | 0.20 Nm   | 11.1 turns                 | 81.08      | CT M6 x 8 mm  | MF 4 x M4 on 50.8 mm dia |
| CV1C-100UC/15   | 10                     | 100                    | 15                                   | 54   | 54.00 (2.13)   | 133.50 (5.26)   | 90.60 (3.57)    | 1    | Screw Drive      | R   | 6.35 (0.25)                    | 0.20 Nm   | 7.9 turns                  | 9.75       | CT M5 x 8 mm  | MF 4 x M4 on 50.8 mm dia |
| CV1C-250UC/15   | 25                     | 250                    | 15                                   | 94   | 54.00 (2.13)   | 133.50 (5.26)   | 90.60 (3.57)    | 1    | Screw Drive      | R   | 6.35 (0.25)                    | 0.20 Nm   | 10.8 turns                 | 20.83      | CT M6 x 8 mm  | MF 4 x M4 on 50.8 mm dia |
| CV1C-250UCP/15  | 25                     | 250                    | 15                                   | 94   | 54.00 (2.13)   | 133.50 (5.26)   | 90.60 (3.57)    | 2    | Linear Drive     | T   | M6                             | 170 N   | 20.1 mm                    | 11.94      | CT M6 x 8 mm  | MF 4 x M4 on 50.8 mm dia |
| CV1C-500UC/12   | 50                     | 500                    | 12                                   | 95   | 63.00 (2.48)   | 133.50 (5.26)   | 90.60 (3.57)    | 1    | Screw Drive      | R   | 6.35 (0.25)                    | 0.20 Nm   | 10.7 turns                 | 42.06      | CT M6 x 8 mm  | MF 4 x M4 on 50.8 mm dia |
|                 |                        |                        |                                      |  |                |                 |                 |      |                  | R = Round<br>F = Flat<br>S = Slot<br>T = Thread | *linear<br>range               | CT = Central Thread   | MF = Mounting Flange       |            |               |                          |

Figure 1

Figure 2



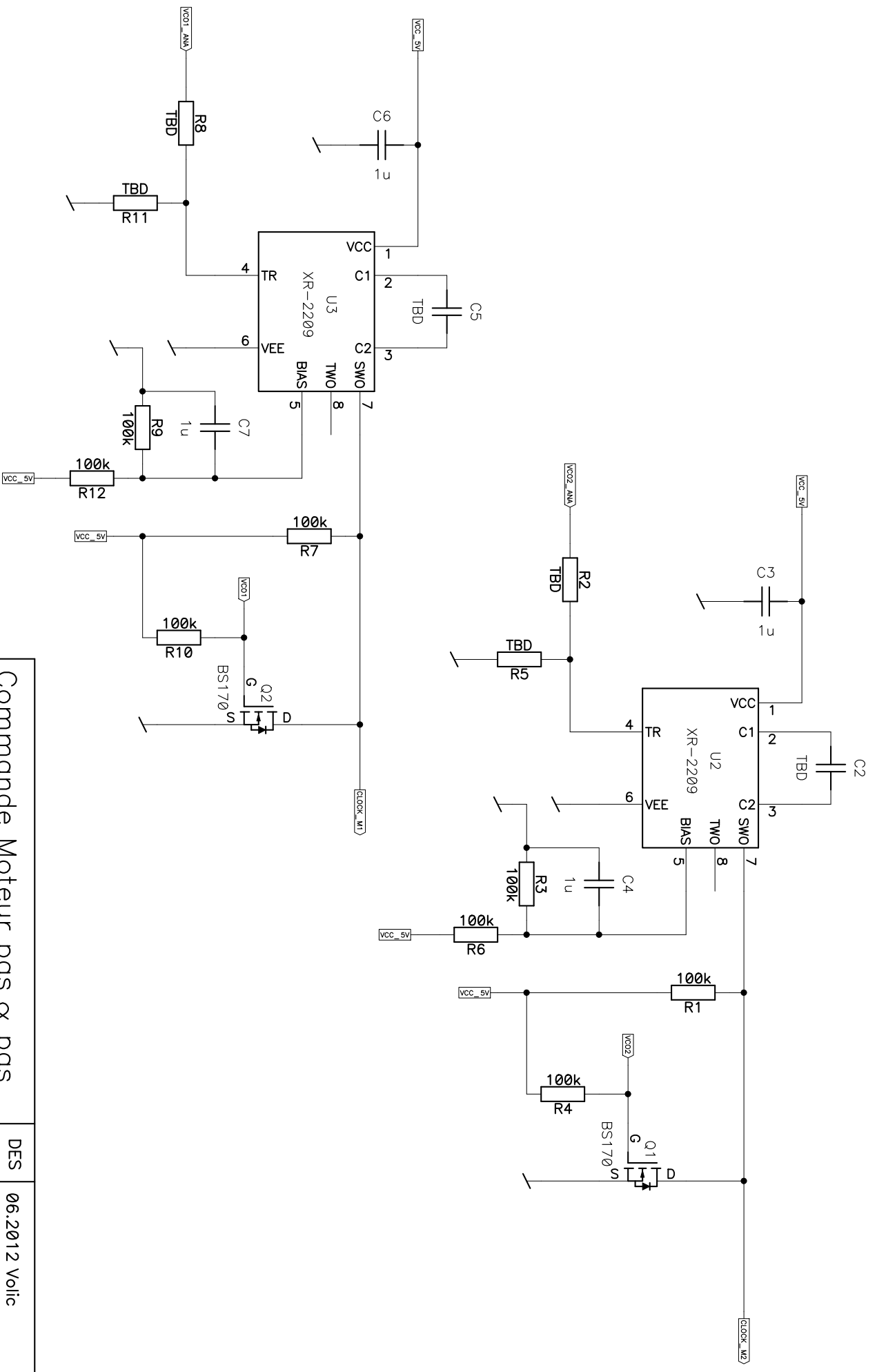
### Further Series Members:

CV03C-1500UCP/4  
 CV05C-500UCG/8  
 CV05C-500UCP/8  
 CV05C-1000UCD/8

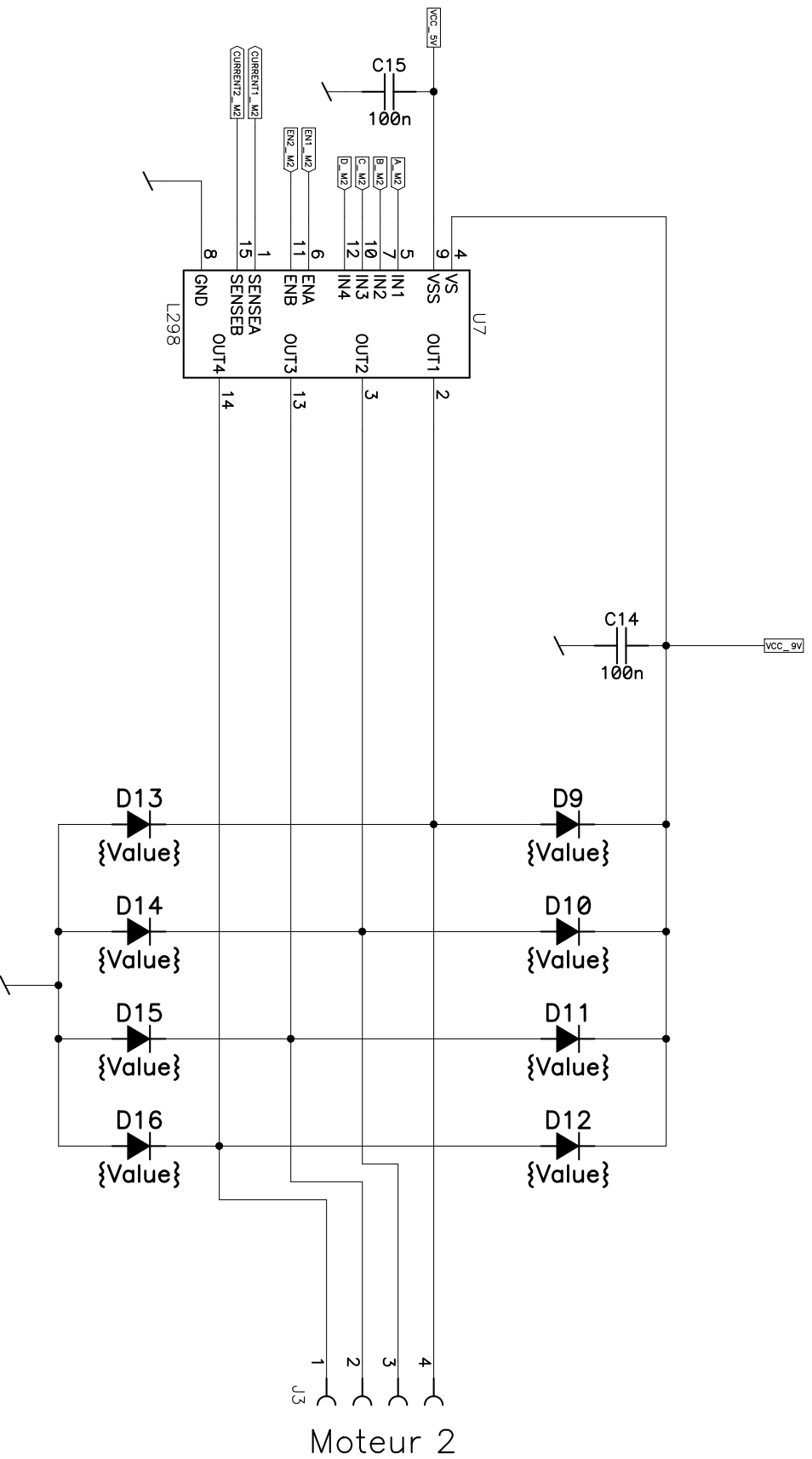
The information above is not to be used for design purposes. For detailed information refer to the individual data sheet, available on our website [www.comet.ch](http://www.comet.ch) or from your local representative.



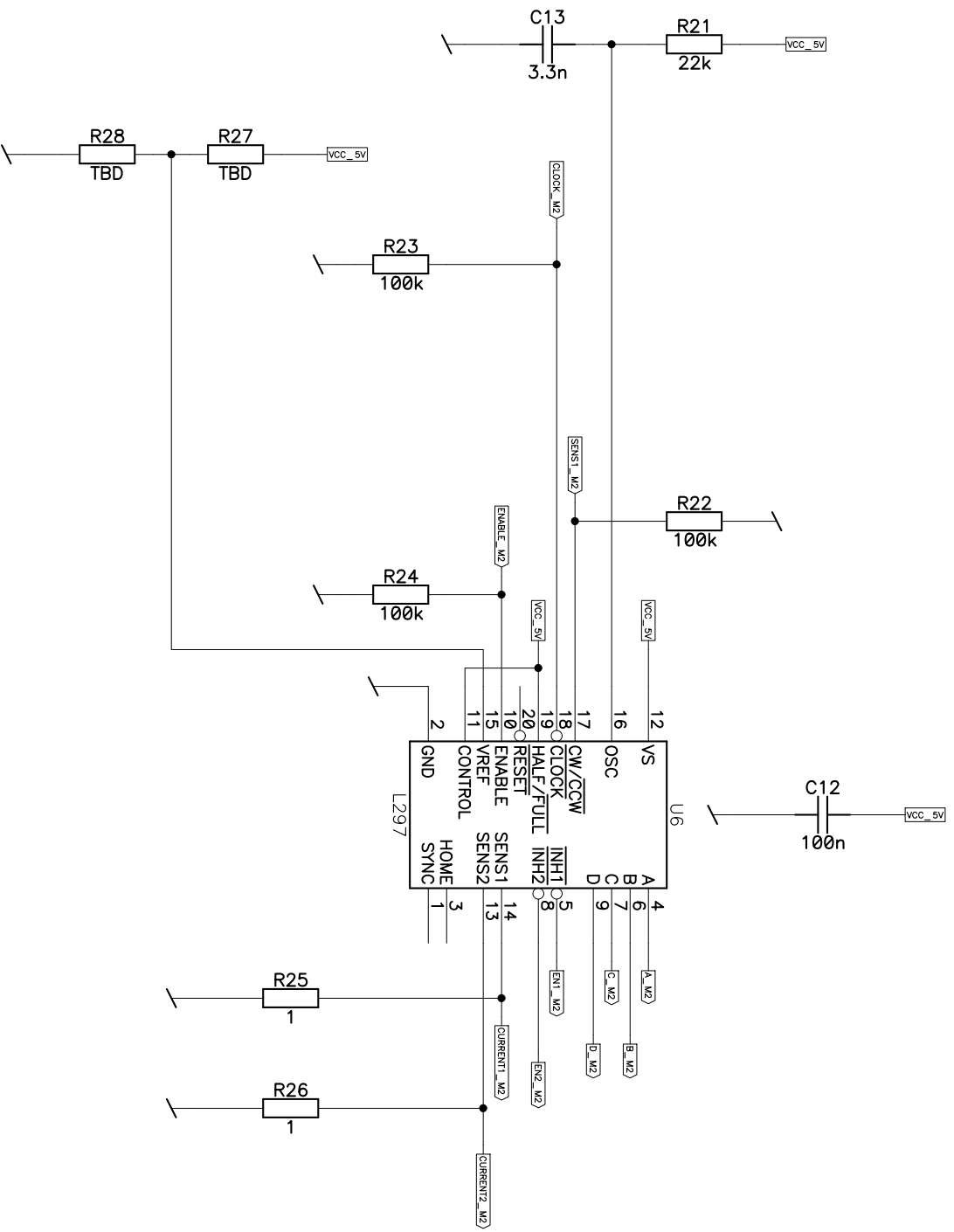




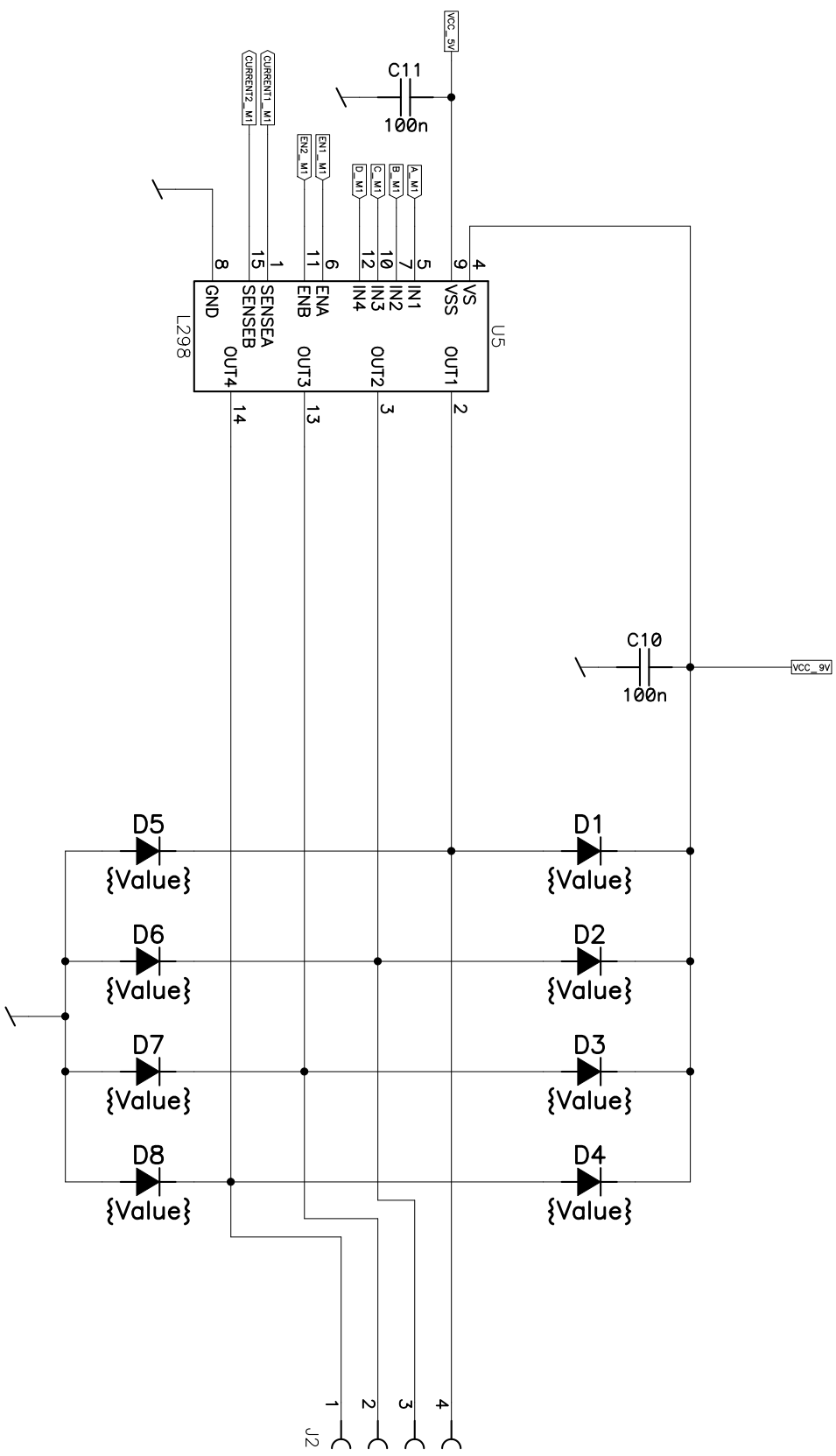
|                           |  |     |                      |
|---------------------------|--|-----|----------------------|
| Commande Moteur pas α pas |  | DES | 06.2012 Volic        |
| PCB1                      |  | REV | V1.0                 |
| HAUTE ECOLE VALAISANNE    |  | 3/7 | {Path}<br>{Filename} |



|                           |  |     |                      |
|---------------------------|--|-----|----------------------|
| Commande Moteur pas à pas |  | DES | 06.2012 Volic        |
| PCB1 Moteur_2_L298        |  | REV | V1.0                 |
| HAUTE ECOLE VALAISANNE    |  | 7/7 | {Path}<br>{Filename} |

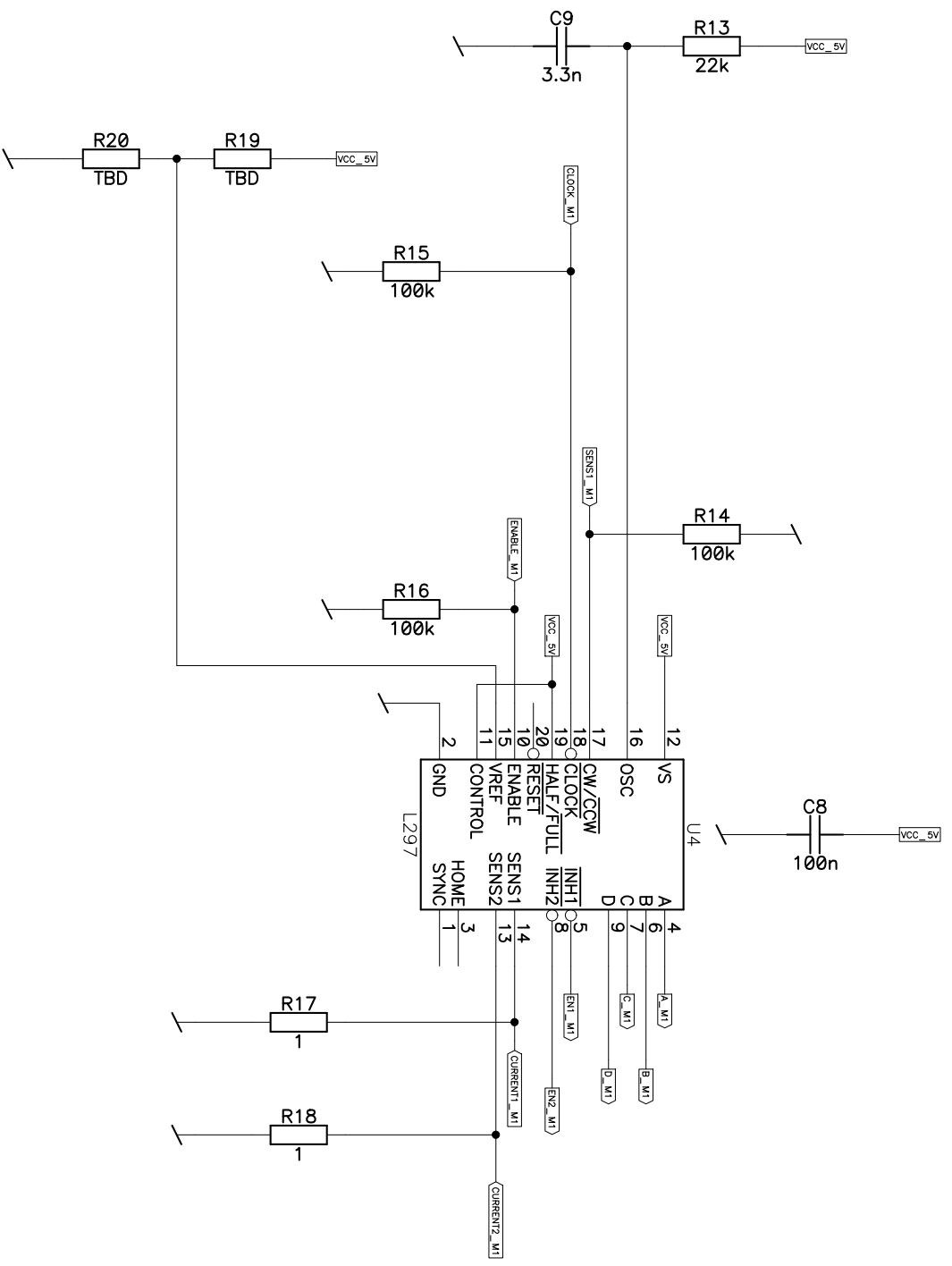


|                           |  |     |                      |
|---------------------------|--|-----|----------------------|
| Commande Moteur pas α pas |  | DES | 06.2012 Volic        |
| PCB1 Moteur_2_L2977       |  | REV | V1.0                 |
| HAUTE ECOLE VALAISANNE    |  | 6/7 | {Path}<br>{Filename} |

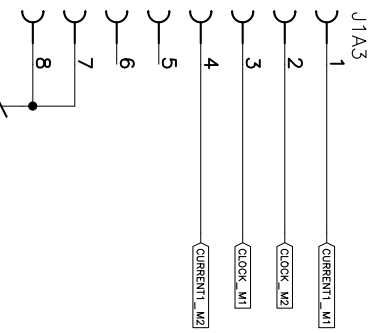
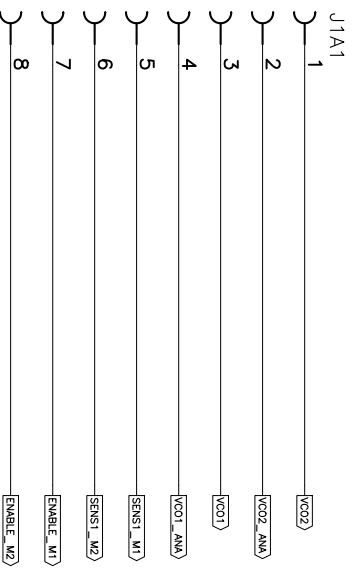


Moteur 1

|                           |  |     |                      |
|---------------------------|--|-----|----------------------|
| Commande Moteur pas α pas |  | DES | 06.2012 Volic        |
| PCB1 Moteur_1_L298        |  | REV | V1.0                 |
| HAUTE ECOLE VALAISANNE    |  | 5/7 | {Path}<br>{Filename} |



|                           |  |     |                      |
|---------------------------|--|-----|----------------------|
| Commande Moteur pas à pas |  | DES | 06.2012 Volic        |
| PCB1 Moteur_1_L297        |  | REV | V1.0                 |
| HAUTE ECOLE VALAISANNE    |  | 4/7 | {Path}<br>{Filename} |

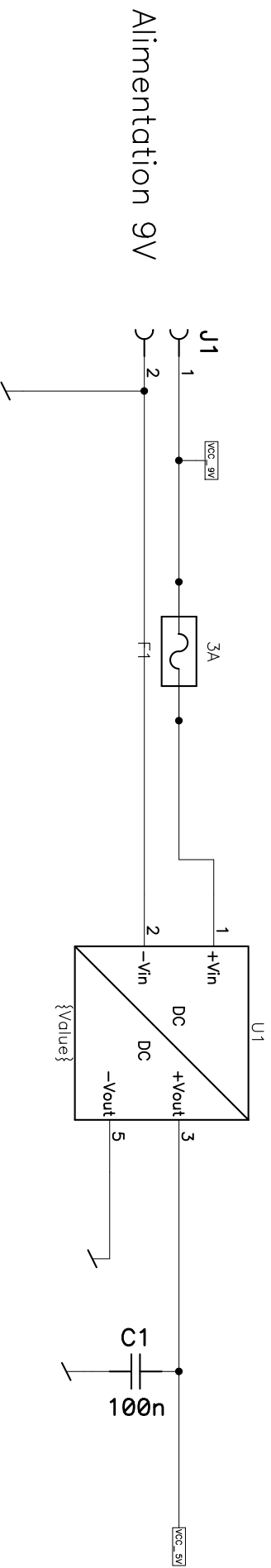


Commande Moteur pas à pas  
 PCB1  
 HAUTE ECOLE VALAISANNE

DES 06.2012 Volic

REV V1.0

1/7 {{Path}}  
 {{Filename}}



|                           |  |     |                      |
|---------------------------|--|-----|----------------------|
| Commande Moteur pas α pas |  | DES | 06.2012 Volic        |
| PCB1                      |  | REV | V1.0                 |
| HAUTE ECOLE VALAISANNE    |  | 2/7 | {Path}<br>{Filename} |

**FEATURES**

- Excellent Temperature Stability (20ppm/°C)
- Linear Frequency Sweep
- Wide Sweep Range (1000:1 Minimum)
- Wide Supply Voltage Range ( $\pm 4V$  to  $\pm 13V$ )
- Low Supply Sensitivity (0.1% /V)
- Wide Frequency Range (0.01Hz to 1MHz)
- Simultaneous Triangle and Squarewave Outputs

**APPLICATIONS**

- Voltage and Current-to-Frequency Conversion
- Stable Phase-Locked Loop
- Waveform Generation  
Triangle, Sawtooth, Pulse, Squarewave
- FM and Sweep Generation

**GENERAL DESCRIPTION**

The XR-2209 is a monolithic voltage-controlled oscillator (VCO) integrated circuit featuring excellent frequency stability and a wide tuning range. The circuit provides simultaneous triangle and squarewave outputs over a frequency range of 0.01Hz to 1MHz. It is ideally suited for FM, FSK, and sweep or tone generation, as well as for

phase-locked loop applications.

The oscillator of the XR-2209 has a typical drift specification of 20ppm/°C. The oscillator frequency can be linearly swept over a 1000:1 range with an external control voltage.

**ORDERING INFORMATION**

| Part No.  | Package             | Operating Temperature Range |
|-----------|---------------------|-----------------------------|
| XR-2209CN | 8 Lead 300 Mil CDIP | 0° to +70°C                 |
| XR-2209M  | 8 Lead 300 Mil CDIP | -55°C to +125°C             |
| XR-2209CP | 8 Lead 300 Mil PDIP | 0°C to +70°C                |

**BLOCK DIAGRAM**

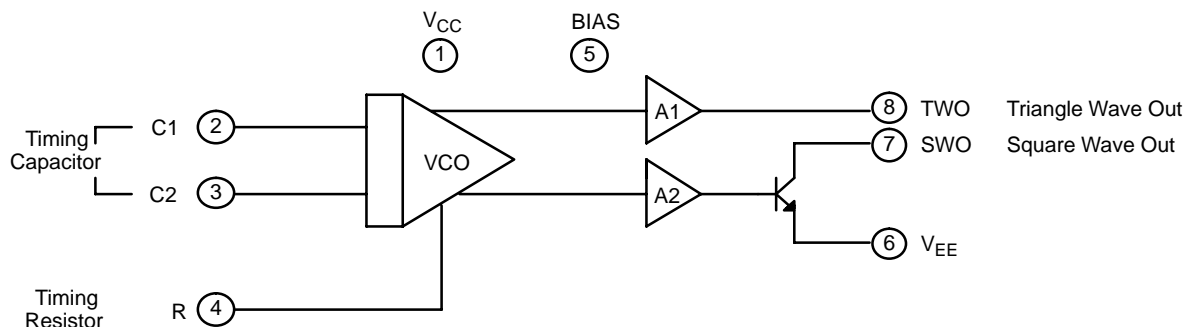
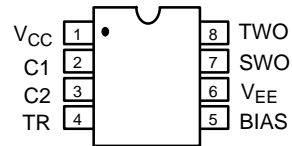


Figure 1. XR-2209 Block Diagram



## PIN CONFIGURATION



8 Lead PDIP, CDIP (0.300")

## PIN DESCRIPTION

| Pin # | Symbol          | Type | Description                             |
|-------|-----------------|------|---|
| 1     | V <sub>CC</sub> |      | Positive Power Supply.                  |
| 2     | C1              | I    | Timing Capacitor Input.                 |
| 3     | C2              | I    | Timing Capacitor Input.                 |
| 4     | TR              | I    | Timing Resistor.                        |
| 5     | BIAS            | I    | Bias Input for Single Supply Operation. |
| 6     | V <sub>EE</sub> |      | Negative Power Supply.                  |
| 7     | SWO             | O    | Square Wave Output Signal.              |
| 8     | TWO             | O    | Triangle Wave Output Signal.            |

## DC ELECTRICAL CHARACTERISTICS

**Test Conditions:** Test Circuit of *Figure 3* and *Figure 4*,  $V_{CC} = 12V$ ,  $T_A = +25^\circ C$ ,  $C = 5000pF$ ,  $R = 20k\Omega$ ,  $R_L = 4.7k\Omega$ ,  $S_1$  and  $S_2$  Closed Unless Otherwise Specified

| Parameters  | XR-2209M      |         |             | XR-2209C      |         |             | Units           | Conditions  |
|---|---------------|---------|-------------|---------------|---------|-------------|-----------------|---|
|   | Min.          | Typ.    | Max.        | Min.          | Typ.    | Max.        |                 |   |
| <b>General Characteristics</b>                        |               |         |             |               |         |             |                 |   |
| Supply Voltage  | 8             |         | 26          | 8             |         | 26          | V               | See <i>Figure 3</i>                                     |
| Single Supply   | $\pm 4$       |         | $\pm 13$    | $\pm 4$       |         | $\pm 13$    | V               | <i>Figure 4</i>   |
| Supply Current  |               |         |             |               |         |             |                 | <i>Figure 3</i>   |
| Single Supply   |               | 5       | 7           | 5             | 8       |             | mA              | Measured at Pin 1, $S_1$ , $S_2$ Open                   |
| Split Supplies  |               |         |             |               |         |             |                 | <i>Figure 4</i>   |
| Positive  |               | 5       | 7           | 5             | 8       |             | mA              | Measured at Pin 1, $S_1$ , $S_2$ Open                   |
| Negative  |               | 4       | 6           | 4             | 7       |             | mA              | Measured at Pin 4, $S_1$ , $S_2$ Open                   |
| <b>Oscillator Section - Frequency Characteristics</b> |               |         |             |               |         |             |                 |   |
| Upper Frequency Limit                                 | <b>0.5</b>    | 1.0     |             | <b>0.5</b>    | 1.0     |             | MHz             | $C = 500pF$ , $R = 2K\Omega$                            |
| Lowest Practical Frequency                            |               | 0.01    |             |               | 0.01    |             | Hz              | $C = 50\mu F$ , $R = 2M\Omega$                          |
| Frequency Accuracy                                    |               | $\pm 1$ | $\pm 3$     |               | $\pm 1$ | $\pm 5$     | % of $f_o$      |   |
| Frequency Stability                                   |               |         |             |               |         |             |                 |   |
| Temperature   |               | 20      | 50          |               | 30      |             | ppm/ $^\circ C$ | $0^\circ C < T_A < 70^\circ C$                          |
| Power Supply  |               | 0.15    |             |               | 0.15    |             | %/V             |   |
| Sweep Range   | <b>1000:1</b> | 3000:1  |             | <b>1000:1</b> |         |             | $f_H/f_L$       | $R = 1.5 K\Omega$ for $f_H$<br>$R = 2M\Omega$ for $f_L$ |
| Sweep Linearity                                       |               |         |             |               |         |             |                 |   |
| 10:1 Sweep  |               | 1       | 2           |               | 1.5     |             | %               | $f_H = 10kHz$ , $f_L = 1kHz$                            |
| 1000:1 Sweep  |               | 5       |             |               | 5       |             | %               | $f_H = 100kHz$ , $f_L = 100Hz$                          |
| FM Distortion   |               | 0.1     |             |               | 0.1     |             | %               | $\pm 10\%$ FM Deviation                                 |
| Recommended Range of Timing Resistor                  | <b>1.5</b>    |         | <b>2000</b> | <b>1.5</b>    |         | <b>2000</b> | $k\Omega$       | See Characteristic Curves                               |
| Impedance at Timing Pins                              |               | 75      |             |               | 75      |             | $\Omega$        | Measured at Pin 4                                       |
| <b>Output Characteristics</b>                         |               |         |             |               |         |             |                 |   |
| Triangle Output                                       |               |         |             |               |         |             |                 | Measured at Pin 8                                       |
| Amplitude   | <b>4</b>      | 6       |             | <b>4</b>      | 6       |             | $V_{pp}$        |   |
| Impedance   |               | 10      |             |               | 10      |             | $\Omega$        |   |
| DC Level  |               | +100    |             |               | +100    |             | mV              | Referenced to Pin 6                                     |
| Linearity   |               | 0.1     |             |               | 0.1     |             | %               | From 10% to 90% of Swing                                |
| Squarewave Output                                     |               |         |             |               |         |             |                 | Measured at Pin 7, $S_2$ Closed                         |
| Amplitude   | <b>11</b>     | 12      |             | <b>11</b>     | 12      |             | $V_{pp}$        |   |
| Saturation Voltage                                    |               | 0.2     | 0.4         |               | 0.2     | <b>0.4</b>  | V               | Referenced to Pin 6                                     |
| Rise Time   |               | 200     |             |               | 200     |             | nsec            | $C_L \leq 10pF$ , $R_L = 4.7K$                          |
| Fall Time   |               | 20      |             |               | 20      |             | nsec            | $C_L \leq 10pF$   |

### Notes

**Bold face parameters** are covered by production test and guaranteed over operating temperature range.

Specifications are subject to change without notice

## ABSOLUTE MAXIMUM RATINGS

|  |         |                                 |                 |
|--|---------|---------------------------------|-----------------|
| Power Supply .....                     | 26V     | Plastic package .....           | 600mW           |
| Power Dissipation (package limitation) |         | Derate above +25°C .....        | 8mW/°C          |
| Ceramic package .....                  | 750mW   | SOIC package .....              | 300mW           |
| Derate above +25°C .....               | 10mW/°C | Derate above +25°C .....        | 4mW/°C          |
|  |         | Storage Temperature Range ..... | -65°C to +150°C |

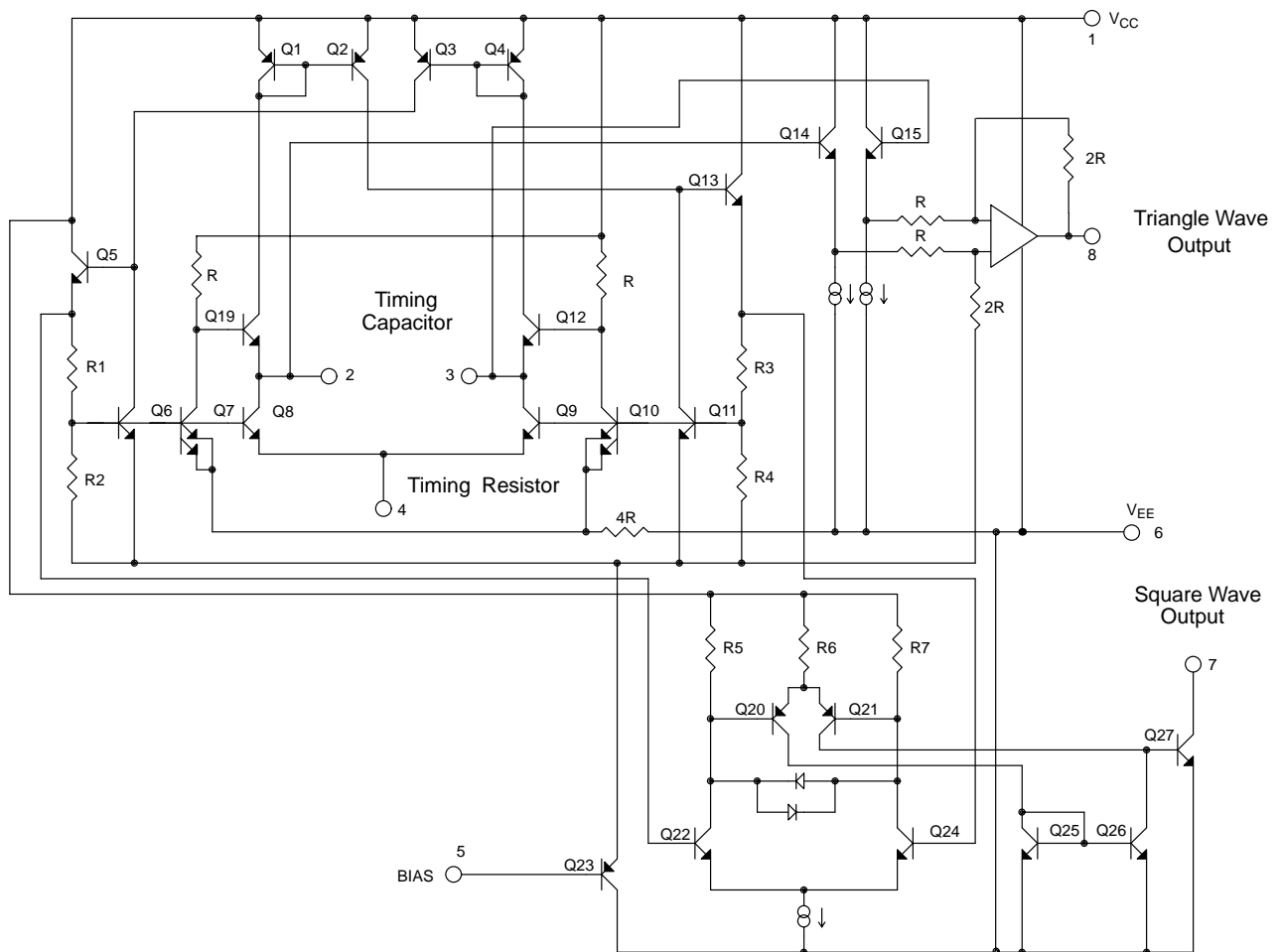


Figure 2. Equivalent Schematic Diagram

**PRECAUTIONS**

The following precautions should be observed when operating the XR-2209 family of integrated circuits:

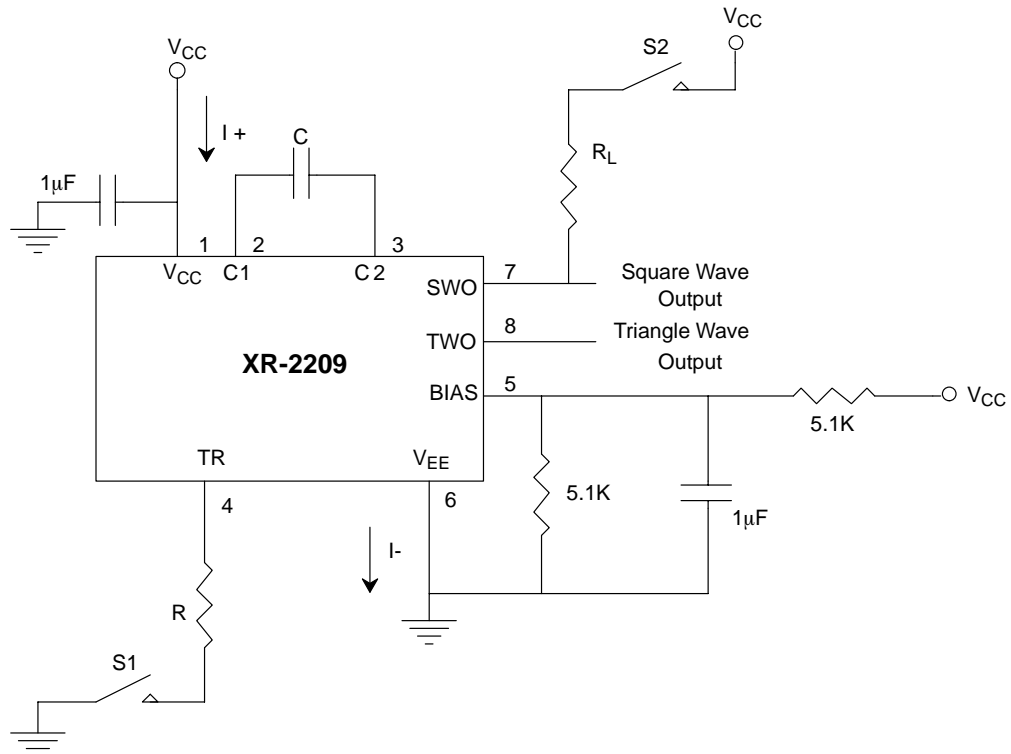
1. Pulling excessive current from the timing terminals will adversely affect the temperature stability of the circuit. To minimize this disturbance, it is recommended that the total current drawn from pin 4 be limited to  $\leq 6\text{mA}$ . In addition, permanent damage to the device may occur if the total timing current exceeds  $10\text{mA}$ .
2. Terminals 2, 3, and 4 have very low internal impedance and should, therefore, be protected from accidental shorting to ground or the supply voltage.

**SYSTEM DESCRIPTION**

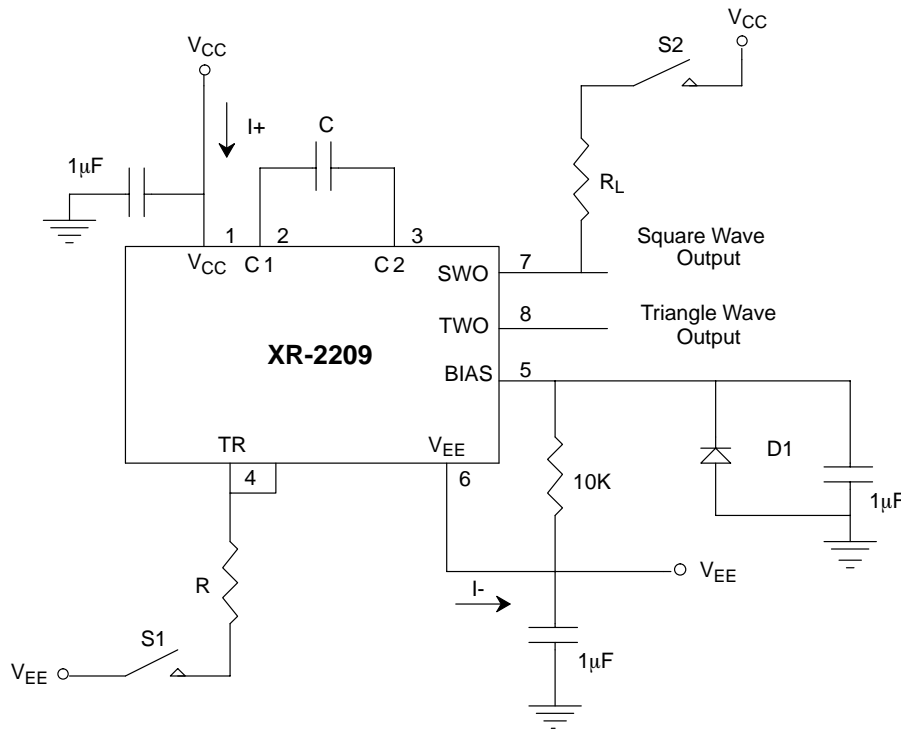
The XR-2209 functional blocks are shown in the block diagram given in *Figure 1*. They are a voltage controlled oscillator (VCO), and two buffer amplifiers for triangle and squarewave outputs. *Figure 2* is a simplified XR-2209 schematic diagram that shows the circuit in greater detail.

The VCO is a modified emitter-coupled current controlled multivibrator. Its oscillation is inversely proportional to the value of the timing capacitor connected to pins 2 and 3, and directly proportional to the total timing current  $I_T$ . This current is determined by the resistor that is connected from the timing terminals (pin 4) to ground.

The triangle output buffer has a low impedance output ( $10\Omega$  typ.) while the squarewave is an open-collector type. An external bias input allows the XR-2209 to be used in either single or split supply applications.



**Figure 3. Test Circuit for Single Supply Operation**



**Figure 4. Test Circuit for Split Supply Operation**

## OPERATING CONSIDERATIONS

### Supply Voltage (Pins 1 and 6)

The XR-2209 is designed to operate over a power supply range of  $\pm 4V$  to  $\pm 13V$  for split supplies, or 8V to 26V for single supplies. *Figure 5* shows the permissible supply voltage for operation with unequal split supply voltages. *Figure 6* and *Figure 7* show supply current versus supply voltage. Performance is optimum for  $\pm 6V$  split supply, or 12V single supply operation. At higher supply voltages, the frequency sweep range is reduced.

### Ground (Pin 6)

For split supply operation, this pin serves as circuit ground. For single supply operation, pin 6 should be ac grounded through a  $1\mu F$  bypass capacitor. During split supply operation, a ground current of  $2 I_T$  flows out of this terminal, where  $I_T$  is the total timing current.

### Bias for Single Supply (Pin 5)

For single supply operation, pin 5 should be externally biased to a potential between  $V_{CC}/3$  and  $V_{CC}/2V$  (see *Figure 3*.) The bias current at pin 5 is nominally 5% of the total oscillation timing current,  $I_T$ .

### Bypass Capacitors

The recommended value for bypass capacitors is  $1\mu F$  although larger values are required for very low frequency operation.

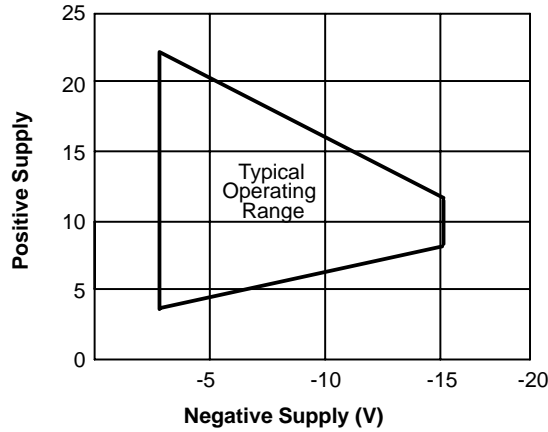
### Timing Resistor (Pin 4)

The timing resistor determines the total timing current,  $I_T$ , available to charge the timing capacitor. Values for the timing resistor can range from  $2k\Omega$  to  $2M\Omega$ ; however, for optimum temperature and power supply stability, recommended values are  $4k\Omega$  to  $200k\Omega$  (see *Figure 8*, *Figure 9*, *Figure 10* and *Figure 11*.) To avoid parasitic pick up, timing resistor leads should be kept as short as possible.

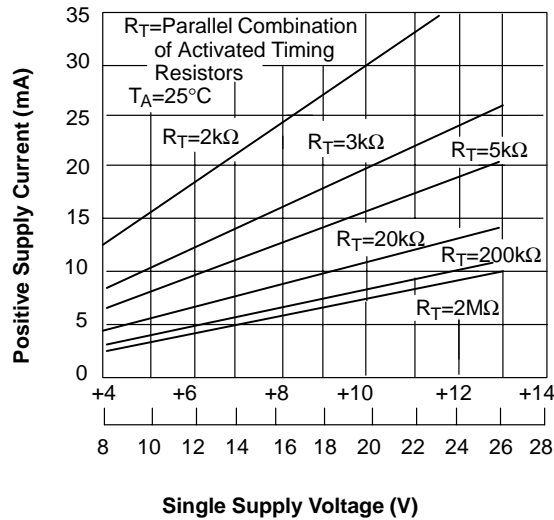
**Timing Capacitor (Pins 2 and 3)**

The oscillator frequency is inversely proportional to the timing capacitor, C. The minimum capacitance value is limited by stray capacitances and the maximum value by

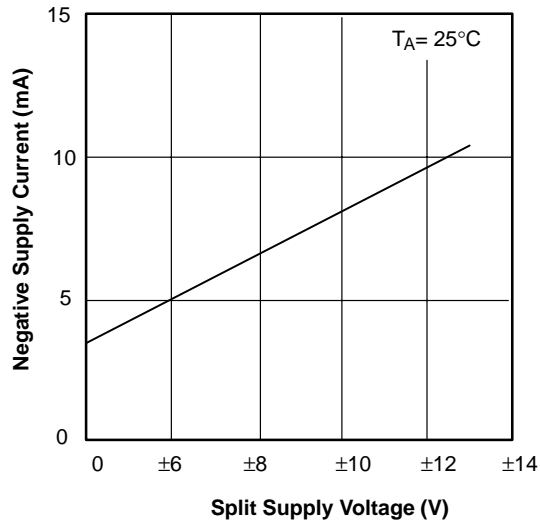
physical size and leakage current considerations. Recommended values range from 100pF to 100μF. The capacitor should be non-polarized.



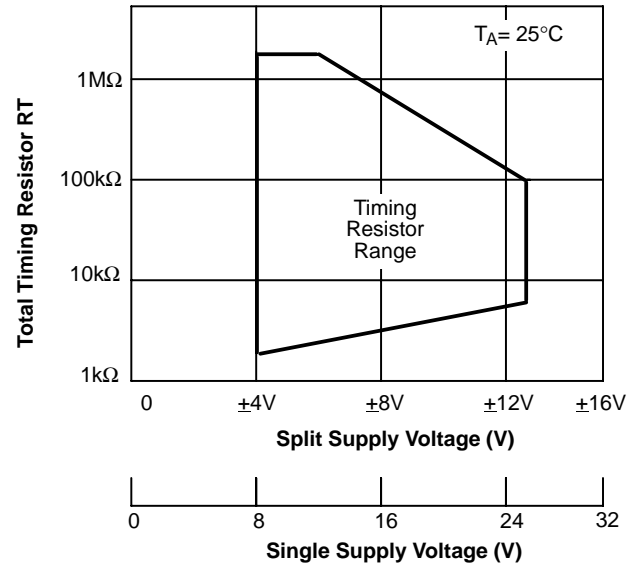
**Figure 5. Operating Range for Unequal Split Supply Voltages**



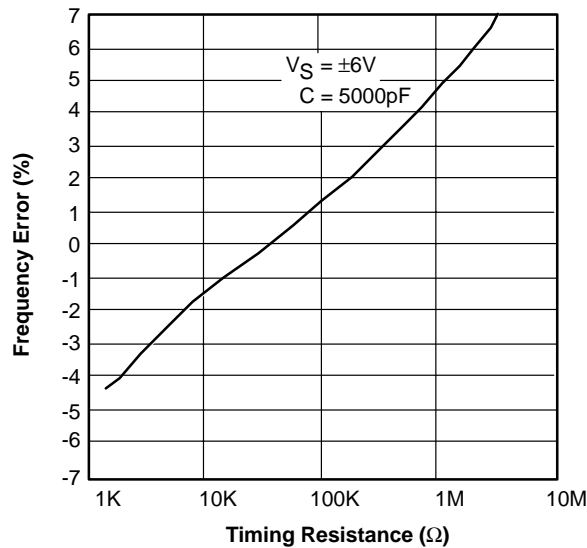
**Figure 6. Positive Supply Current, I+ (Measured at Pin 1) vs. Supply Voltage**



**Figure 7. Negative Supply Current, I<sub>-</sub> (Measured at Pin 6) vs. Supply Voltage**



**Figure 8. Recommended Timing Resistor Value vs. Power Supply Voltage**



**Figure 9. Frequency Accuracy vs. Timing Resistance**

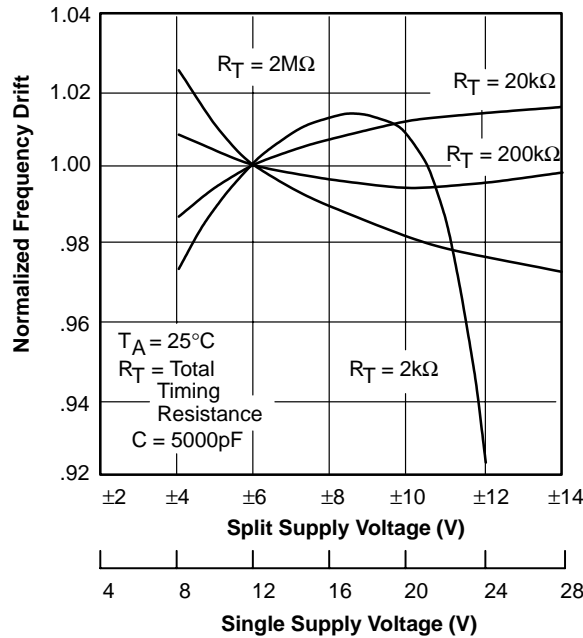


Figure 10. Frequency Drift vs. Supply Voltage

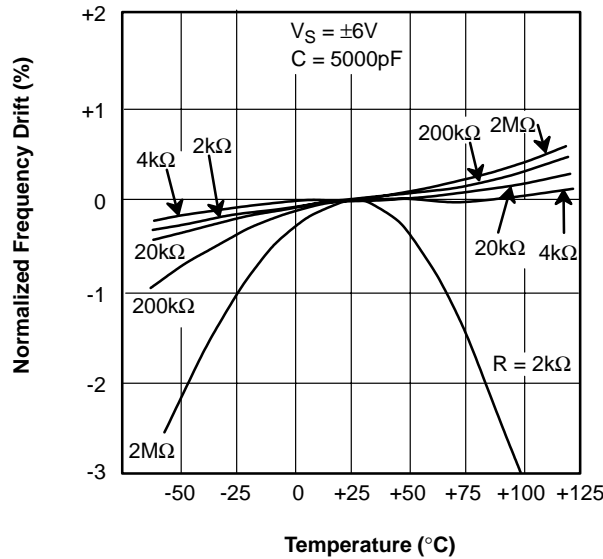


Figure 11. Normalized Frequency Drift with Temperature

### Squarewave Output (Pin 7)

The squarewave output at pin 7 is an “open-collector” stage capable of sinking up to 20mA of load current.  $R_L$  serves as a pull-up load resistor for this output. Recommended values for  $R_L$  range from 1k $\Omega$  to 100k $\Omega$ .

### Triangle Output (Pin 8)

The output at pin 8 is a triangle wave with a peak swing of approximately one-half of the total supply voltage. Pin 8 has a 10 $\Omega$  output impedance and is internally protected against short circuits.



## MODES OF OPERATION

### Split Supply Operation

Figure 12 is the recommended configuration for split supply operation. Diode  $D_1$  in the figure assures that the triangle output swing at pin 8 is symmetrical about ground. The circuit operates with supply voltages ranging from  $\pm 4V$  to  $\pm 13V$ . Minimum drift occurs with  $\pm 6V$  supplies. For operation with unequal supply voltages, see Figure 5.

With the generalized circuit of Figure 12, the frequency of

operation is determined by the timing capacitor,  $C$ , and the timing resistor.

The squarewave output is obtained at pin 7 and has a peak-to-peak voltage swing equal to the supply voltages. This output is an "open-collector" type and requires an external pull-up load resistor (nominally  $5k\Omega$ ) to the positive supply. The triangle waveform obtained at pin 8 is centered about ground and has a peak amplitude of  $V_{CC}/2$ .

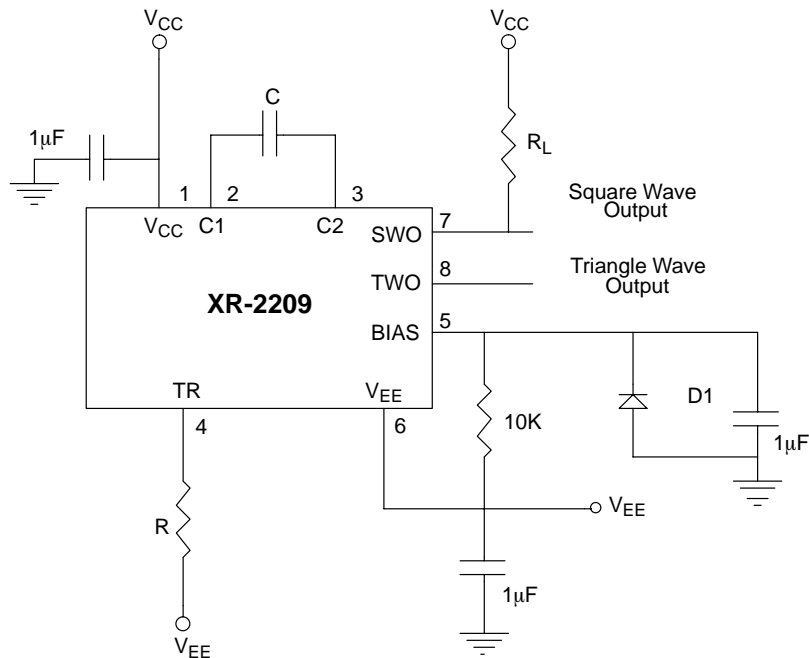
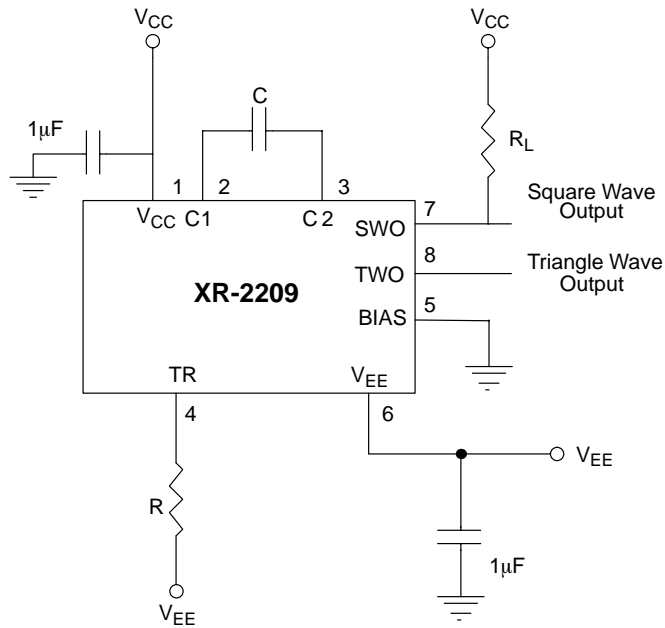


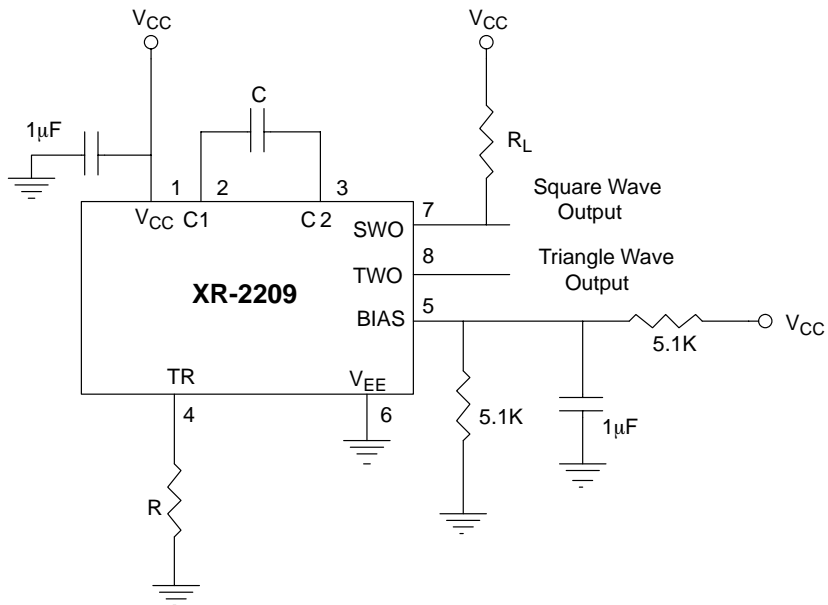
Figure 12. Split-Supply Operation, Recommended Configuration

Figure 13 is a simplified configuration for operation with split supplies in excess of  $\pm 7V$ . This circuit eliminates the diode D1 used in Figure 12 by grounding pin 5 directly;

however, the triangle wave output now has a +0.6V DC offset with respect to ground.



**Figure 13. Split-Supply Operation, Simplified Configuration**



**Figure 14. Single Supply Operation**

### Single Supply Operation

The circuit should be interconnected as shown in *Figure 14* for single supply operation. Pin 6 should be grounded, and pin 5 biased from  $V_{CC}$  through a resistive divider to a value of bias voltage between  $V_{CC}/3$  and  $V_{CC}/2$ .

The frequency of operation is determined by the timing capacitor  $C$  and the timing resistor  $R$ , and is equal to  $1/RC$ . The squarewave output is obtained at pin 7 and has a peak-to-peak voltage swing equal to the supply voltage. This output is an “open-collector” type and requires an external pull-up load resistor (nominally  $5k\Omega$ ) to  $V_+$ . The triangle waveform obtained at pin 8 is centered about a voltage level  $V_O$  where:

$$V_O = V_B + 0.6V$$

where  $V_B$  is the bias voltage at pin 5. The peak-to-peak output swing of triangle wave is approximately equal to  $V_{CC}/2$ .

### Frequency Control (Sweep and FM) - Split Supply

The circuit given in *Figure 15* shows a frequency sweep method for split supply operation.

The frequency of operation is controlled by varying the total timing current,  $I_T$ , drawn from the activated timing pin 4. The timing current can be modulated by applying a control voltage,  $V_C$ , to the timing pin through a series resistor  $R$ . As the control voltage becomes more negative, both the total timing current,  $I_T$ , and the oscillation frequency increase.

The frequency of operation, is now proportional to the control voltage,  $V_C$ , and determined as:

$$f = \frac{1}{RC} \left[ 1 + \frac{V_C R}{R_C V_{EE}} \right] \text{ Hz}$$

If  $R = 2M\Omega$ ,  $R_C = 2k\Omega$ ,  $C = 5000pF$ , then a 1000:1 frequency sweep would result for a negative sweep voltage  $V_C \approx V_{EE}$ .

The voltage to frequency conversion gain,  $K$ , is controlled by the series resistance  $R_C$  and can be expressed as:

$$K = \frac{\Delta f}{\Delta V_C} = -\frac{1}{R_C C V_{EE}} \text{ Hz/V}$$

The circuit of *Figure 15* can operate both with positive and negative values of control voltage. However, for positive values of  $V_C$  with small ( $R_C/R$ ) ratio, the direction of the timing current  $I_T$  is reversed and the oscillations will stop.

**Frequency Control (Sweep and FM) - Single Supply**

The circuit given in *Figure 16* shows the frequency sweep method for single supply operation. Here, the oscillation

frequency is given as:

$$f = \frac{1}{RC} \left[ 1 + \frac{R}{R_C} \left( 1 - \frac{V_C}{V_T} \right) \right]$$

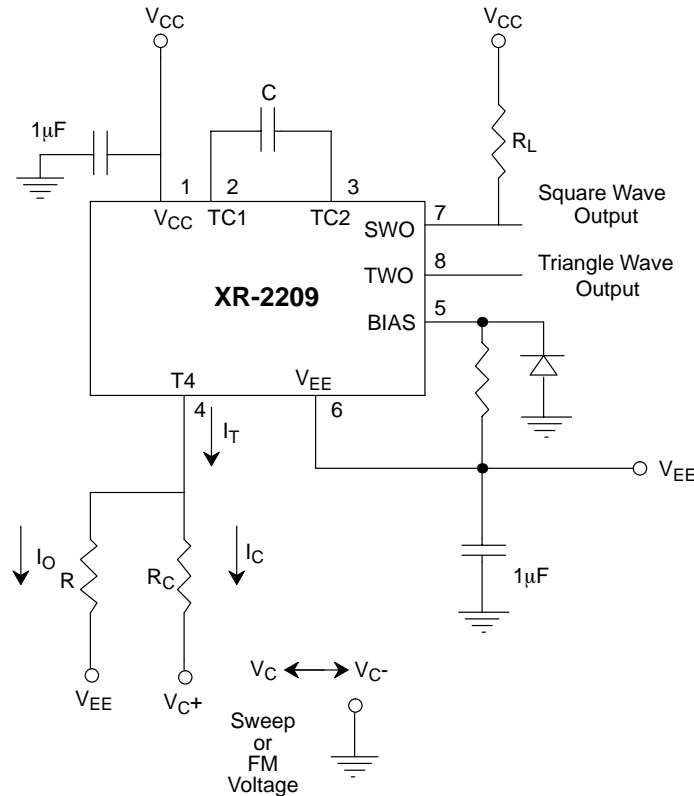
where  $V_T = V_{pin4} \sim V_{bias} + 0.7V$ .

This equation is valid from  $V_C = 0V$  where  $R_C$  is in parallel with  $R$  and  $I_T$  is maximum to:

$$V_C = V_T \left( 1 + \frac{R_C}{R} \right)$$

where  $I_T = 0$  and oscillation ceases.

**Caution:** Total timing current  $I_T$  must be less than 6mA over the frequency control range.



**Figure 15. Frequency Sweep Operation, Split Supply**

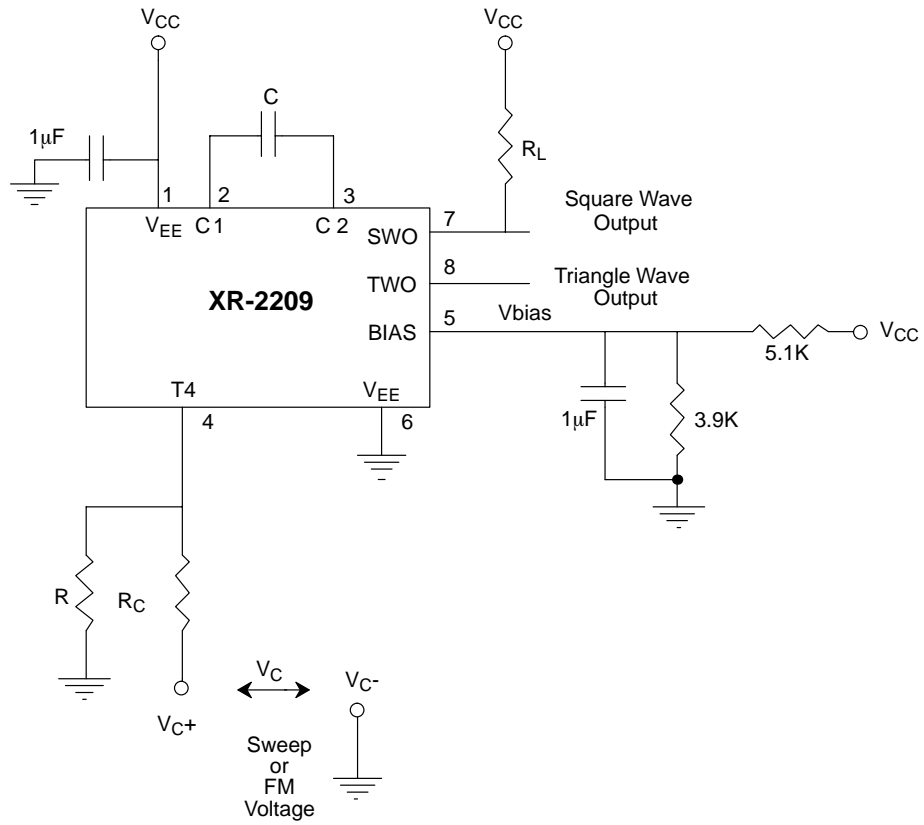
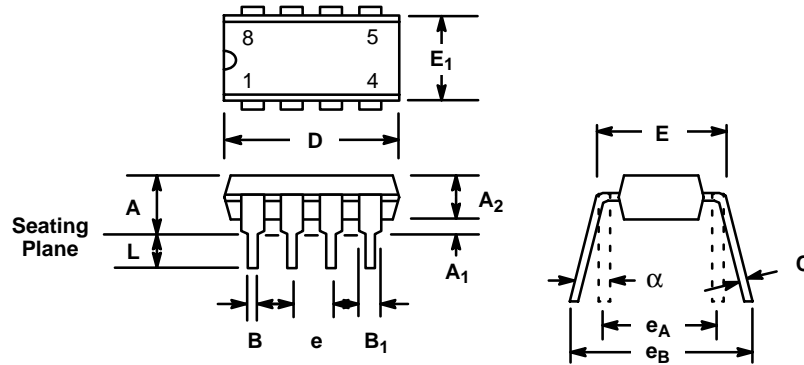


Figure 16. Frequency Sweep Operation, Single Supply

**8 LEAD PLASTIC DUAL-IN-LINE  
(300 MIL PDIP)**

Rev. 1.00

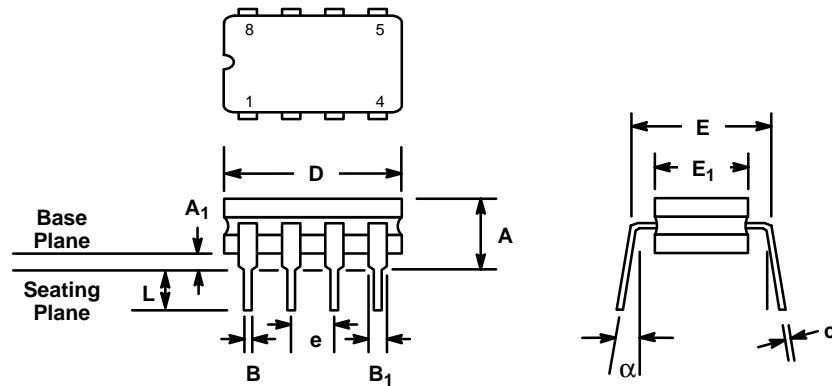


| SYMBOL         | INCHES    |       | MILLIMETERS |       |
|----------------|-----------|-------|-------------|-------|
|                | MIN       | MAX   | MIN         | MAX   |
| A              | 0.145     | 0.210 | 3.68        | 5.33  |
| A <sub>1</sub> | 0.015     | 0.070 | 0.38        | 1.78  |
| A <sub>2</sub> | 0.015     | 0.195 | 2.92        | 4.95  |
| B              | 0.014     | 0.024 | 0.36        | 0.56  |
| B <sub>1</sub> | 0.030     | 0.070 | 0.76        | 1.78  |
| C              | 0.008     | 0.014 | 0.20        | 0.38  |
| D              | 0.348     | 0.430 | 8.84        | 10.92 |
| E              | 0.300     | 0.325 | 7.62        | 8.26  |
| E <sub>1</sub> | 0.240     | 0.280 | 6.10        | 7.11  |
| e              | 0.100 BSC |       | 2.54 BSC    |       |
| e <sub>A</sub> | 0.300 BSC |       | 7.62 BSC    |       |
| e <sub>B</sub> | 0.310     | 0.430 | 7.87        | 10.92 |
| L              | 0.115     | 0.160 | 2.92        | 4.06  |
| α              | 0°        | 15°   | 0°          | 15°   |

Note: The control dimension is the inch column

## 8 LEAD CERAMIC DUAL-IN-LINE (300 MIL CDIP)

Rev. 1.00



| SYMBOL         | INCHES    |       | MILLIMETERS |       |
|----------------|-----------|-------|-------------|-------|
|                | MIN       | MAX   | MIN         | MAX   |
| A              | 0.100     | 0.200 | 2.54        | 5.08  |
| A <sub>1</sub> | 0.015     | 0.060 | 0.38        | 1.52  |
| B              | 0.014     | 0.026 | 0.36        | 0.66  |
| B <sub>1</sub> | 0.045     | 0.065 | 1.14        | 1.65  |
| c              | 0.008     | 0.018 | 0.20        | 0.46  |
| D              | 0.305     | 0.405 | 7.75        | 10.29 |
| E <sub>1</sub> | 0.250     | 0.310 | 6.35        | 7.87  |
| E              | 0.300 BSC |       | 7.62 BSC    |       |
| e              | 0.100 BSC |       | 2.54 BSC    |       |
| L              | 0.125     | 0.200 | 3.18        | 5.08  |
| α              | 0°        | 15°   | 0°          | 15°   |

Note: The control dimension is the inch column

# Notes



**Notes**

# Notes

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## THE L297 STEPPER MOTOR CONTROLLER

*The L297 integrates all the control circuitry required to control bipolar and unipolar stepper motors. Used with a dual bridge driver such as the L298N forms a complete microprocessor-to-bipolar stepper motor interface. Unipolar stepper motor can be driven with an L297 plus a quad darlington array. This note describes the operation of the circuit and shows how it is used.*

The L297 Stepper Motor Controller is primarily intended for use with an L298N or L293E bridge driver in stepper motor driving applications.

It receives control signals from the system's controller, usually a microcomputer chip, and provides all the necessary drive signals for the power stage. Additionally, it includes two PWM chopper circuits to regulate the current in the motor windings.

With a suitable power actuator the L297 drives two phase bipolar permanent magnet motors, four phase unipolar permanent magnet motors and four phase variable reluctance motors. Moreover, it handles normal, wave drive and half step drive modes. (This is all explained in the section "Stepper Motor Basics").

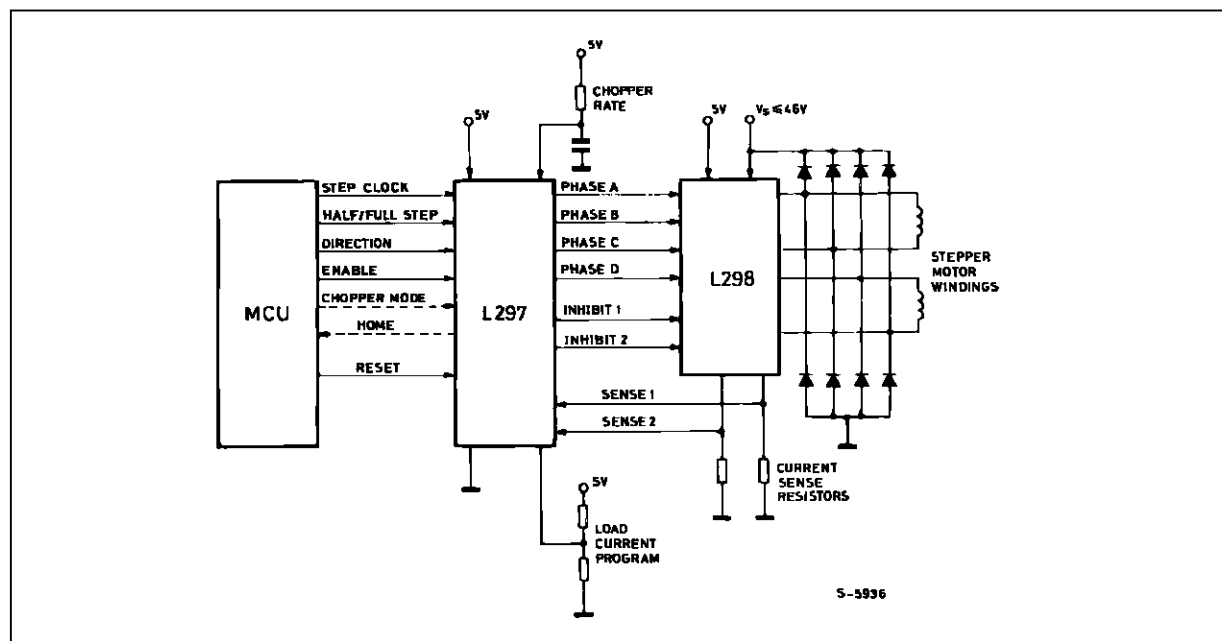
Two versions of the device are available : the regular

L297 and a special version called L297A. The L297A incorporates a step pulse doubler and is designed specifically for floppy-disk head positioning applications.

### ADVANTAGES

The L297 + driver combination has many advantages : very few components are required (so assembly costs are low, reliability high and little space required), software development is simplified and the burden on the micro is reduced. Further, the choice of a two-chip approach gives a high degree of flexibility-the L298N can be used on its own for DC motors and the L297 can be used with any power stage, including discrete power devices (it provides 20mA drive for this purpose).

**Figure 1 :** In this typical configuration an L297 stepper motor controller and L298 dual bridge driver combine to form a complete microprocessor to bipolar stepper motor interface.



## APPLICATION NOTE

For bipolar motors with winding currents up to 2A the L297 should be used with the L298N ; for winding currents up to 1A the L293E is recommended (the L293 will also be useful if the chopper isn't needed). Higher currents are obtained with power transistors or darlingtontons and for unipolar motors a darlington array such as the ULN2075B is suggested. The block diagram, figure 1, shows a typical system.

Applications of the L297 can be found almost everywhere ... printers (carriage position, daisy position, paper feed, ribbon feed), typewriters, plotters, numerically controlled machines, robots, floppy disk drives, electronic sewing machines, cash registers, photocopiers, telex machines, electronic carburetors, telecopiers, photographic equipment, paper tape readers, optical character recognisers, electric valves and so on.

The L297 is made with SGS' analog/digital compatible I<sup>2</sup>L technology (like Zodiac) and is assembled in a 20-pin plastic DIP. A 5V supply is used and all signal lines are TTL/CMOS compatible or open collector transistors. High density is one of the key features of the technology so the L297 die is very compact.

### THE L298N AND L293E

Since the L297 is normally used with an L298N or L293E bridge driver a brief review of these devices will make the rest of this note easier to follow.

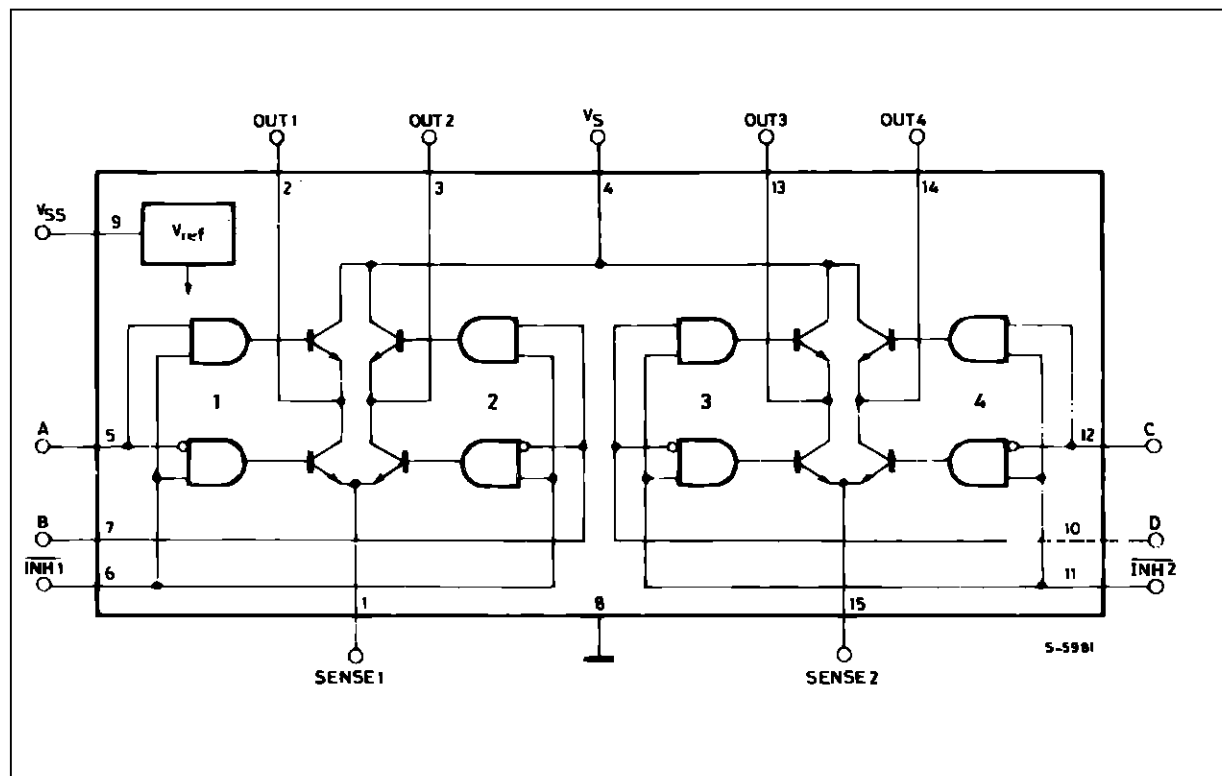
The L298N and L293E contain two bridge driver stages, each controlled by two TTL-level logic inputs and a TTL-level enable input. In addition, the emitter connections of the lower transistors are brought out to external terminals to allow the connection of current sensing resistors (figure 2).

For the L298N SGS' innovative ion-implanted high voltage/high current technology is used, allowing it to handle effective powers up to 160W (46V supply, 2A per bridge). A separate 5V logic supply input is provided to reduce dissipation and to allow direct connection to the L297 or other control logic.

In this note the pins of the L298N are labelled with the pin names of the corresponding L297 terminals to avoid unnecessary confusion.

The L298N is supplied in a 15-lead Multiwatt plastic power package. It's smaller brother, the functionally identical L293E, is packaged in a Powerdip – a copper frame DIP that uses the four center pins to conduct heat to the circuit board copper.

**Figure 2 :** The L298N contains two bridge drivers (four push pull stages) each controlled by two logic inputs and an enable input. External emitter connections are provided for current sense resistors. The L293E has external connections for all four emitters.



## STEPPER MOTOR BASICS

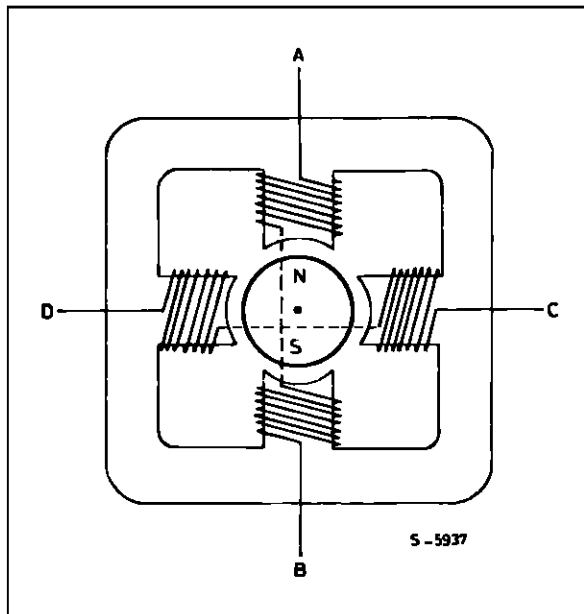
There are two basic types of stepper motor in common use: permanent magnet and variable reluctance. Permanent magnet motors are divided into bipolar and unipolar types.

### BIPOLAR MOTORS

Simplified to the bare essentials, a bipolar permanent magnet motor consists of a rotating permanent magnet surrounded by stator poles carrying the windings (figure 3). Bidirectional drive current is used and the motor is stepped by switching the windings in sequence.

For a motor of this type there are three possible drive sequences.

**Figure 3 :** Greatly simplified, a bipolar permanent magnet stepper motor consist of a rotating magnet surrounded by stator poles as shown.



The first is to energize the windings in the sequence AB/CD/BA/DC (BA means that the winding AB is energized but in the opposite sense). This sequence is known as "one phase on" full step or wave drive

mode. Only one phase is energized at any given moment (figure 4a).

The second possibility is to energize both phases together, so that the rotor always aligns itself between two pole positions. Called "two-phase-on" full step, this mode is the normal drive sequence for a bipolar motor and gives the highest torque (figure 4b).

The third option is to energize one phase, then two, then one, etc., so that the motor moves in half step increments. This sequence, known as half step mode, halves the effective step angle of the motor but gives a less regular torque (figure 4c).

For rotation in the opposite direction (counter-clockwise) the same three sequences are used, except of course that the order is reserved.

As shown in these diagrams the motor would have a step angle of  $90^\circ$ . Real motors have multiple poles to reduce the step angle to a few degrees but the number of windings and the drive sequences are unchanged. A typical bipolar stepper motor is shown in figure 5.

### UNIPOLAR MOTORS

A unipolar permanent magnet motor is identical to the bipolar machine described above except that bifilar windings are used to reverse the stator flux, rather than bidirectional drive (figure 6).

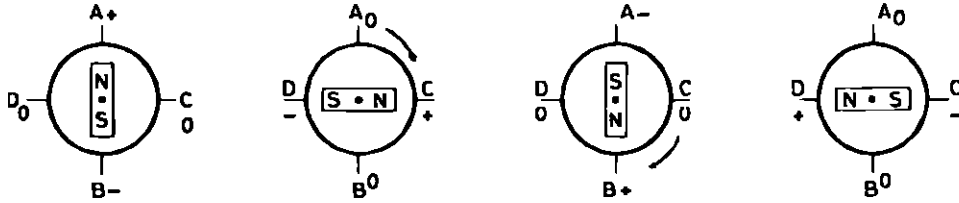
This motor is driven in exactly the same way as a bipolar motor except that the bridge drivers are replaced by simple unipolar stages - four darlington or a quad darlington array. Clearly, unipolar motors are more expensive because they have twice as many windings. Moreover, unipolar motors give less torque for a given motor size because the windings are made with thinner wire. In the past unipolar motors were attractive to designers because they simplify the driver stage. Now that monolithic push pull drivers like the L298N are available bipolar motors are becoming more popular.

All permanent magnet motors suffer from the counter EMF generated by the rotor, which limits the rotation speed. When very high slewing speeds are necessary a variable reluctance motor is used.

## APPLICATION NOTE

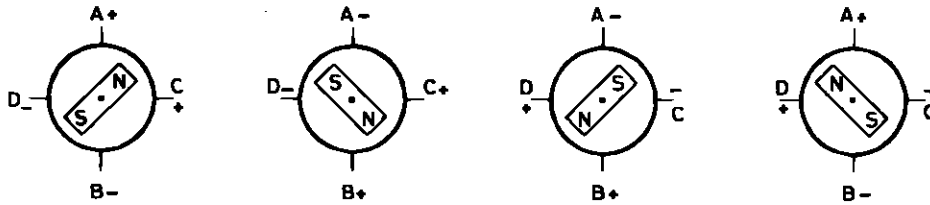
**Figure 4 :** The three drive sequences for a two phase bipolar stepper motor. Clockwise rotation is shown.

**Figure 4a :** Wave drive (one phase on).



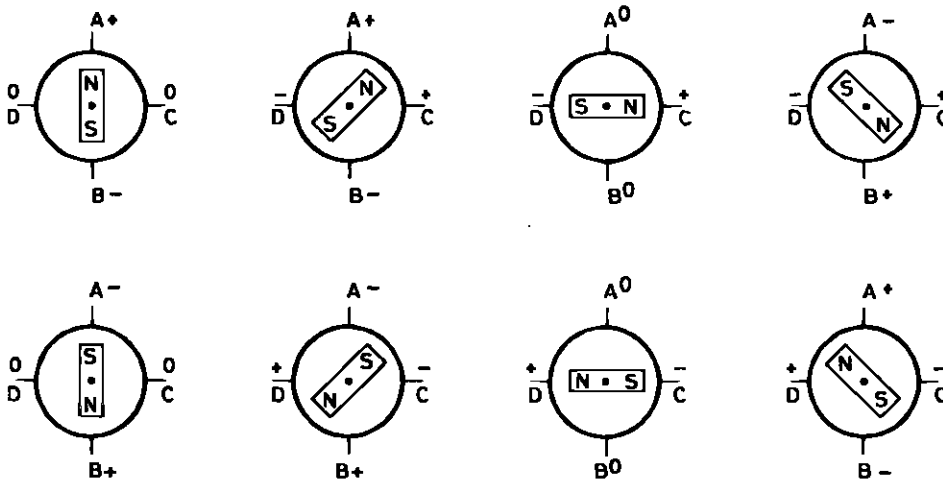
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**Figure 4b :** Two phase on drive.

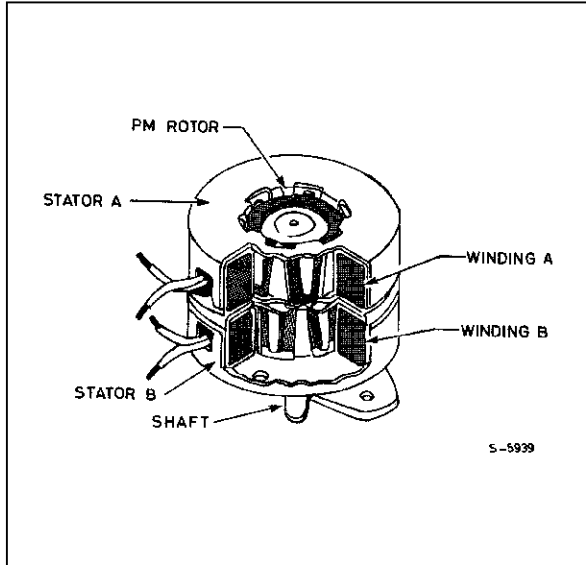


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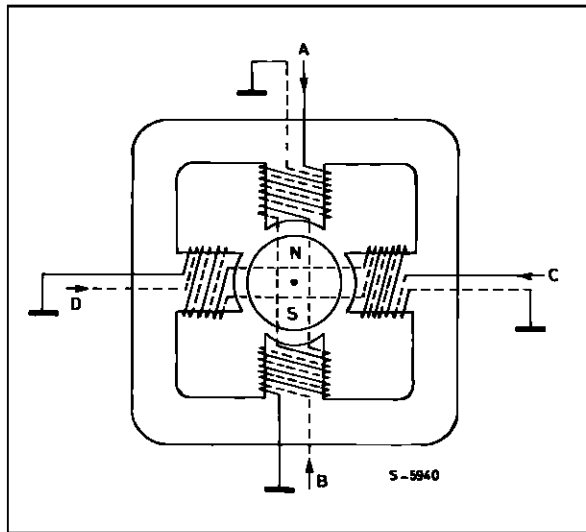
**Figure 4c :** Half step drive.



**Figure 5 :** A real motor. Multiple poles are normally employed to reduce the step angle to a practical value. The principle of operation and drive sequences remain the same.



**Figure 6 :** A unipolar PM motor uses bifilar windings to reverse the flux in each phase.



**VARIABLE RELUCTANCE MOTORS**

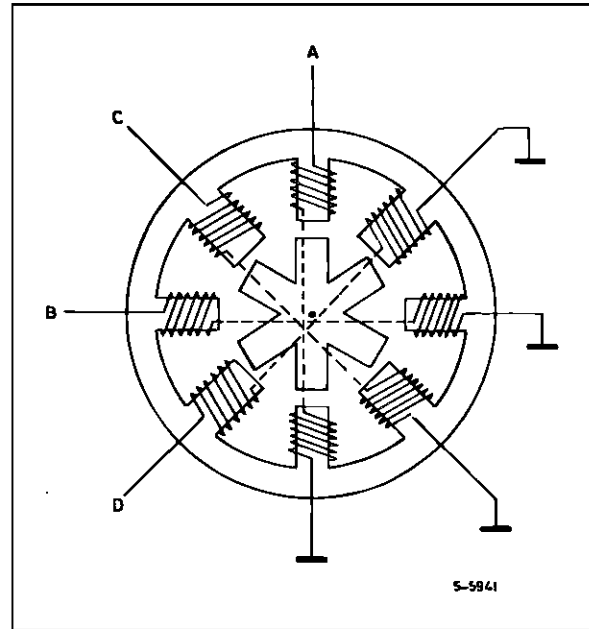
A variable reluctance motor has a non-magnetized soft iron rotor with fewer poles than the stator (figure 7). Unipolar drive is used and the motor is stepped by energizing stator pole pairs to align the rotor with the pole pieces of the energized winding.

Once again three different phase sequences can be used. The wave drive sequence is A/C/B/D ; two-

phase-on is AC/CB/BD/DA and the half step sequence is A/AC/C/BC/B/BD/D/DA. Note that the step angle for the motor shown above is 15°, not 45°.

As before, practical motors normally employ multiple poles to give a much smaller step angle. This does not, however, affect the principle of operation of the drive sequences.

**Figure 7 :** A variable reluctance motor has a soft iron rotor with fewer poles than the stator. The step angle is 15° for this motor.



**GENERATING THE PHASE SEQUENCES**

The heart of the L297 block diagram, figure 8, is a block called the translator which generates suitable phase sequences for half step, one-phase-on full step and two-phase-on full step operation. This block is controlled by two mode inputs – direction (CW/ CCW) and HALF/ FULL – and a step clock which advances the translator from one step to the next.

Four outputs are provided by the translator for subsequent processing by the output logic block which implements the inhibit and chopper functions.

Internally the translator consists of a 3-bit counter plus some combinational logic which generates a basic eight-step gray code sequence as shown in figure 9. All three drive sequences can be generated easily from this master sequence. This state sequence corresponds directly to half step mode, selected by a high level on the HALF/ FULL input.



## APPLICATION NOTE

The output waveforms for this sequence are shown in figure 10.

Note that two other signals,  $\overline{INH1}$  and  $\overline{INH2}$  are generated in this sequence. The purpose of these signals is explained a little further on.

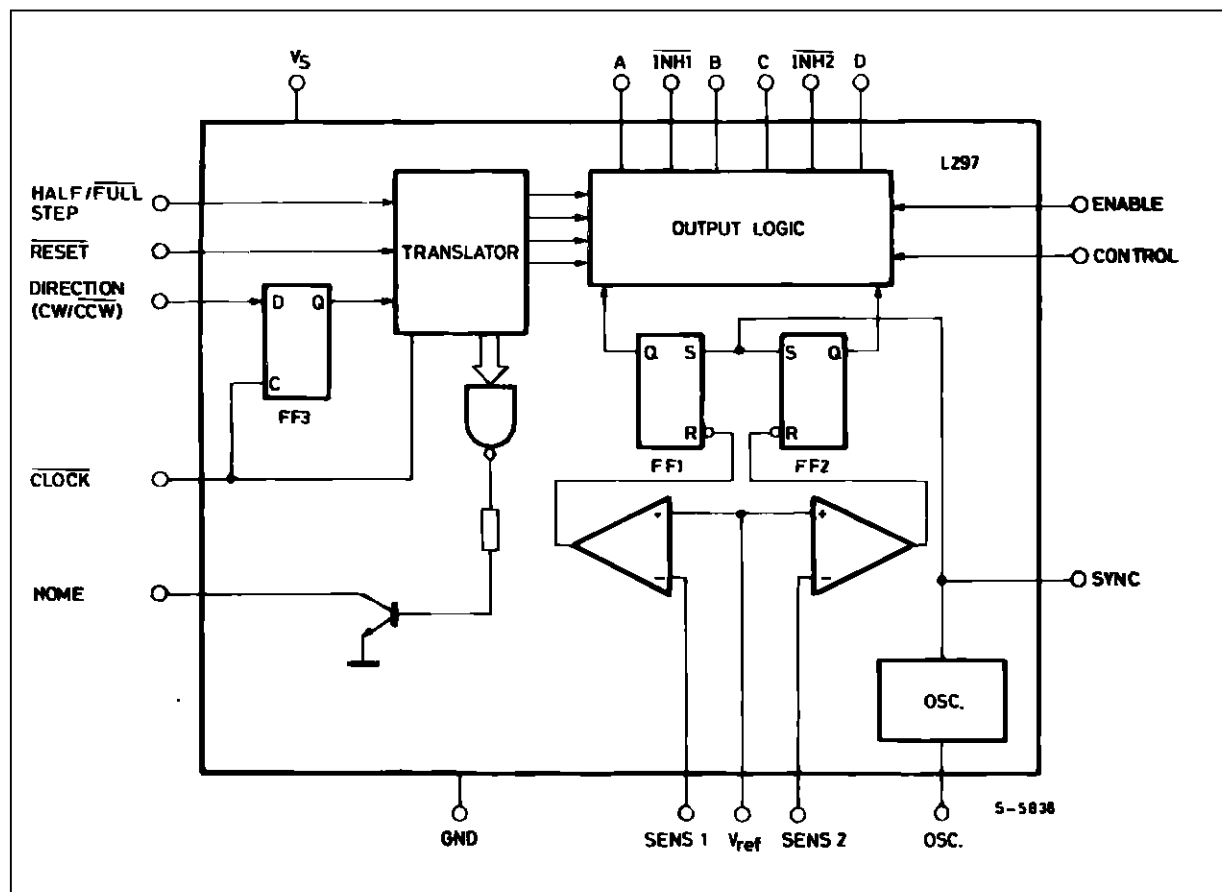
The full step modes are both obtained by skipping alternate states in the eight-step sequence. What happens is that the step clock bypasses the first stage of the 3-bit counter in the translator. The least significant bit of this counter is not affected therefore

the sequence generated depends on the state of the translator when full step mode is selected (the HALF/ FULL input brought low).

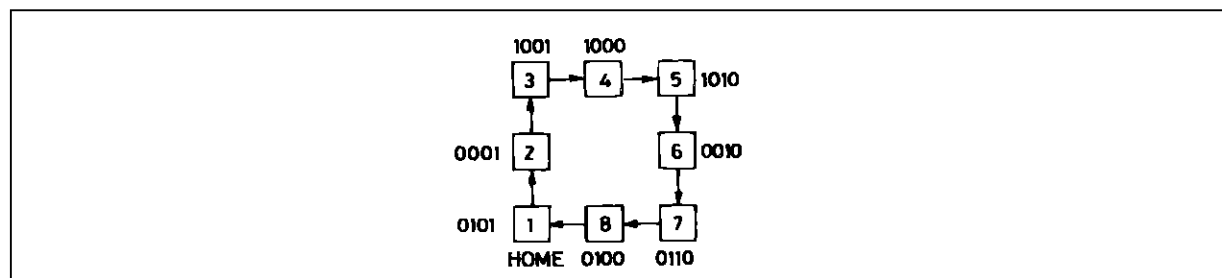
If full step mode is selected when the translator is at any odd-numbered state we get the two-phase-on full step sequence shown in figure 11.

By contrast, one-phase-on full step mode is obtained by selecting full step mode when the translator is at an even-numbered state (figure 12).

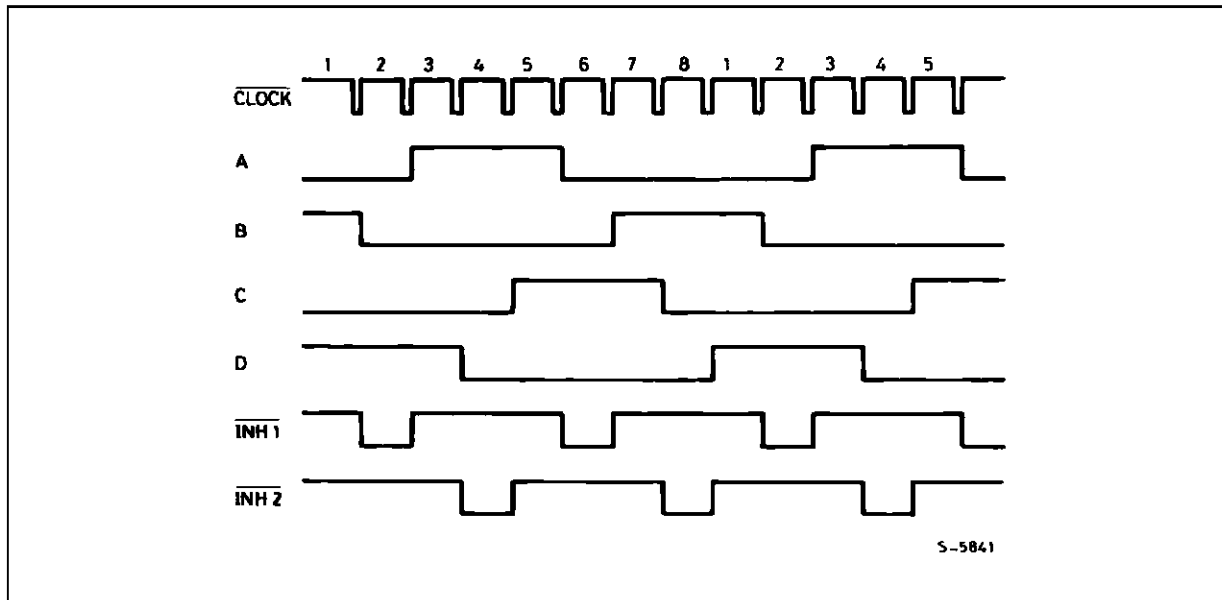
**Figure 8 :** The L297 contains translator (phase sequence generator), a dual PWM chopper and output control logic.



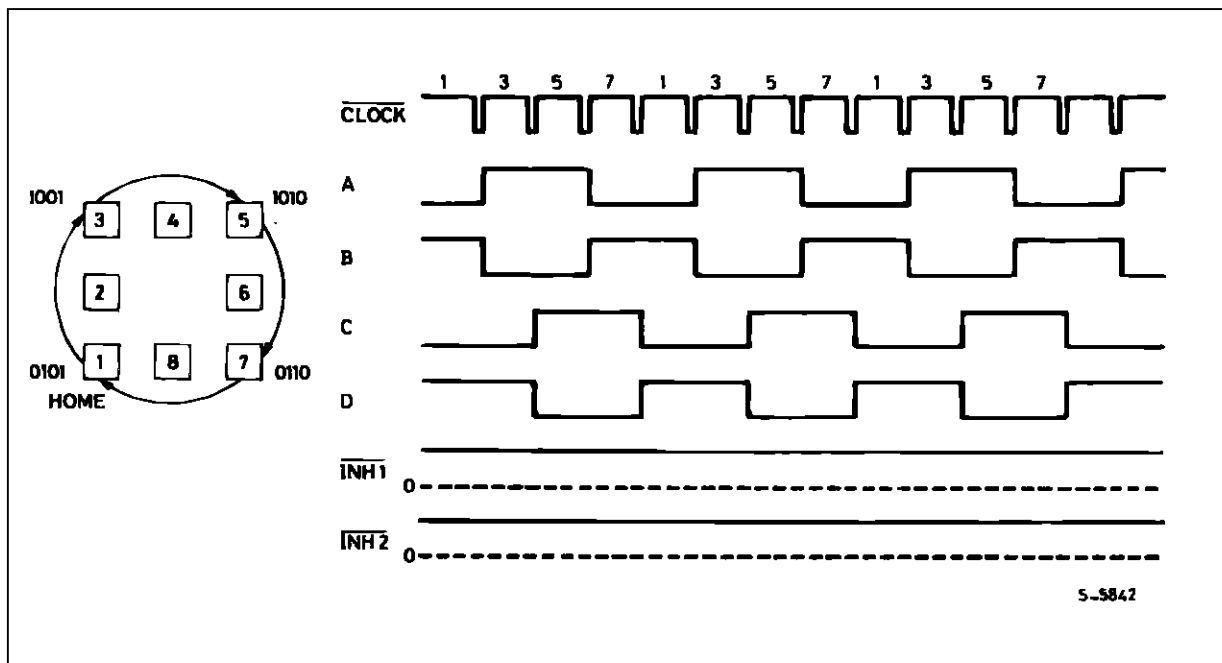
**Figure 9 :** The eight step master sequence of the translator. This corresponds to half step mode. Clockwise rotation is indicated.



**Figure 10 :** The output waveforms corresponding to the half step sequence. The chopper action is not shown.

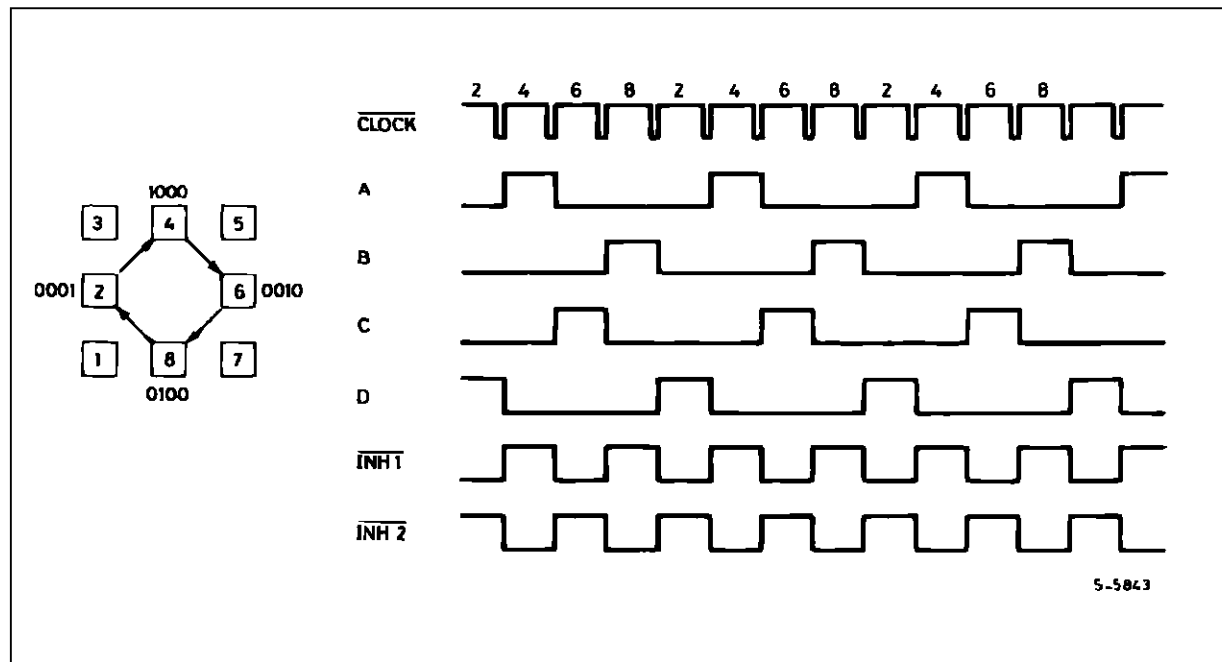


**Figure 11 :** State sequence and output waveforms for the two phase on sequence.  $\overline{\text{INH1}}$  and  $\overline{\text{INH2}}$  remain high throughout.



## APPLICATION NOTE

**Figure 12 :** State Sequence and Output Waveforms for Wave Drive (one phase on).



### $\overline{\text{INH1}}$ AND $\overline{\text{INH2}}$

In half step and one-phase-on full step modes two other signals are generated:  $\overline{\text{INH1}}$  and  $\overline{\text{INH2}}$ . These are inhibit signals which are coupled to the L298N's enable inputs and serve to speed the current decay when a winding is switched off.

Since both windings are energized continuously in two-phase-on full step mode no winding is ever switched off and these signals are not generated.

To see what these signals do let's look at one half of the L298N connected to the first phase of a two-phase bipolar motor (figure 13). Remember that the L298N's A and B inputs determine which transistor in each push pull pair will be on.  $\overline{\text{INH1}}$ , on the other hand, turns off all four transistors.

Assume that A is high, B low and current flowing through Q1, Q4 and the motor winding. If A is now brought low the current would recirculate through D2, Q4 and  $R_s$ , giving a slow decay and increased dissipation in  $R_s$ . If, on the other hand, A is brought low and  $\overline{\text{INH1}}$  is activated, all four transistors are turned off. The current recirculates in this case from ground to  $V_s$  via D2 and D3, giving a faster decay thus allowing faster operation of the motor. Also, since the recirculation current does not flow through  $R_s$ , a less expensive resistor can be used.

Exactly the same thing happens with the second winding, the other half of the L298 and the signals C, D and  $\overline{\text{INH2}}$ .

The  $\overline{\text{INH1}}$  and  $\overline{\text{INH2}}$  signals are generated by OR functions:

$$A + B = \overline{\text{INH1}} \quad C + D = \overline{\text{INH2}}$$

However, the output logic is more complex because inhibit lines are also used by the chopper, as we will see further on.

### OTHER SIGNALS

Two other signals are connected to the translator block: the RESET input and the HOME output

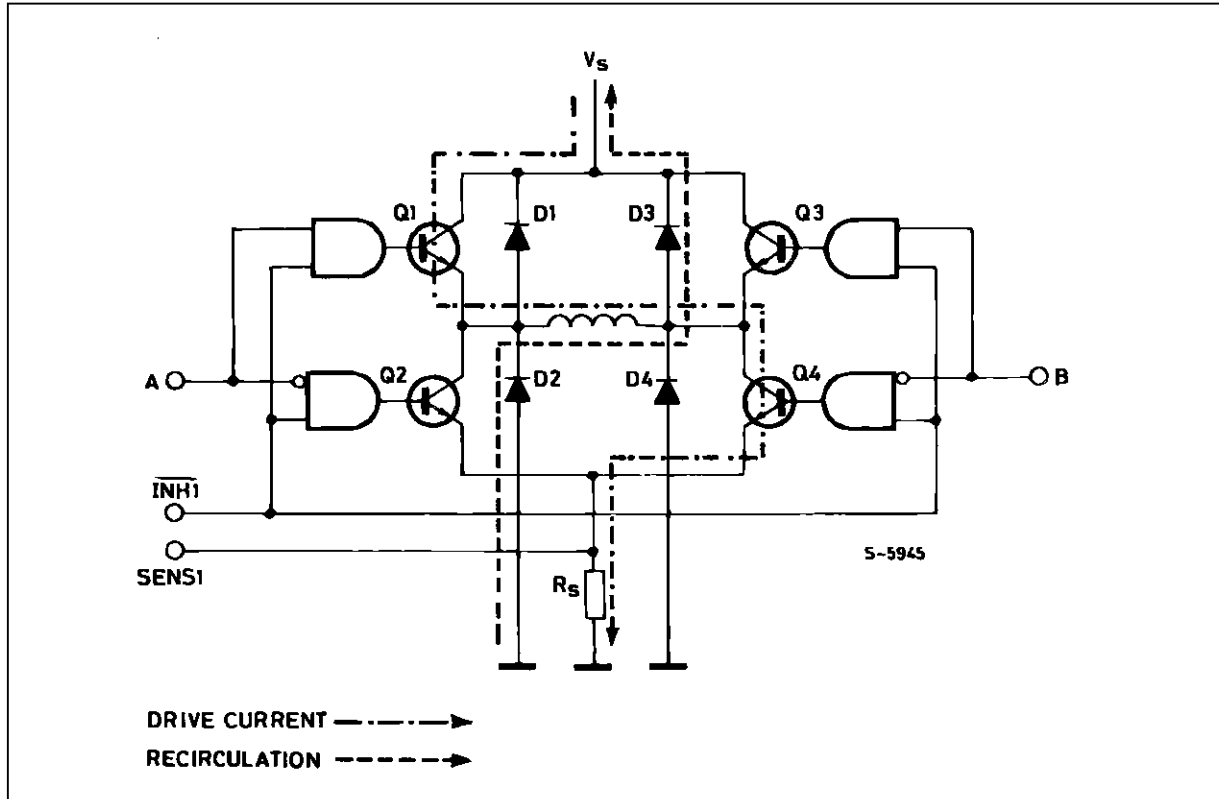
RESET is an asynchronous reset input which restores the translator block to the home position (state 1, ABCD = 0101). The HOME output (open collector) signals this condition and is intended to the AN-Ded with the output of a mechanical home position sensor.

Finally, there is an ENABLE input connected to the output logic. A low level on this input brings  $\overline{\text{INH1}}$ ,  $\overline{\text{INH2}}$ , A, B, C and D low. This input is useful to disable the motor driver when the system is initialized.

### LOAD CURRENT REGULATION

Some form of load current control is essential to obtain good speed and torque characteristics. There are several ways in which this can be done – switching the supply between two voltages, pulse rate modulation chopping or pulse width modulation chopping.

**Figure 13 :** When a winding is switched off the inhibit input is activated to speed current decay. If this were not done the current would recirculate through D2 and Q4 in this example. Dissipation in  $R_s$  is also reduced.

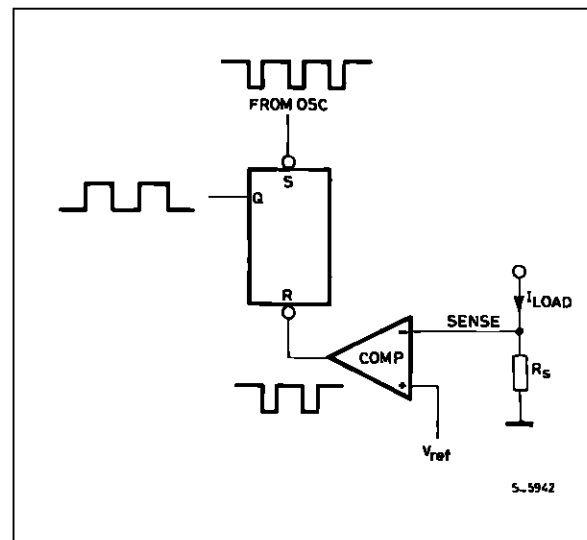


The L297 provides load current control in the form of two PWM choppers, one for each phase of a bipolar motor or one for each pair of windings for a unipolar motor. (In a unipolar motor the A and B windings are never energized together so they can share a chopper ; the same applies to C and D).

Each chopper consists of a comparator, a flip flop and an external sensing resistor. A common on chip oscillator supplies pulses at the chopper rate to both choppers.

In each chopper (figure 14) the flip flop is set by each pulse from the oscillator, enabling the output and allowing the load current to increase. As it increases the voltage across the sensing resistor increases, and when this voltage reaches  $V_{ref}$  the flip flop is reset, disabling the output until the next oscillator pulse arrives. The output of this circuit (the flip flop's Q output) is therefore a constant rate PWM signal. Note that  $V_{ref}$  determines the peak load current.

**Figure 14 :** Each chopper circuit consists of a comparator, flip flop and external sense resistor. A common oscillator clocks both circuits.



## APPLICATION NOTE

### PHASE CHOPPING AND INHIBIT CHOPPING

The chopper can act on either the phase lines (ABCD) or on the inhibit lines INH1 and INH2. An input named CONTROL decides which. Inhibit chopping is used for unipolar motors but you can choose between phase chopping and inhibit chopping for bipolar motors. The reasons for this choice are best explained with another example.

First let's examine the situation when the phase lines are chopped.

As before, we are driving a two phase bipolar motor and A is high, B low (figure 15). Current therefore flows through Q1, winding, Q4 and  $R_s$ . When the voltage across  $R_s$  reaches  $V_{ref}$  the chopper brings B high to switch off the winding.

The energy stored in the winding is dissipated by current recirculating through Q1 and D3. Current decay through this path is rather slow because the volt-

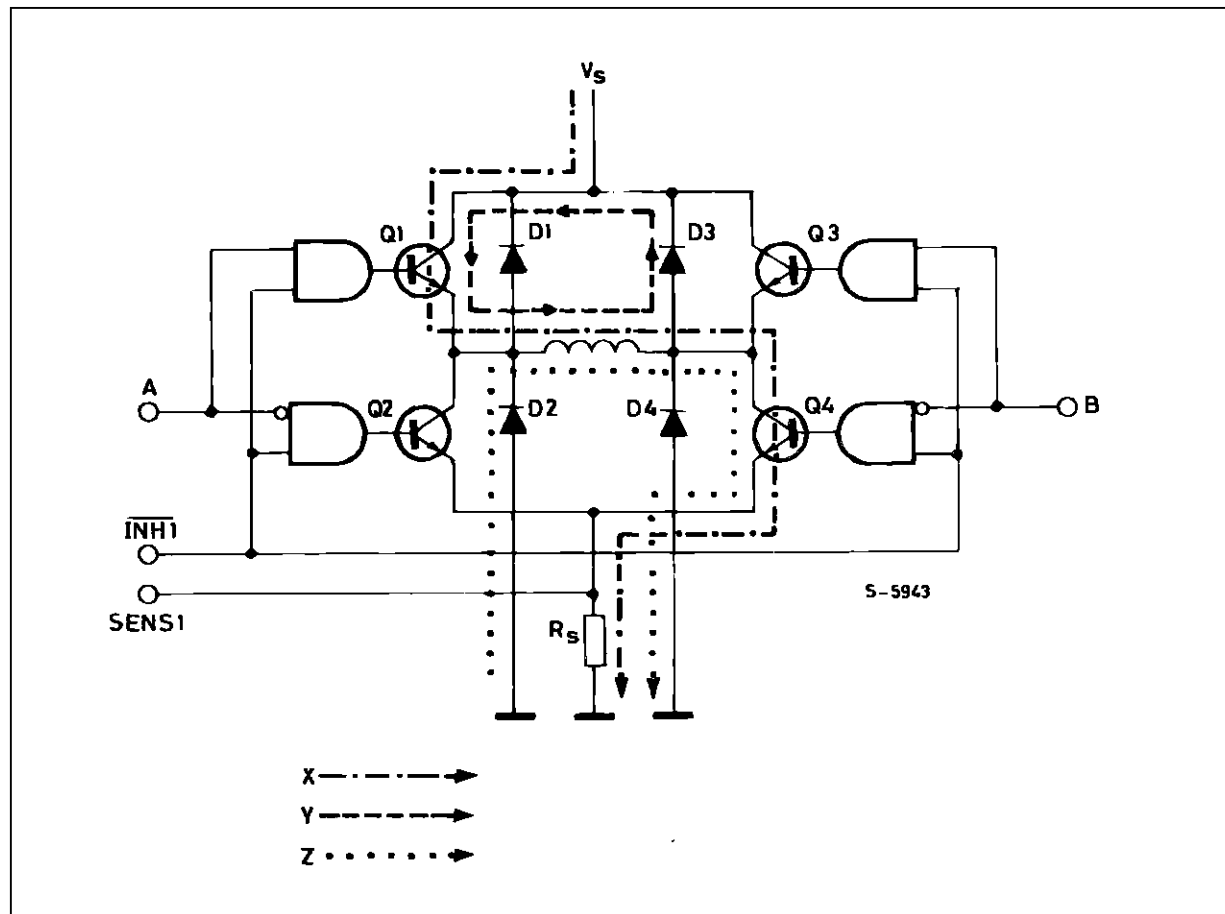
age on the winding is low ( $V_{CEsat} Q1 + V_{D3}$ ) (figure 16).

Why is B pulled high, why push A low? The reason is to avoid the current decaying through  $R_s$ . Since the current recirculates in the upper half of the bridge, current only flows in the sensing resistor when the winding is driven. Less power is therefore dissipated in  $R_s$  and we can get away with a cheaper resistor.

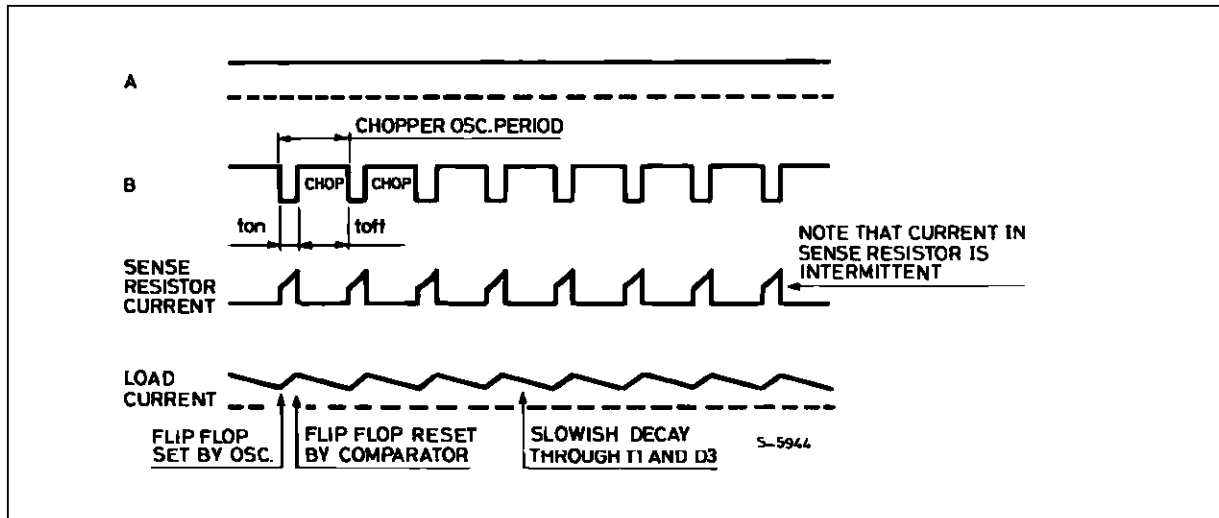
This explain why phase chopping is not suitable for unipolar motors : when the A winding is driven the chopper acts on the B winding. Clearly, this is no use at all for a variable reluctance motor and would be slow and inefficient for a bifilar wound permanent magnet motor.

The alternative is to tie the CONTROL input to ground so that the chopper acts on INH1 and INH2. Looking at the same example, A is high and B low. Q1 and Q4 are therefore conducting and current flows through Q1, the winding, Q4 and  $R_s$ , (figure 17).

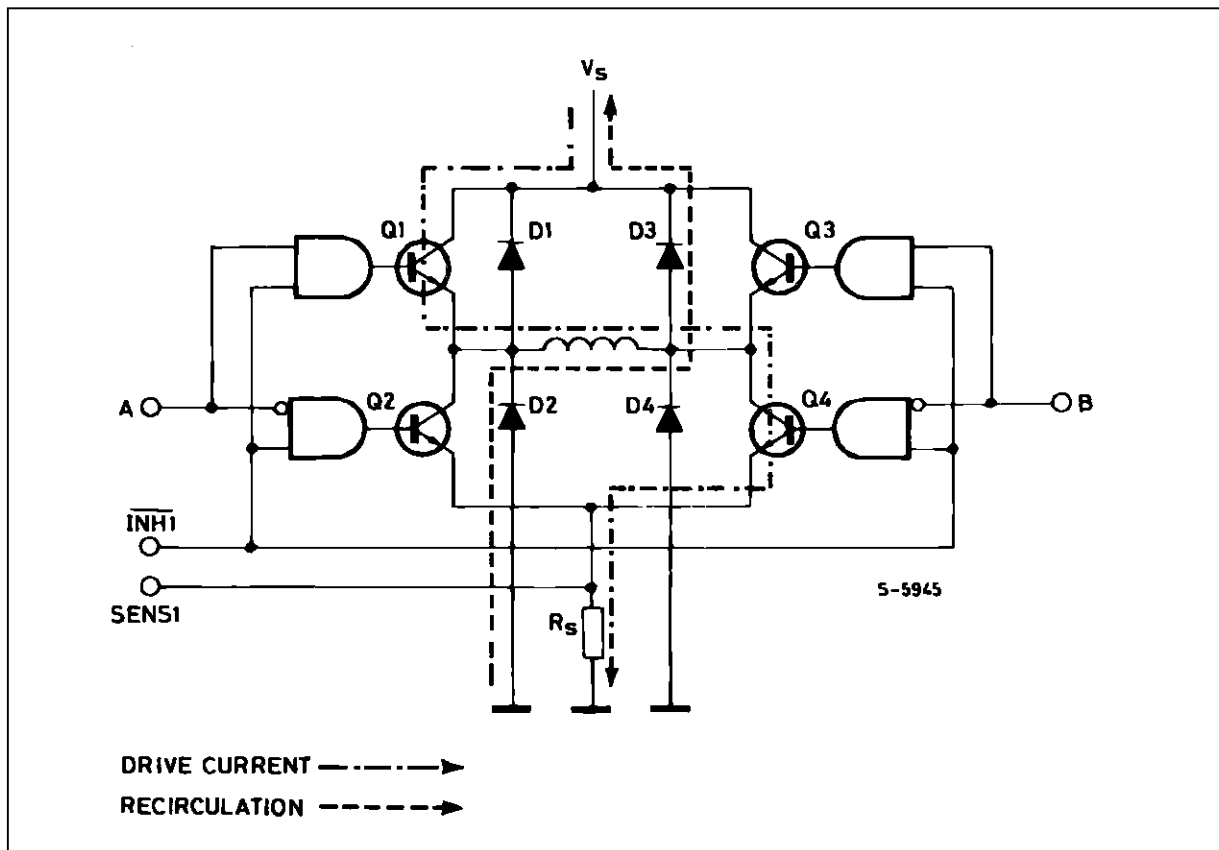
**Figure 15 :** Phase Chopping. In this example the current X is interrupted by activating B, giving the recirculation path Y. The alternative, de-activating A, would give the recirculation path Z, increasing dissipation in  $R_s$ .



**Figure 16 :** Phase Chopping Waveforms. The example shows AB winding energized with A positive with respect to B. Control is high.



**Figure 17 :** Inhibit Chopping. The drive current (Q1, winding, Q4) in this case is interrupted by activating INH1. The decay path through D2 and D3 is faster than the path Y of Figure 15.



## APPLICATION NOTE

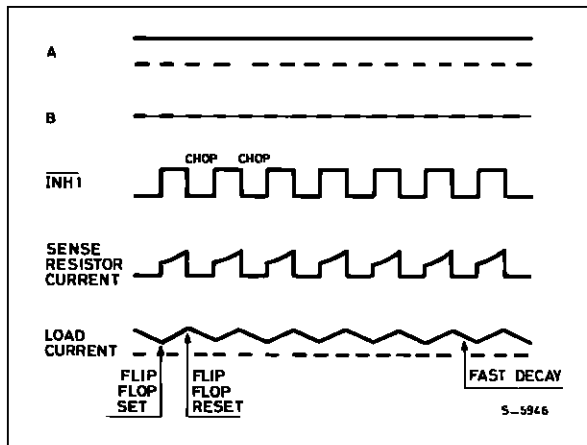
In this case when the voltage across  $R_S$  reaches  $V_{REF}$  the chopper flip flop is reset and  $\overline{INH1}$  activated (brought low).  $\overline{INH1}$ , remember, turns off all four transistors therefore the current recirculates from ground, through D2, the winding and D3 to  $V_S$ . Discharged across the supply, which can be up to 46V, the current decays very rapidly (figure 18).

The usefulness of this second faster decay option is fairly obvious ; it allows fast operation with bipolar motors and it is the only choice for unipolar motors. But why do we offer the slower alternative, phase chopping ?

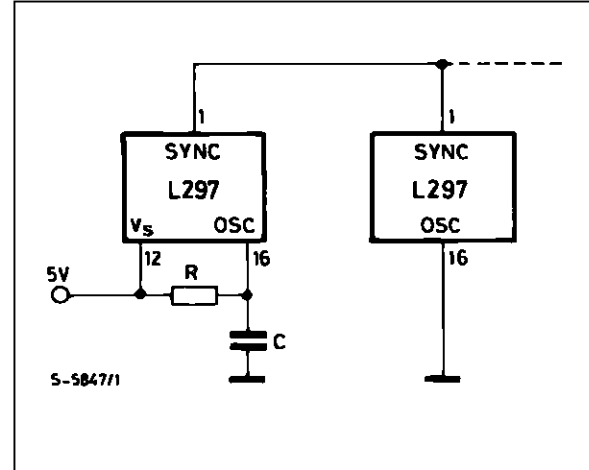
The answer is that we might be obliged to use a low chopper rate with a motor that does not store much energy in the windings. If the decay is very fast the average motor current may be too low to give an useful torque. Low chopper rates may, for example, be imposed if there is a larger motor in the same system. To avoid switching noise on the ground plane all drivers should be synchronized and the chopper rate is therefore determined by the largest motor in the system.

Multiple L297s are synchronized easily using the SYNC pin. This pin is the squarewave output of the on-chip oscillator and the clock input for the choppers. The first L297 is fitted with the oscillator components and outputs a squarewave signal on this pin (figure 19). Subsequent L297s do not need the oscillator components and use SYNC as a clock input. An external clock may also be injected at this terminal if an L297 must be synchronized to other system components.

**Figure 18 :** Inhibit Chopper Waveforms. Winding AB is energized and CONTROL is low.



**Figure 19 :** The Chopper oscillator of multiple L297s are synchronized by connecting the SYNC Inputs together.



### THE L297A

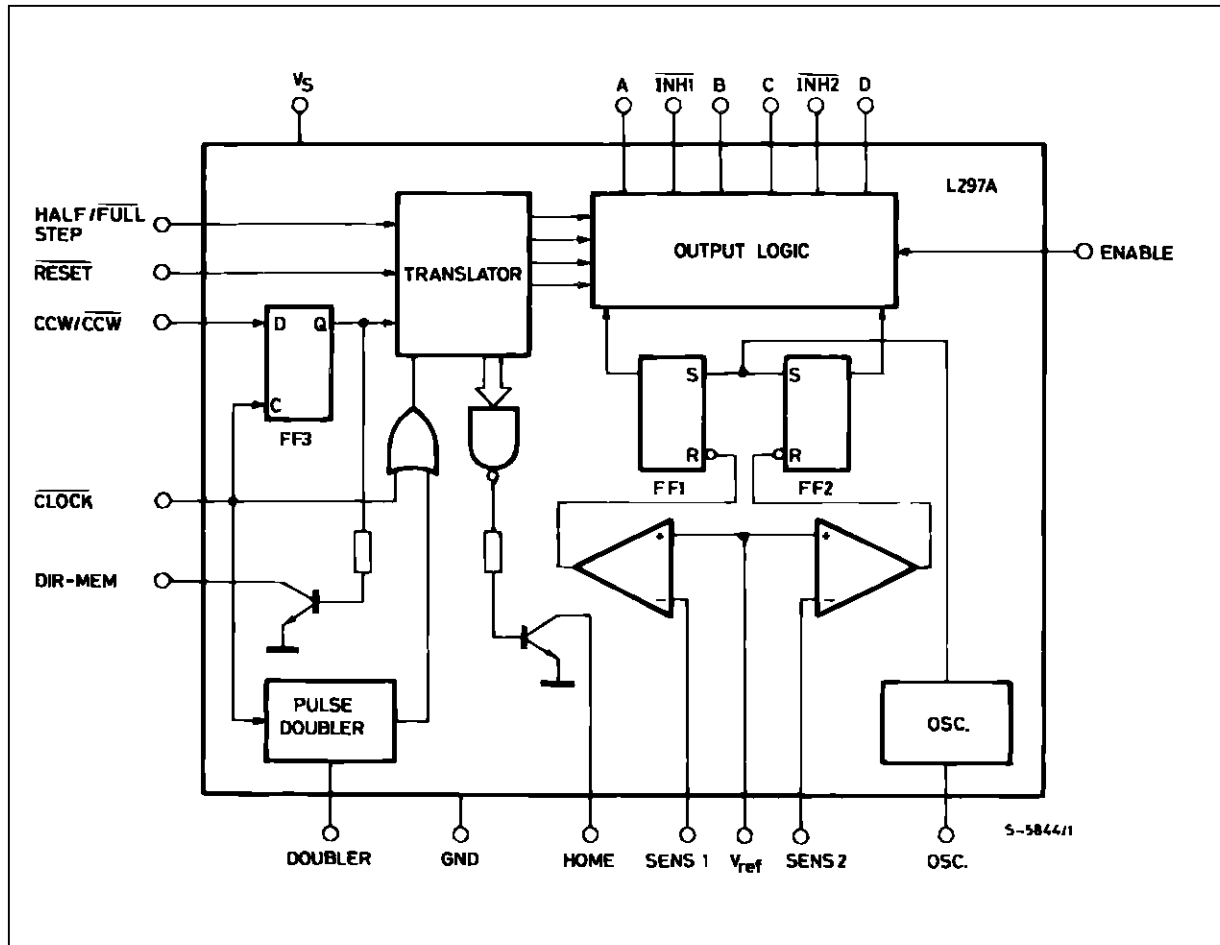
The L297A is a special version of the L297 developed originally for head positioning in floppy disk drives. It can, however, be used in other applications.

Compared to the standard L297 the difference are the addition of a pulse doubler on the step clock input and the availability of the output of the direction flip flop (block diagram, figure 20). To add these functions while keeping the low-cost 20-pin package the CONTROL and SYNC pins are not available on this version (they are not needed anyway). The chopper acts on the ABCD phase lines.

The pulse doubler generates a ghost pulse internally for each input clock pulse. Consequently the translator moves two steps for each input pulse. An external RC network sets the delay time between the input pulse and ghost pulse and should be chosen so that the ghost pulses fall roughly halfway between input pulses, allowing time for the motor to step.

This feature is used to improve positioning accuracy. Since the angular position error of a stepper motor is noncumulative (it cancels out to zero every four steps in a four step sequence motor) accuracy is improved by stepping two of four steps at a time.

**Figure 20 :** The L297A, includes a clock pulse doubler and provides an output from the direction flip flop (DIR - MEM).



**APPLICATION HINTS**

Bipolar motors can be driven with an L297, an L298N or L293E bridge driver and very few external components (figure 21). Together these two chips form a complete microprocessor-to-stepper motor interface. With an L298N this configuration drives motors with winding currents up to 2A ; for motors up to 1A per winding and L293E is used. If the PWM choppers are not required an L293 could also be used (it doesn't have the external emitter connections for sensing resistors) but the L297 is underutilized. If very high powers are required the bridge driver is replaced by an equivalent circuit made with discrete transistors. For currents to 3.5A two L298N's with paralleled outputs may be used.

For unipolar motors the best choice is a quad darlington array. The L702B can be used if the choppers are not required but an ULN2075B is preferred.

This quad darlington has external emitter connections which are connected to sensing resistors (figure 22). Since the chopper acts on the inhibit lines, four AND gates must be added in this application.

Also shown in the schematic are the protection diodes.

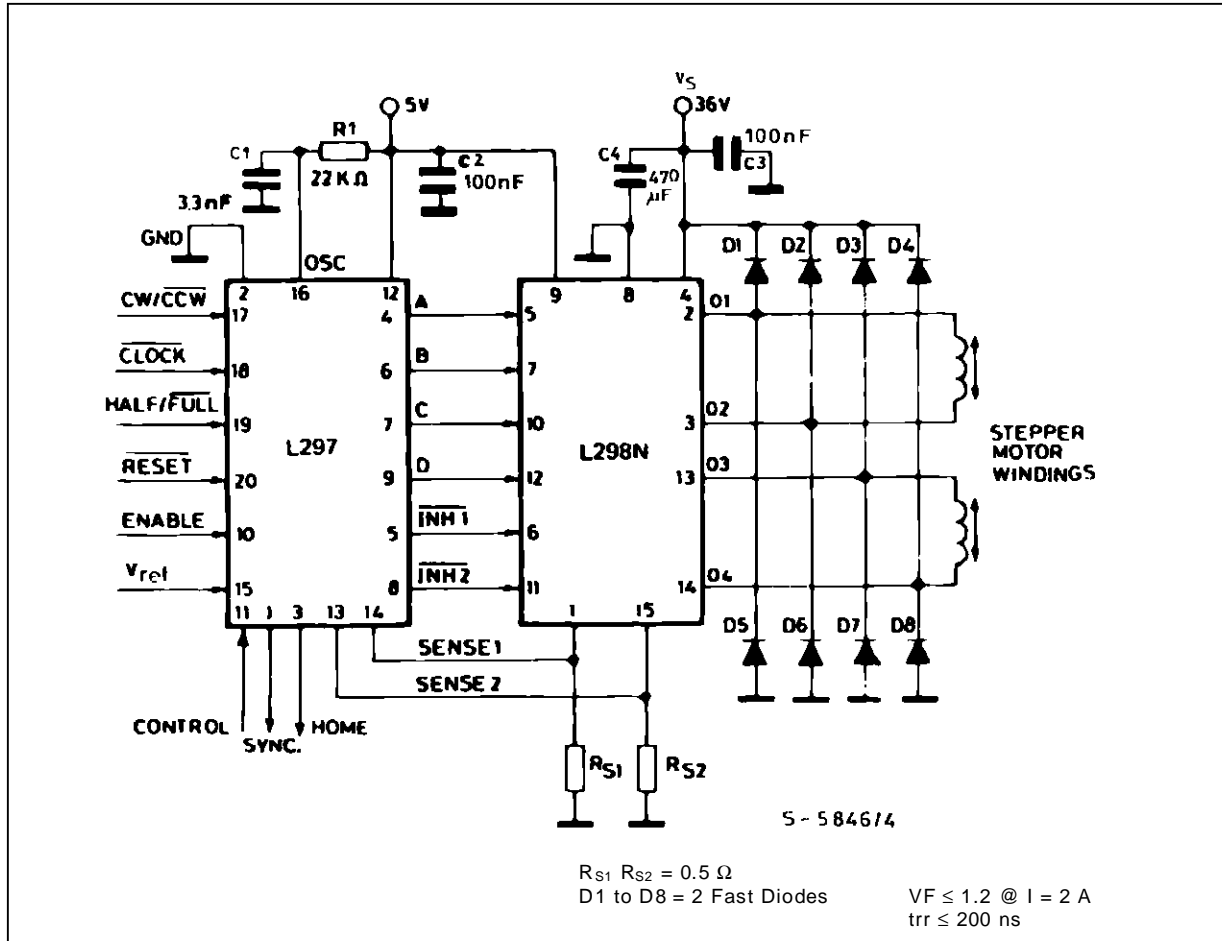
In all applications where the choppers are not used it is important to remember that the sense inputs must be grounded and  $V_{REF}$  connected either to  $V_S$  or any potential between  $V_S$  and ground.

The chopper oscillator frequency is determined by the RC network on pin 16. The frequency is roughly  $1/0.7 RC$  and R must be more than 10 K $\Omega$ . When the L297A's pulse doubler is used, the delay time is determined by the network  $R_d C_d$  and is approximately  $0.75 R_d C_d$ .  $R_d$  should be in the range 3 k $\Omega$  to 100 k $\Omega$  (figure 23).

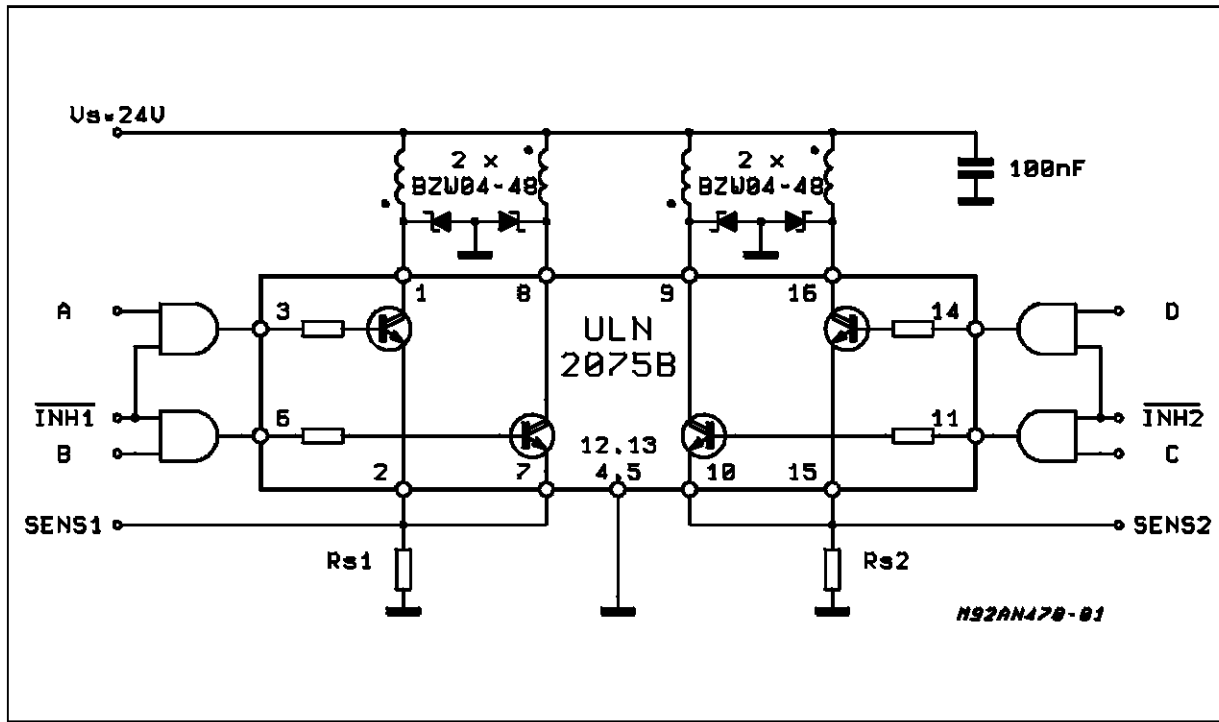


## APPLICATION NOTE

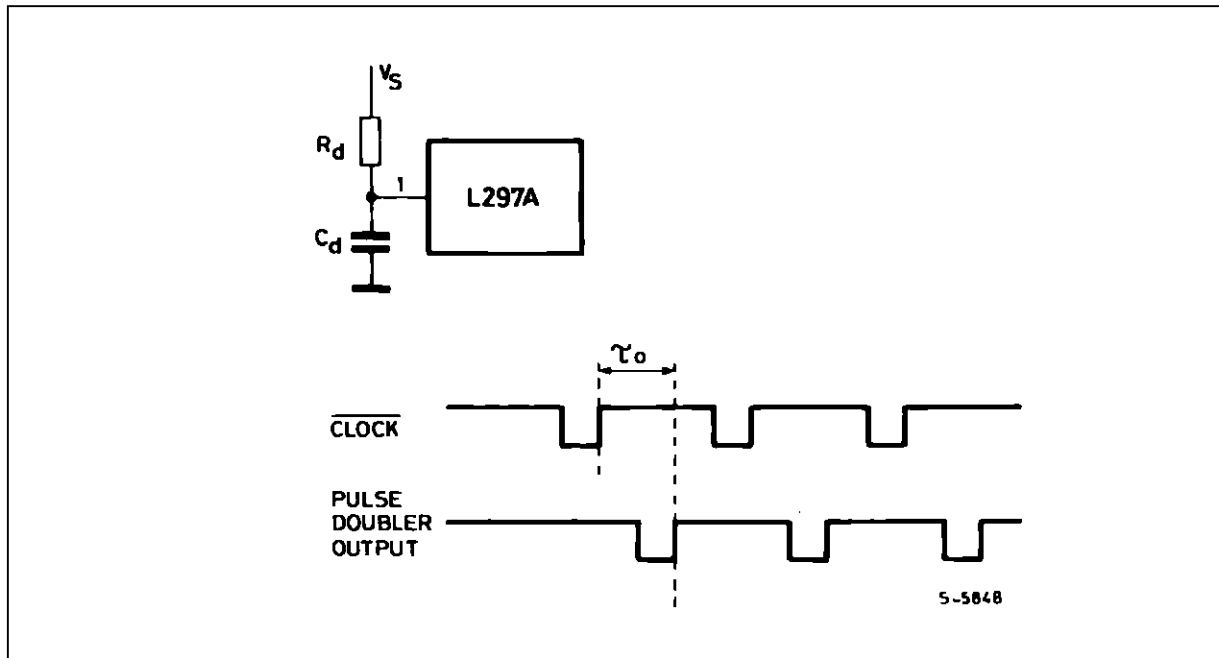
**Figure 21** : This typical application shows an L297 and L298N driving a Bipolar Stepper Motor with phase currents up to 2A.



**Figure 22 :** For Unipolar Motors a Quad Darlington Array is coupled to the L297. Inhibit chopping is used so the four AND gates must be added.



**Figure 23 :** The Clock pulse doubler inserts a ghost pulse  $\tau_0$  seconds after the Input clock pulse.  $R_d C_d$  is chosen to give a delay of approximately half the Input clock period.

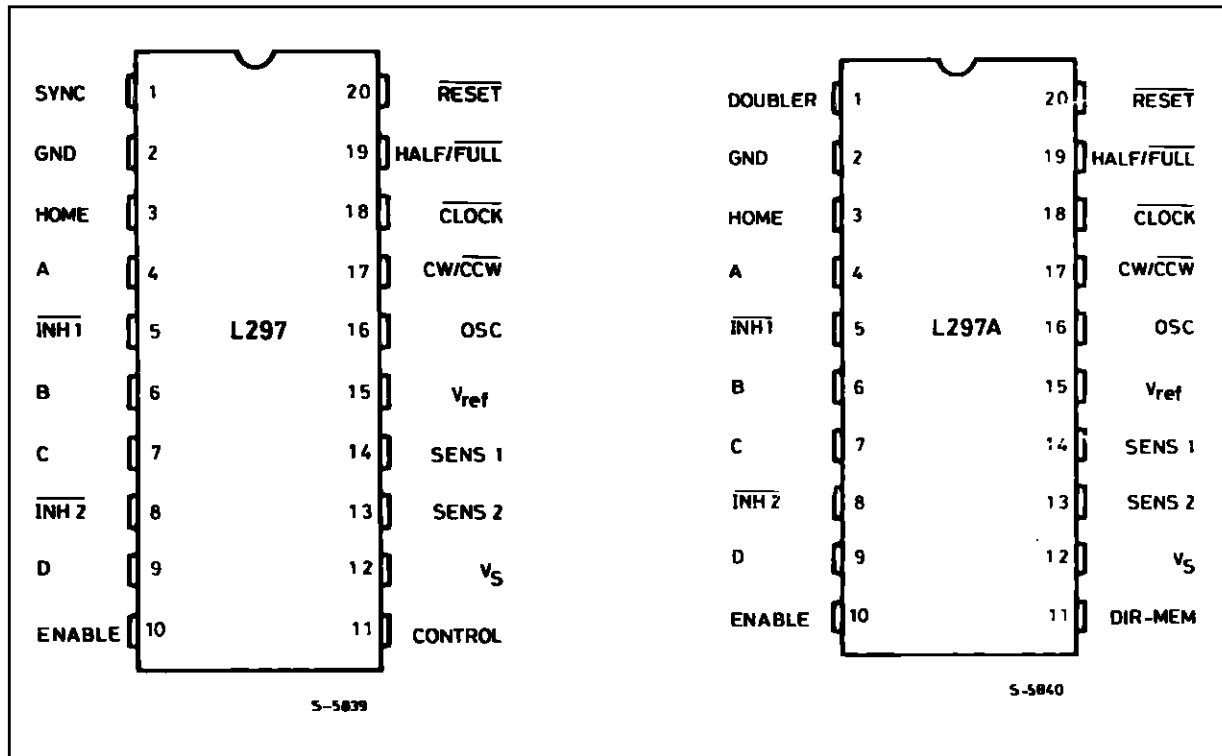


## APPLICATION NOTE

### PIN FUNCTIONS - L297

| N°   | NAME                          | FUNCTION   |
|--|-------------------------------|--|
| 1  | SYNC                          | Output of the on-chip chopper oscillator.<br>The SYNC connections of all L297s to be synchronized are connected together and the oscillator components are omitted on all but one. If an external clock source is used it is injected at this terminal.  |
| 2  | GND                           | Ground connection.   |
| 3  | HOME                          | Open collector output that indicates when the L297 is in its initial state (ABCD = 0101). The transistor is open when this signal is active.   |
| 4  | A                             | Motor phase A drive signal for power stage.  |
| 5  | $\overline{\text{INH1}}$      | Active low inhibit control for driver stage of A and B phases.<br>When a bipolar bridge is used this signal can be used to ensure fast decay of load current when a winding is de-energized. Also used by chopper to regulate load current if CONTROL input is low.  |
| 6  | B                             | Motor phase B drive signal for power stage.  |
| 7  | C                             | Motor phase C drive signal for power stage.  |
| 8  | $\overline{\text{INH2}}$      | Active low inhibit control for drive stages of C and D phases.<br>Same functions as INH1.  |
| 9  | D                             | Motor phase D drive signal for power stage.  |
| 10   | ENABLE                        | Chip enable input. When low (inactive) INH1, INH2, A, B, C and D are brought low.  |
| 11   | CONTROL                       | Control input that defines action of chopper.<br>When low chopper acts on INH1 and INH2; when high chopper acts on phase lines ABCD.   |
| 12   | V <sub>s</sub>                | 5V supply input.   |
| 13   | SENS <sub>2</sub>             | Input for load current sense voltage from power stages of phases C and D.  |
| 14   | SENS <sub>1</sub>             | Input for load current sense voltage from power stages of phases A and B.  |
| 15   | V <sub>ref</sub>              | Reference voltage for chopper circuit. A voltage applied to this pin determines the peak load current.   |
| 16   | OSC                           | An RC network (R to V <sub>CC</sub> , C to ground) connected to this terminal determines the chopper rate. This terminal is connected to ground on all but one device in synchronized multi - L297 configurations. $f \cong 1/0.69 RC$   |
| 17   | $\overline{\text{CW/CCW}}$    | Clockwise/counterclockwise direction control input.<br>Physical direction of motor rotation also depends on connection of windings.<br>Synchronized internally therefore direction can be changed at any time.   |
| 18   | $\overline{\text{CLOCK}}$     | Step clock. An active low pulse on this input advances the motor one increment. The step occurs on the rising edge of this signal.   |
| 19   | $\overline{\text{HALF/FULL}}$ | Half/full step select input. When high selects half step operation, when low selects full step operation. One-phase-on full step mode is obtained by selecting FULL when the L297's translator is at an even-numbered state.<br>Two-phase-on full step mode is set by selecting FULL when the translator is at an odd numbered position. (The home position is designate state 1). |
| 20   | $\overline{\text{RESET}}$     | Reset input. An active low pulse on this input restores the translator to the home position (state 1, ABCD = 0101).  |
| <b>PIN FUNCTIONS - L297A</b> (Pin function of the L297A are identical to those of the L297 except for pins 1 and 11) |                               |  |
| 1  | DOUBLER                       | An RC network connected to this pin determines the delay between an input clock pulse and the corresponding ghost pulse.   |
| 11   | DIR-MEM                       | Direction Memory. Inverted output of the direction flip flop. Open collector output.   |

Figure 24 : Pin connections.



## APPLICATION NOTE

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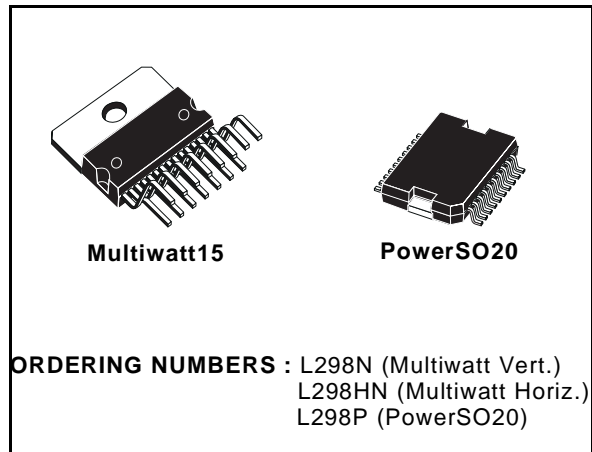
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## DUAL FULL-BRIDGE DRIVER

- OPERATING SUPPLY VOLTAGE UP TO 46 V
- TOTAL DC CURRENT UP TO 4 A
- LOW SATURATION VOLTAGE
- OVERTEMPERATURE PROTECTION
- LOGICAL "0" INPUT VOLTAGE UP TO 1.5 V (HIGH NOISE IMMUNITY)

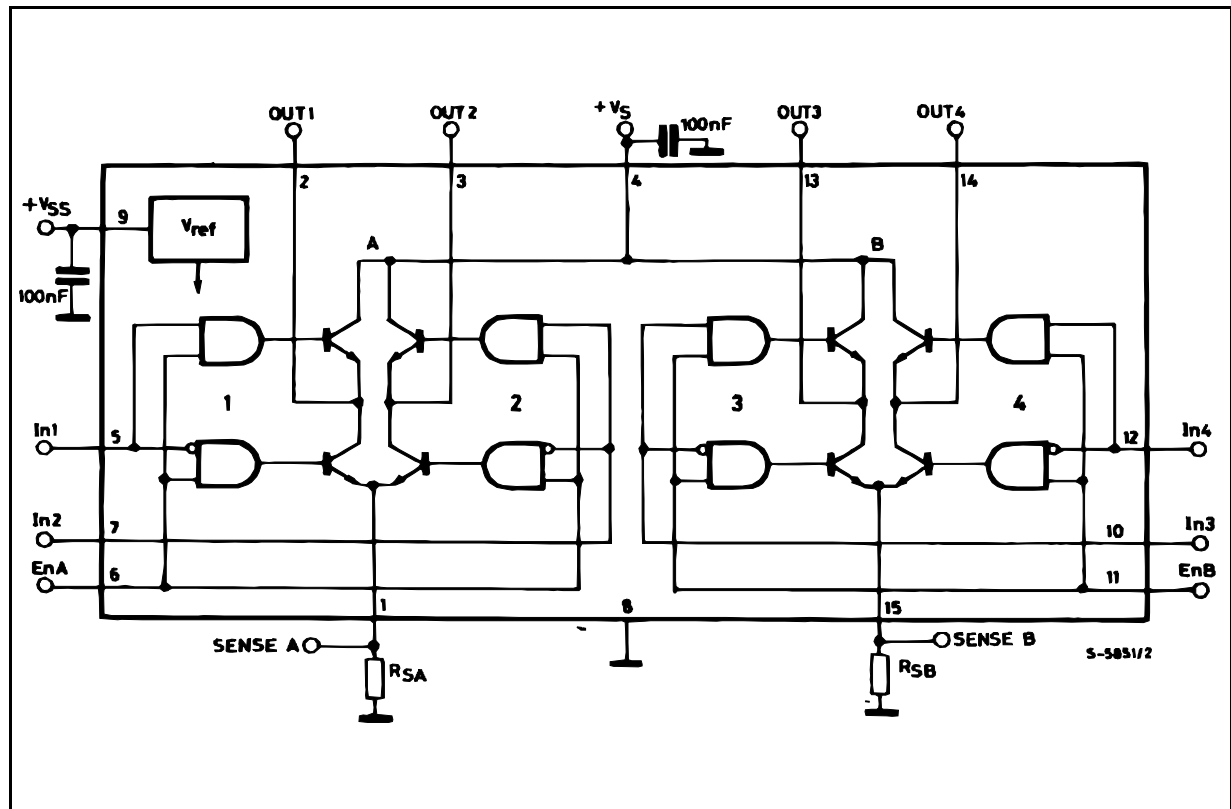
### DESCRIPTION

The L298 is an integrated monolithic circuit in a 15-lead Multiwatt and PowerSO20 packages. It is a high voltage, high current dual full-bridge driver designed to accept standard TTL logic levels and drive inductive loads such as relays, solenoids, DC and stepping motors. Two enable inputs are provided to enable or disable the device independently of the input signals. The emitters of the lower transistors of each bridge are connected together and the corresponding external terminal can be used for the con-



nection of an external sensing resistor. An additional supply input is provided so that the logic works at a lower voltage.

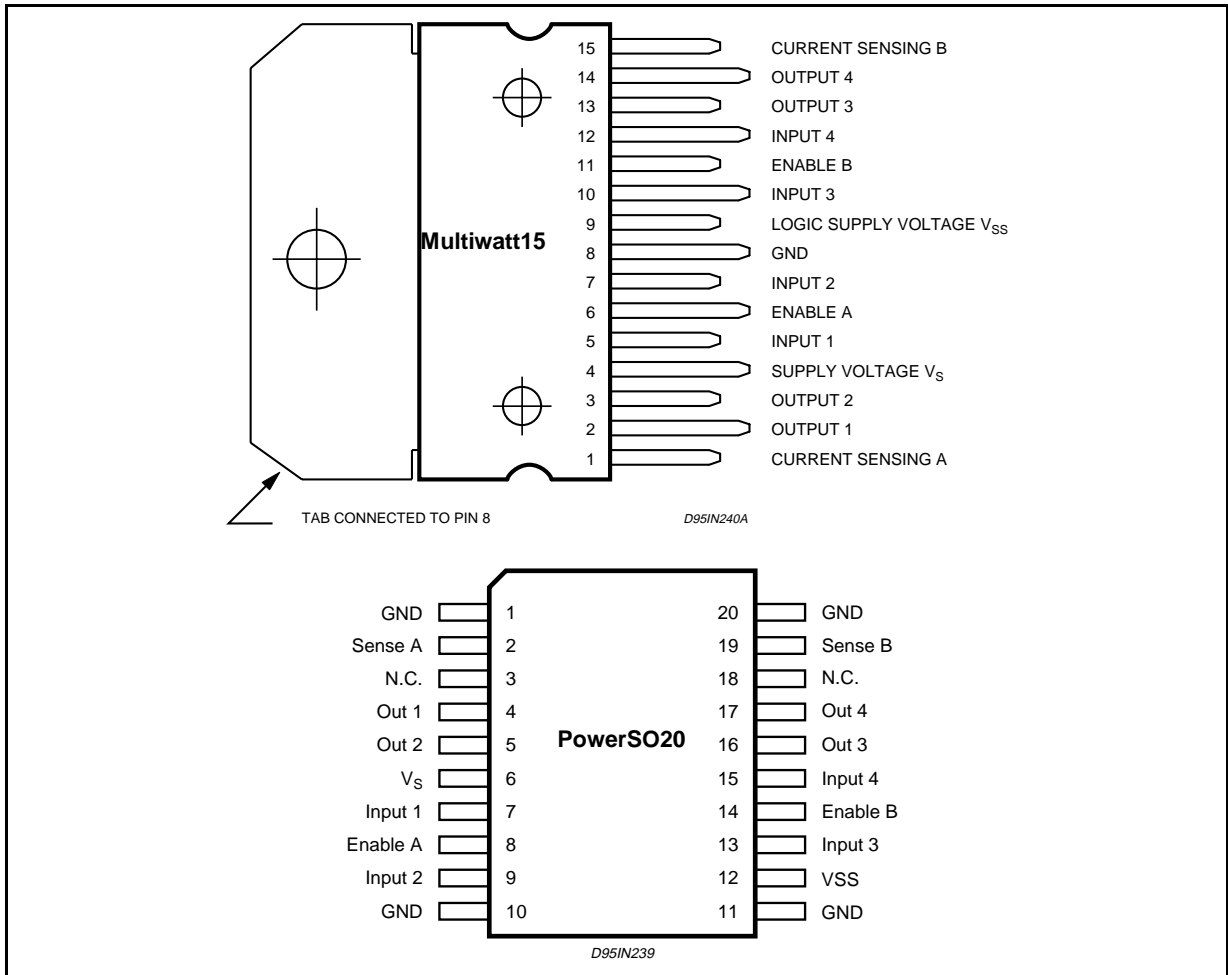
### BLOCK DIAGRAM



**ABSOLUTE MAXIMUM RATINGS**

| Symbol         | Parameter   | Value      | Unit       |
|----------------|---|------------|------------|
| $V_S$          | Power Supply  | 50         | V          |
| $V_{SS}$       | Logic Supply Voltage                                | 7          | V          |
| $V_I, V_{En}$  | Input and Enable Voltage                            | -0.3 to 7  | V          |
| $I_O$          | Peak Output Current (each Channel)                  |            |            |
|                | - Non Repetitive ( $t = 100\mu s$ )                 | 3          | A          |
|                | - Repetitive (80% on -20% off; $t_{on} = 10ms$ )    | 2.5        | A          |
|                | -DC Operation                                       | 2          | A          |
| $V_{sens}$     | Sensing Voltage                                     | -1 to 2.3  | V          |
| $P_{tot}$      | Total Power Dissipation ( $T_{case} = 75^\circ C$ ) | 25         | W          |
| $T_{op}$       | Junction Operating Temperature                      | -25 to 130 | $^\circ C$ |
| $T_{stg}, T_j$ | Storage and Junction Temperature                    | -40 to 150 | $^\circ C$ |

**PIN CONNECTIONS (top view)**



**THERMAL DATA**

| Symbol          | Parameter                           |      | PowerSO20 | Multiwatt15 | Unit         |
|-----------------|-------------------------------------|------|-----------|-------------|--------------|
| $R_{th j-case}$ | Thermal Resistance Junction-case    | Max. | -         | 3           | $^\circ C/W$ |
| $R_{th j-amb}$  | Thermal Resistance Junction-ambient | Max. | 13 (*)    | 35          | $^\circ C/W$ |

(\*) Mounted on aluminum substrate



**PIN FUNCTIONS** (refer to the block diagram)

| MW.15  | PowerSO    | Name               | Function  |
|--------|------------|--------------------|---|
| 1;15   | 2;19       | Sense A; Sense B   | Between this pin and ground is connected the sense resistor to control the current of the load.                               |
| 2;3    | 4;5        | Out 1; Out 2       | Outputs of the Bridge A; the current that flows through the load connected between these two pins is monitored at pin 1.      |
| 4      | 6          | V <sub>s</sub>     | Supply Voltage for the Power Output Stages.<br>A non-inductive 100nF capacitor must be connected between this pin and ground. |
| 5;7    | 7;9        | Input 1; Input 2   | TTL Compatible Inputs of the Bridge A.  |
| 6;11   | 8;14       | Enable A; Enable B | TTL Compatible Enable Input: the L state disables the bridge A (enable A) and/or the bridge B (enable B).                     |
| 8      | 1,10,11,20 | GND                | Ground.   |
| 9      | 12         | V <sub>SS</sub>    | Supply Voltage for the Logic Blocks. A100nF capacitor must be connected between this pin and ground.                          |
| 10; 12 | 13;15      | Input 3; Input 4   | TTL Compatible Inputs of the Bridge B.  |
| 13; 14 | 16;17      | Out 3; Out 4       | Outputs of the Bridge B. The current that flows through the load connected between these two pins is monitored at pin 15.     |
| –      | 3;18       | N.C.               | Not Connected   |

**ELECTRICAL CHARACTERISTICS** (V<sub>S</sub> = 42V; V<sub>SS</sub> = 5V, T<sub>j</sub> = 25°C; unless otherwise specified)

| Symbol                 | Parameter                                      | Test Conditions   | Min.                 | Typ.       | Max.            | Unit     |
|------------------------|--|---|----------------------|------------|-----------------|----------|
| V <sub>S</sub>         | Supply Voltage (pin 4)                         | Operative Condition   | V <sub>IH</sub> +2.5 |            | 46              | V        |
| V <sub>SS</sub>        | Logic Supply Voltage (pin 9)                   |   | 4.5                  | 5          | 7               | V        |
| I <sub>S</sub>         | Quiescent Supply Current (pin 4)               | V <sub>en</sub> = H; I <sub>L</sub> = 0<br>V <sub>i</sub> = L<br>V <sub>i</sub> = H |                      | 13<br>50   | 22<br>70        | mA<br>mA |
|                        |  | V <sub>en</sub> = L<br>V <sub>i</sub> = X   |                      |            | 4               | mA       |
| I <sub>SS</sub>        | Quiescent Current from V <sub>SS</sub> (pin 9) | V <sub>en</sub> = H; I <sub>L</sub> = 0<br>V <sub>i</sub> = L<br>V <sub>i</sub> = H |                      | 24<br>7    | 36<br>12        | mA<br>mA |
|                        |  | V <sub>en</sub> = L<br>V <sub>i</sub> = X   |                      |            | 6               | mA       |
| V <sub>iL</sub>        | Input Low Voltage (pins 5, 7, 10, 12)          |   | –0.3                 |            | 1.5             | V        |
| V <sub>iH</sub>        | Input High Voltage (pins 5, 7, 10, 12)         |   | 2.3                  |            | V <sub>SS</sub> | V        |
| I <sub>iL</sub>        | Low Voltage Input Current (pins 5, 7, 10, 12)  | V <sub>i</sub> = L  |                      |            | –10             | μA       |
| I <sub>iH</sub>        | High Voltage Input Current (pins 5, 7, 10, 12) | V <sub>i</sub> = H ≤ V <sub>SS</sub> – 0.6V   |                      | 30         | 100             | μA       |
| V <sub>en</sub> = L    | Enable Low Voltage (pins 6, 11)                |   | –0.3                 |            | 1.5             | V        |
| V <sub>en</sub> = H    | Enable High Voltage (pins 6, 11)               |   | 2.3                  |            | V <sub>SS</sub> | V        |
| I <sub>en</sub> = L    | Low Voltage Enable Current (pins 6, 11)        | V <sub>en</sub> = L   |                      |            | –10             | μA       |
| I <sub>en</sub> = H    | High Voltage Enable Current (pins 6, 11)       | V <sub>en</sub> = H ≤ V <sub>SS</sub> – 0.6V  |                      | 30         | 100             | μA       |
| V <sub>CEsat</sub> (H) | Source Saturation Voltage                      | I <sub>L</sub> = 1A<br>I <sub>L</sub> = 2A  | 0.95                 | 1.35<br>2  | 1.7<br>2.7      | V<br>V   |
| V <sub>CEsat</sub> (L) | Sink Saturation Voltage                        | I <sub>L</sub> = 1A (5)<br>I <sub>L</sub> = 2A (5)                                  | 0.85                 | 1.2<br>1.7 | 1.6<br>2.3      | V<br>V   |
| V <sub>CEsat</sub>     | Total Drop                                     | I <sub>L</sub> = 1A (5)<br>I <sub>L</sub> = 2A (5)                                  | 1.80                 |            | 3.2<br>4.9      | V<br>V   |
| V <sub>sens</sub>      | Sensing Voltage (pins 1, 15)                   |   | –1 (1)               |            | 2               | V        |



ELECTRICAL CHARACTERISTICS (continued)

| Symbol                            | Parameter                     | Test Conditions                                    | Min. | Typ. | Max. | Unit |
|-----------------------------------|-------------------------------|--|------|------|------|------|
| T <sub>1</sub> (V <sub>i</sub> )  | Source Current Turn-off Delay | 0.5 V <sub>i</sub> to 0.9 I <sub>L</sub> (2); (4)  |      | 1.5  |      | μs   |
| T <sub>2</sub> (V <sub>i</sub> )  | Source Current Fall Time      | 0.9 I <sub>L</sub> to 0.1 I <sub>L</sub> (2); (4)  |      | 0.2  |      | μs   |
| T <sub>3</sub> (V <sub>i</sub> )  | Source Current Turn-on Delay  | 0.5 V <sub>i</sub> to 0.1 I <sub>L</sub> (2); (4)  |      | 2    |      | μs   |
| T <sub>4</sub> (V <sub>i</sub> )  | Source Current Rise Time      | 0.1 I <sub>L</sub> to 0.9 I <sub>L</sub> (2); (4)  |      | 0.7  |      | μs   |
| T <sub>5</sub> (V <sub>i</sub> )  | Sink Current Turn-off Delay   | 0.5 V <sub>i</sub> to 0.9 I <sub>L</sub> (3); (4)  |      | 0.7  |      | μs   |
| T <sub>6</sub> (V <sub>i</sub> )  | Sink Current Fall Time        | 0.9 I <sub>L</sub> to 0.1 I <sub>L</sub> (3); (4)  |      | 0.25 |      | μs   |
| T <sub>7</sub> (V <sub>i</sub> )  | Sink Current Turn-on Delay    | 0.5 V <sub>i</sub> to 0.9 I <sub>L</sub> (3); (4)  |      | 1.6  |      | μs   |
| T <sub>8</sub> (V <sub>i</sub> )  | Sink Current Rise Time        | 0.1 I <sub>L</sub> to 0.9 I <sub>L</sub> (3); (4)  |      | 0.2  |      | μs   |
| f <sub>c</sub> (V <sub>i</sub> )  | Commutation Frequency         | I <sub>L</sub> = 2A                                |      | 25   | 40   | KHz  |
| T <sub>1</sub> (V <sub>en</sub> ) | Source Current Turn-off Delay | 0.5 V <sub>en</sub> to 0.9 I <sub>L</sub> (2); (4) |      | 3    |      | μs   |
| T <sub>2</sub> (V <sub>en</sub> ) | Source Current Fall Time      | 0.9 I <sub>L</sub> to 0.1 I <sub>L</sub> (2); (4)  |      | 1    |      | μs   |
| T <sub>3</sub> (V <sub>en</sub> ) | Source Current Turn-on Delay  | 0.5 V <sub>en</sub> to 0.1 I <sub>L</sub> (2); (4) |      | 0.3  |      | μs   |
| T <sub>4</sub> (V <sub>en</sub> ) | Source Current Rise Time      | 0.1 I <sub>L</sub> to 0.9 I <sub>L</sub> (2); (4)  |      | 0.4  |      | μs   |
| T <sub>5</sub> (V <sub>en</sub> ) | Sink Current Turn-off Delay   | 0.5 V <sub>en</sub> to 0.9 I <sub>L</sub> (3); (4) |      | 2.2  |      | μs   |
| T <sub>6</sub> (V <sub>en</sub> ) | Sink Current Fall Time        | 0.9 I <sub>L</sub> to 0.1 I <sub>L</sub> (3); (4)  |      | 0.35 |      | μs   |
| T <sub>7</sub> (V <sub>en</sub> ) | Sink Current Turn-on Delay    | 0.5 V <sub>en</sub> to 0.9 I <sub>L</sub> (3); (4) |      | 0.25 |      | μs   |
| T <sub>8</sub> (V <sub>en</sub> ) | Sink Current Rise Time        | 0.1 I <sub>L</sub> to 0.9 I <sub>L</sub> (3); (4)  |      | 0.1  |      | μs   |

- 1) Sensing voltage can be -1 V for t ≤ 50 μsec; in steady state V<sub>sens</sub> min ≥ -0.5 V.
- 2) See fig. 2.
- 3) See fig. 4.
- 4) The load must be a pure resistor.

Figure 1 : Typical Saturation Voltage vs. Output Current.

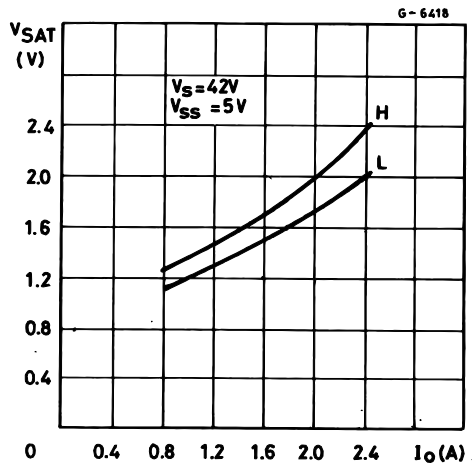
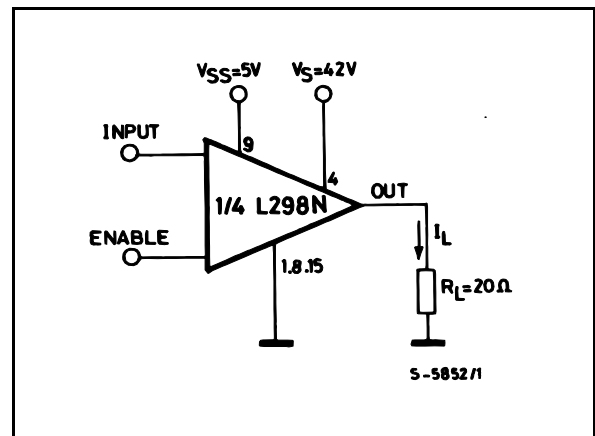
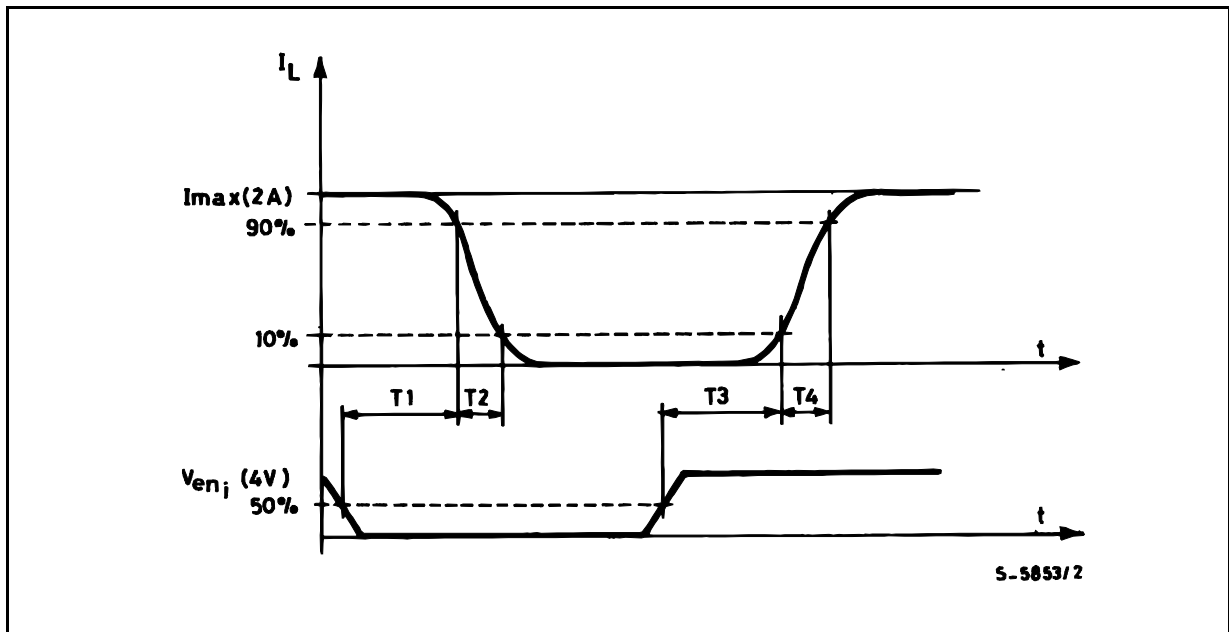


Figure 2 : Switching Times Test Circuits.

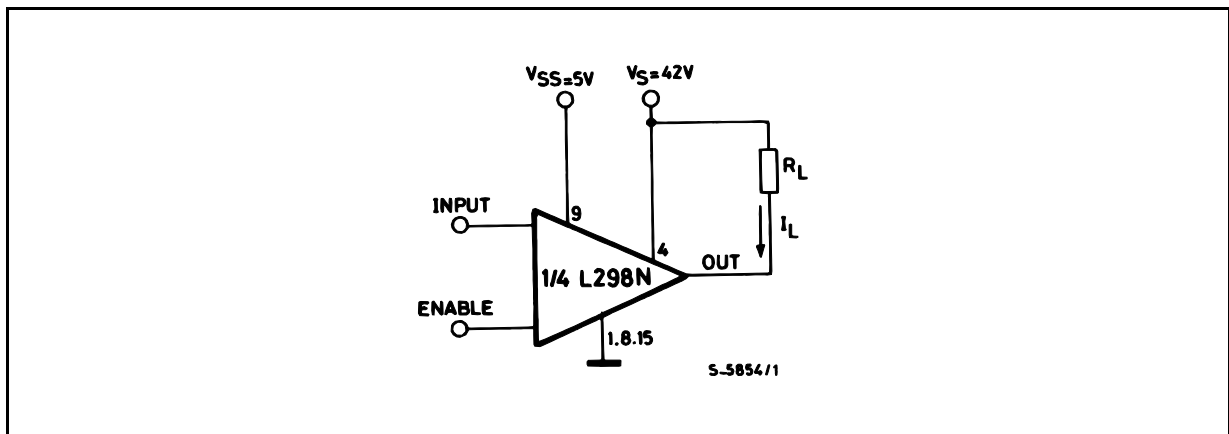


Note : For INPUT Switching, set EN = H  
 For ENABLE Switching, set IN = H

**Figure 3 :** Source Current Delay Times vs. Input or Enable Switching.



**Figure 4 :** Switching Times Test Circuits.



Note : For INPUT Switching, set EN = H  
For ENABLE Switching, set IN = L

Figure 5 : Sink Current Delay Times vs. Input 0 V Enable Switching.

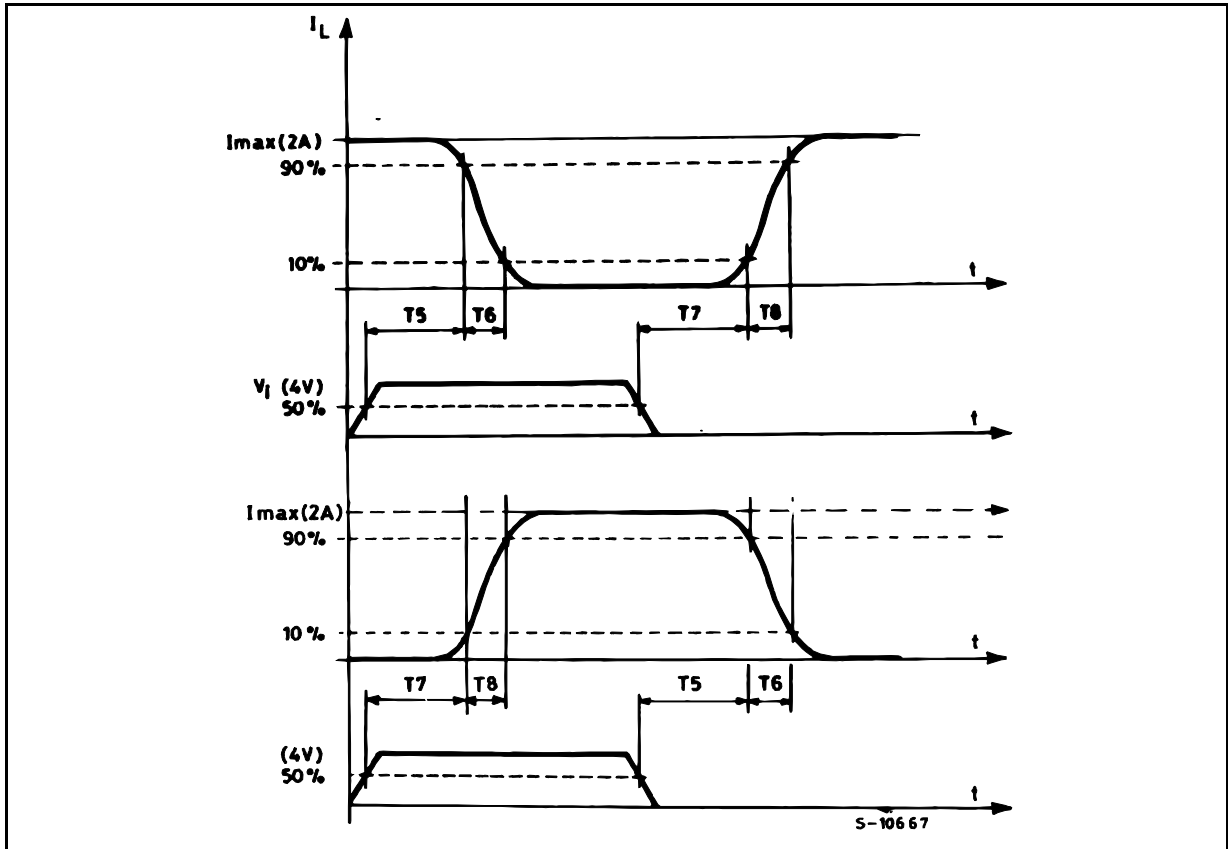
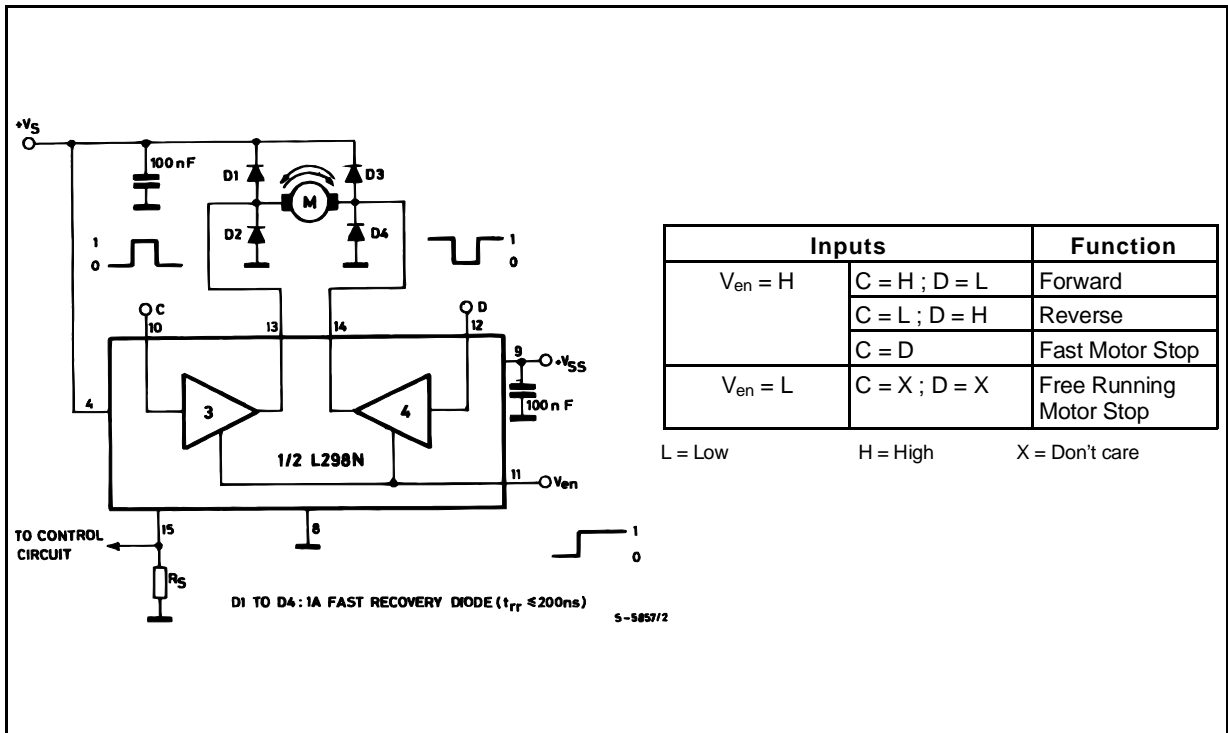
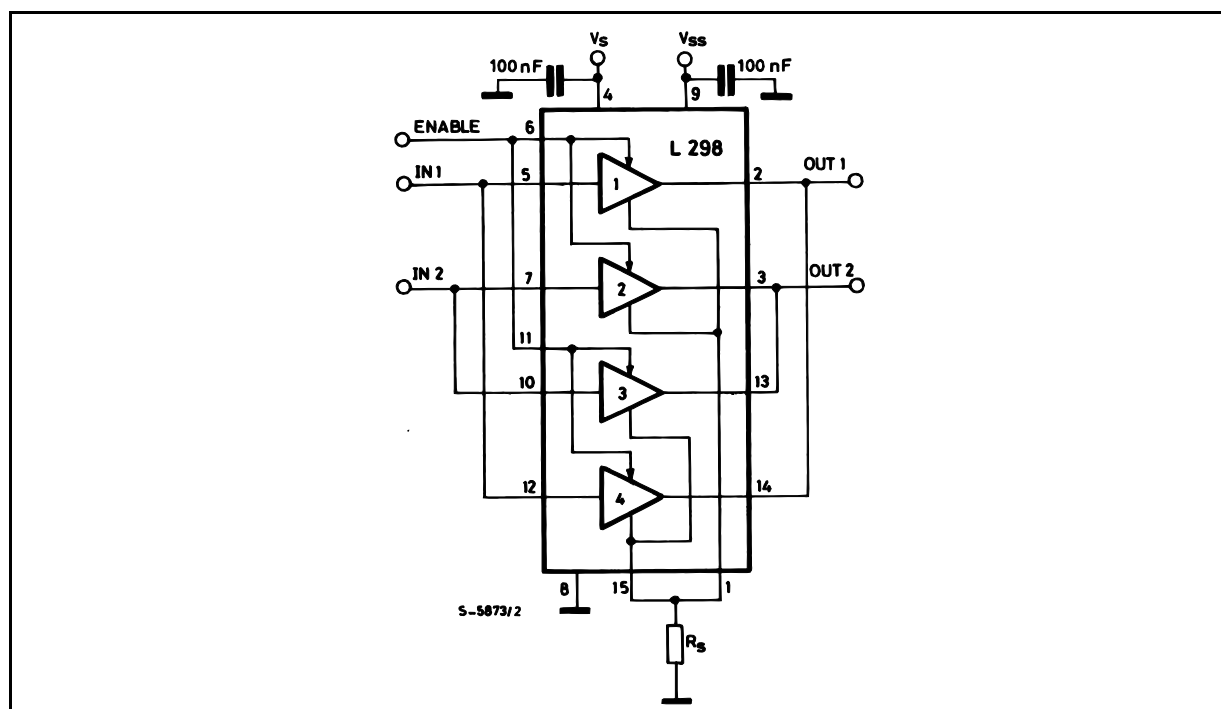


Figure 6 : Bidirectional DC Motor Control.



**Figure 7 :** For higher currents, outputs can be paralleled. Take care to parallel channel 1 with channel 4 and channel 2 with channel 3.



## APPLICATION INFORMATION (Refer to the block diagram)

### 1.1. POWER OUTPUT STAGE

The L298 integrates two power output stages (A ; B). The power output stage is a bridge configuration and its outputs can drive an inductive load in common or differenzial mode, depending on the state of the inputs. The current that flows through the load comes out from the bridge at the sense output : an external resistor ( $R_{SA}$  ;  $R_{SB}$ .) allows to detect the intensity of this current.

### 1.2. INPUT STAGE

Each bridge is driven by means of four gates the input of which are In1 ; In2 ; EnA and In3 ; In4 ; EnB. The In inputs set the bridge state when The En input is high ; a low state of the En input inhibits the bridge. All the inputs are TTL compatible.

## 2. SUGGESTIONS

A non inductive capacitor, usually of 100 nF, must be foreseen between both Vs and Vss, to ground, as near as possible to GND pin. When the large capacitor of the power supply is too far from the IC, a second smaller one must be foreseen near the L298.

The sense resistor, not of a wire wound type, must be grounded near the negative pole of Vs that must be near the GND pin of the I.C.

Each input must be connected to the source of the driving signals by means of a very short path.

Turn-On and Turn-Off : Before to Turn-ON the Supply Voltage and before to Turn it OFF, the Enable input must be driven to the Low state.

## 3. APPLICATIONS

Fig 6 shows a bidirectional DC motor control Schematic Diagram for which only one bridge is needed. The external bridge of diodes D1 to D4 is made by four fast recovery elements ( $t_{tr} \leq 200$  nsec) that must be chosen of a VF as low as possible at the worst case of the load current.

The sense output voltage can be used to control the current amplitude by chopping the inputs, or to provide overcurrent protection by switching low the enable input.

The brake function (Fast motor stop) requires that the Absolute Maximum Rating of 2 Amps must never be overcome.

When the repetitive peak current needed from the load is higher than 2 Amps, a paralleled configuration can be chosen (See Fig.7).

An external bridge of diodes are required when inductive loads are driven and when the inputs of the IC are chopped ; Schottky diodes would be preferred.

This solution can drive until 3 Amps In DC operation and until 3.5 Amps of a repetitive peak current.

On Fig 8 it is shown the driving of a two phase bipolar stepper motor ; the needed signals to drive the inputs of the L298 are generated, in this example, from the IC L297.

Fig 9 shows an example of P.C.B. designed for the application of Fig 8.

**Figure 8 :** Two Phase Bipolar Stepper Motor Circuit.

This circuit drives bipolar stepper motors with winding currents up to 2 A. The diodes are fast 2 A types.

Fig 10 shows a second two phase bipolar stepper motor control circuit where the current is controlled by the I.C. L6506.

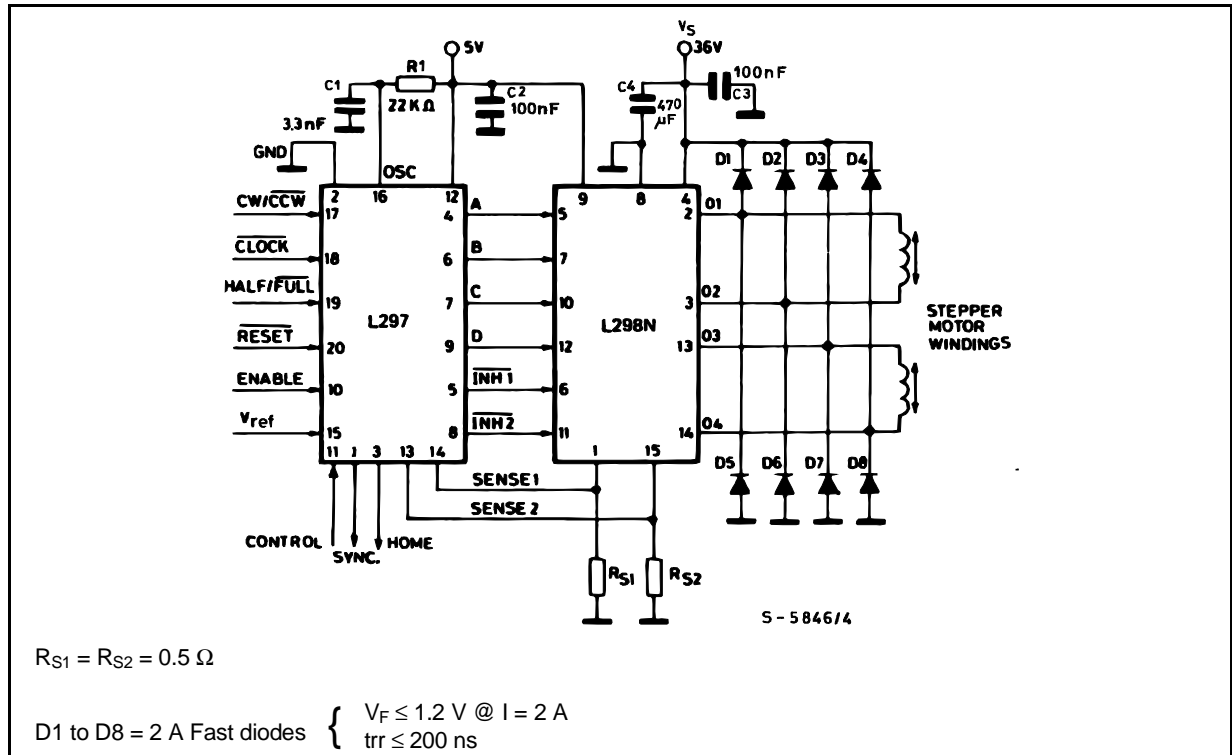


Figure 9 : Suggested Printed Circuit Board Layout for the Circuit of fig. 8 (1:1 scale).

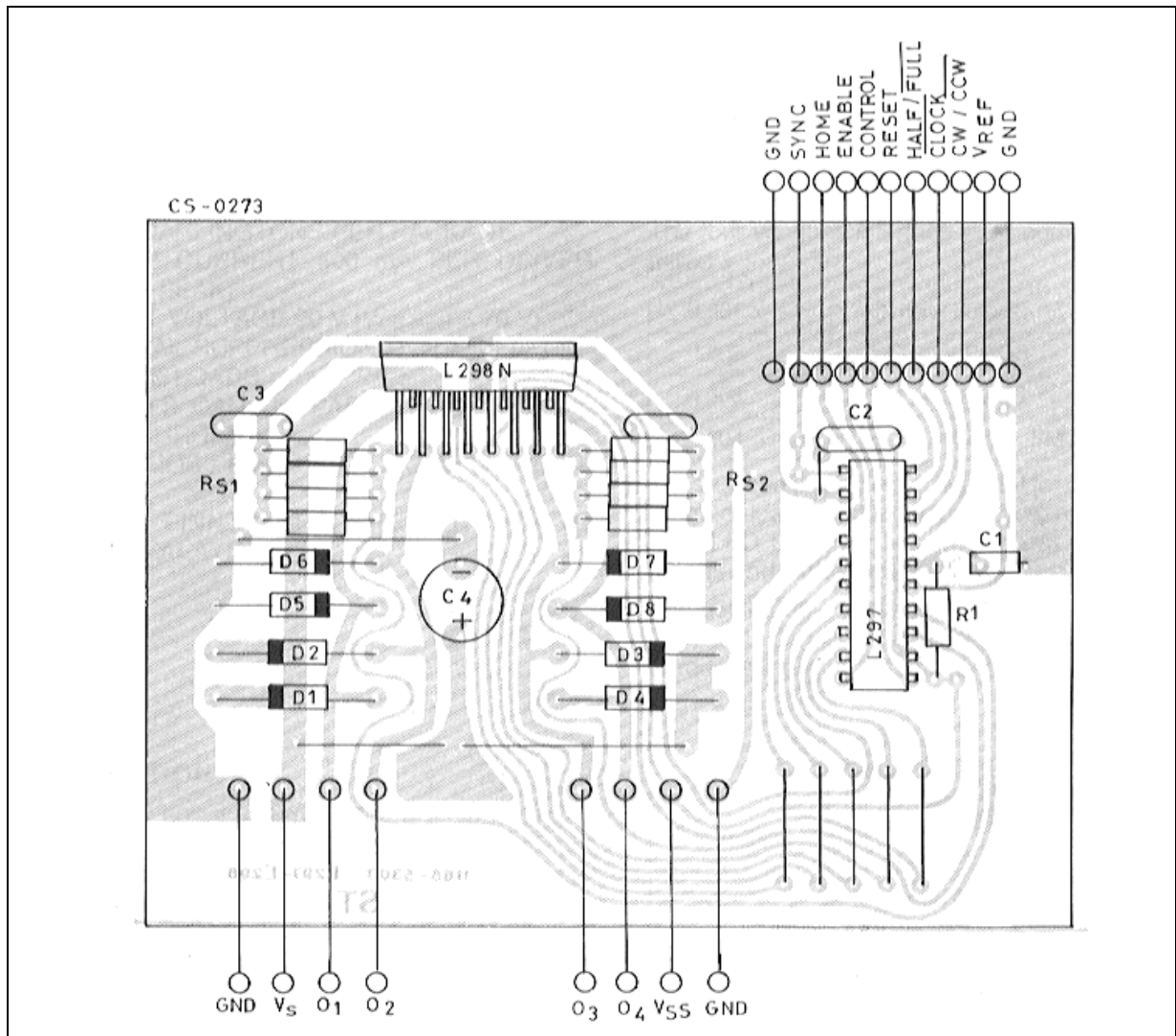
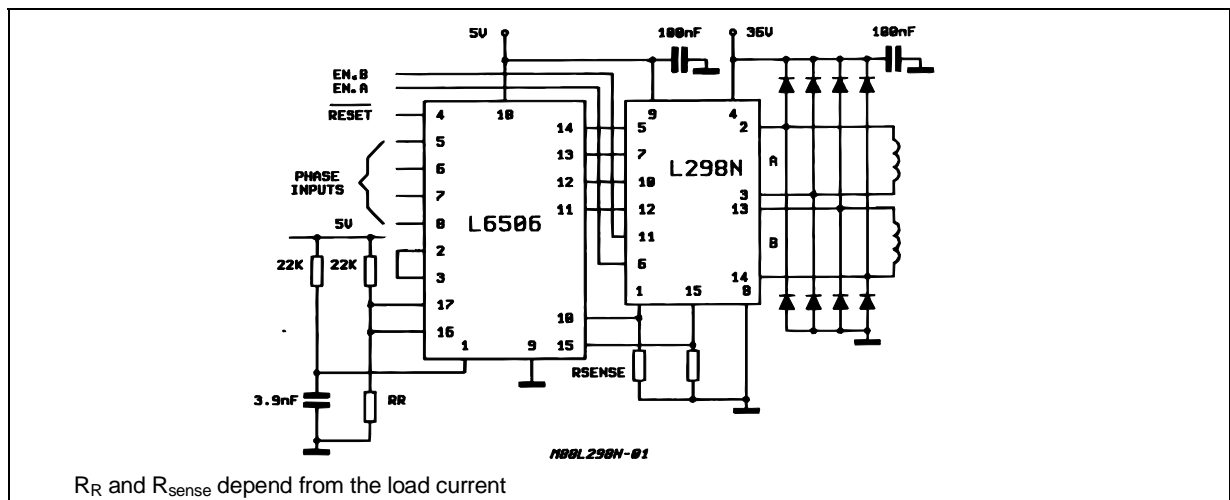
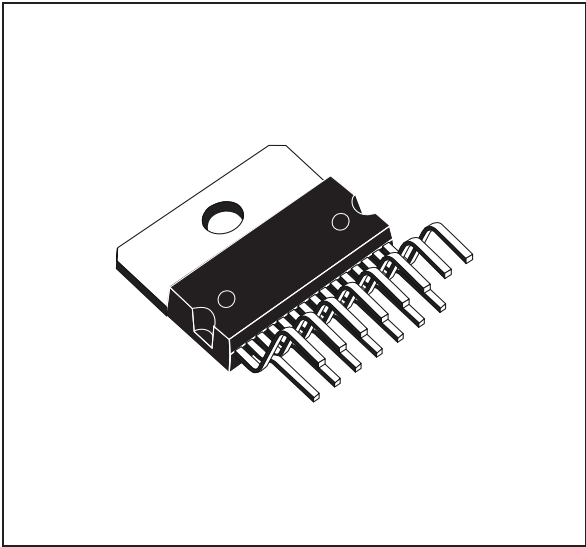


Figure 10 : Two Phase Bipolar Stepper Motor Control Circuit by Using the Current Controller L6506.

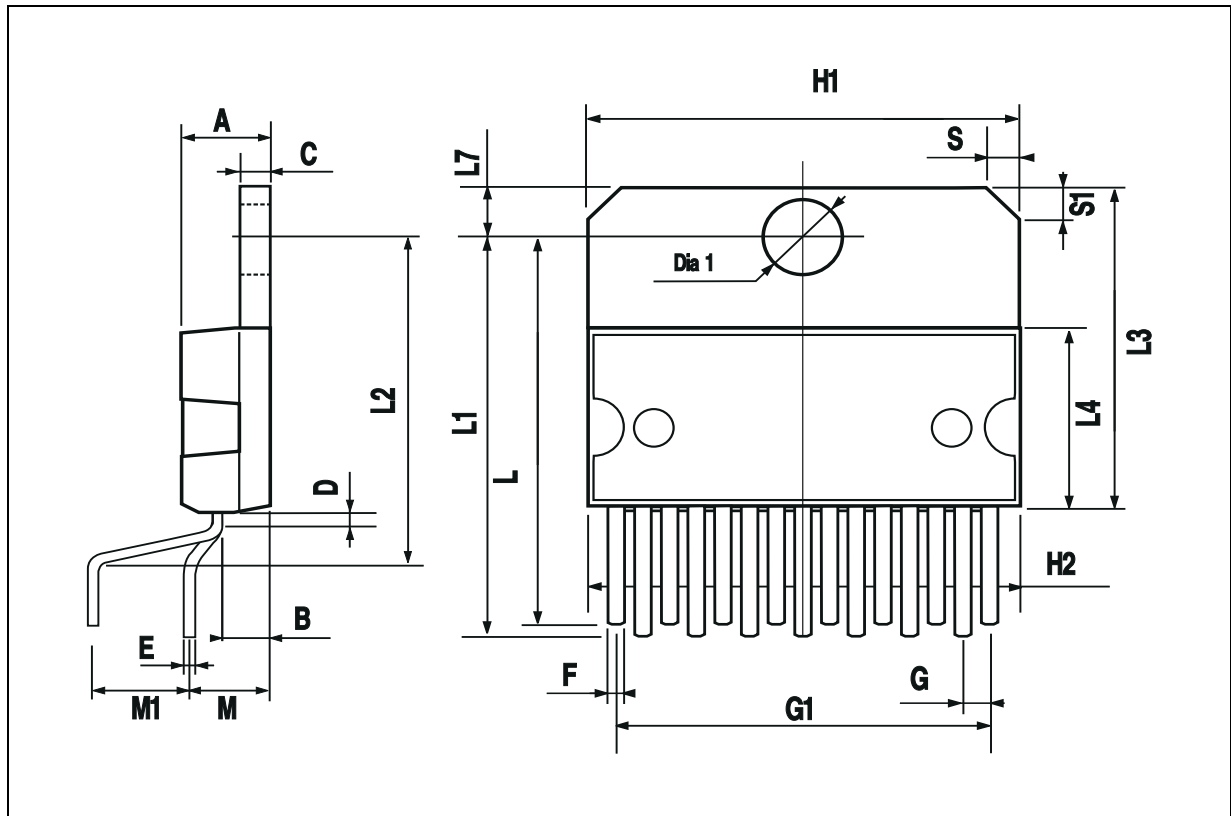


| DIM. | mm    |       |       | inch  |       |       |
|------|-------|-------|-------|-------|-------|-------|
|      | MIN.  | TYP.  | MAX.  | MIN.  | TYP.  | MAX.  |
| A    |       |       | 5     |       |       | 0.197 |
| B    |       |       | 2.65  |       |       | 0.104 |
| C    |       |       | 1.6   |       |       | 0.063 |
| D    |       | 1     |       |       | 0.039 |       |
| E    | 0.49  |       | 0.55  | 0.019 |       | 0.022 |
| F    | 0.66  |       | 0.75  | 0.026 |       | 0.030 |
| G    | 1.02  | 1.27  | 1.52  | 0.040 | 0.050 | 0.060 |
| G1   | 17.53 | 17.78 | 18.03 | 0.690 | 0.700 | 0.710 |
| H1   | 19.6  |       |       | 0.772 |       |       |
| H2   |       |       | 20.2  |       |       | 0.795 |
| L    | 21.9  | 22.2  | 22.5  | 0.862 | 0.874 | 0.886 |
| L1   | 21.7  | 22.1  | 22.5  | 0.854 | 0.870 | 0.886 |
| L2   | 17.65 |       | 18.1  | 0.695 |       | 0.713 |
| L3   | 17.25 | 17.5  | 17.75 | 0.679 | 0.689 | 0.699 |
| L4   | 10.3  | 10.7  | 10.9  | 0.406 | 0.421 | 0.429 |
| L7   | 2.65  |       | 2.9   | 0.104 |       | 0.114 |
| M    | 4.25  | 4.55  | 4.85  | 0.167 | 0.179 | 0.191 |
| M1   | 4.63  | 5.08  | 5.53  | 0.182 | 0.200 | 0.218 |
| S    | 1.9   |       | 2.6   | 0.075 |       | 0.102 |
| S1   | 1.9   |       | 2.6   | 0.075 |       | 0.102 |
| Dia1 | 3.65  |       | 3.85  | 0.144 |       | 0.152 |

**OUTLINE AND MECHANICAL DATA**

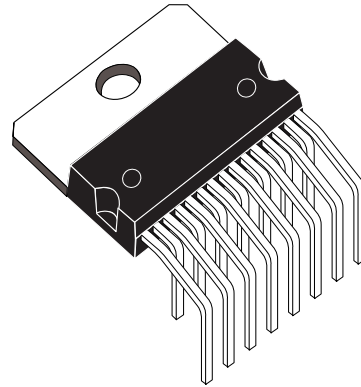


**Multiwatt15 V**

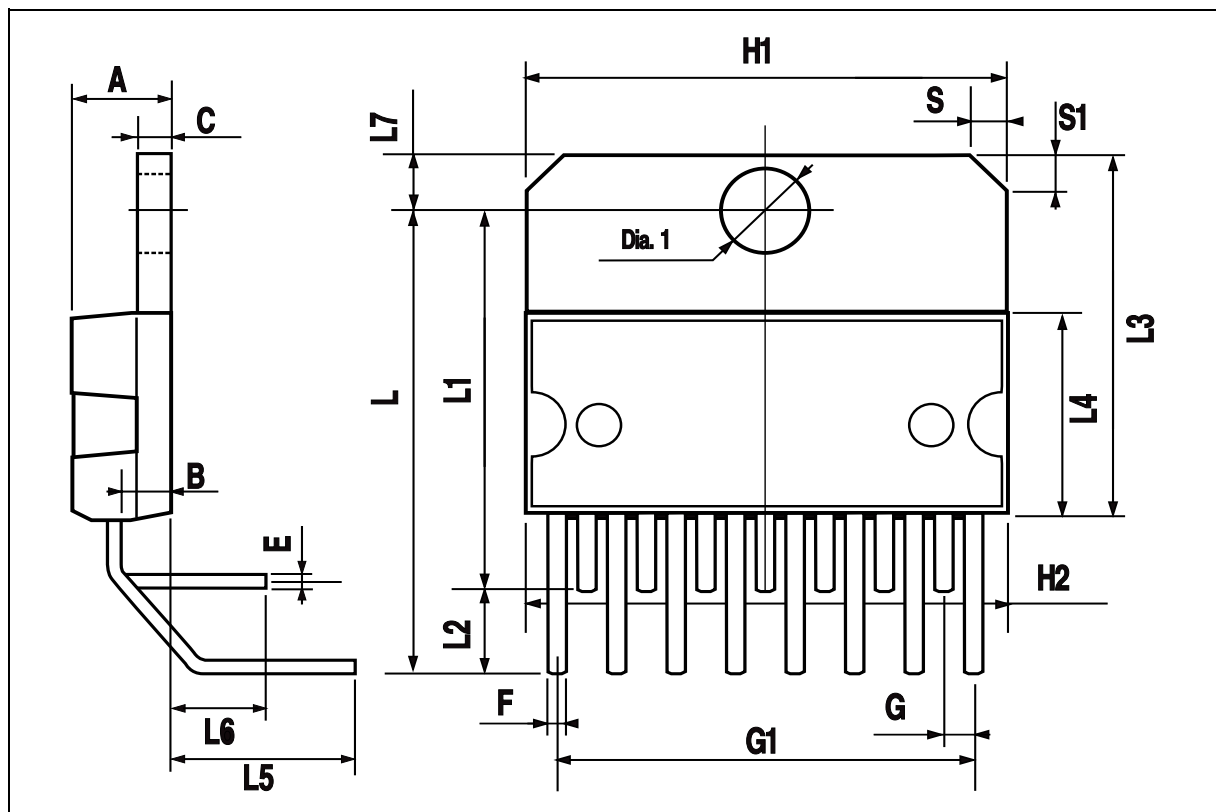


| DIM. | mm    |       |       | inch  |       |       |
|------|-------|-------|-------|-------|-------|-------|
|      | MIN.  | TYP.  | MAX.  | MIN.  | TYP.  | MAX.  |
| A    |       |       | 5     |       |       | 0.197 |
| B    |       |       | 2.65  |       |       | 0.104 |
| C    |       |       | 1.6   |       |       | 0.063 |
| E    | 0.49  |       | 0.55  | 0.019 |       | 0.022 |
| F    | 0.66  |       | 0.75  | 0.026 |       | 0.030 |
| G    | 1.14  | 1.27  | 1.4   | 0.045 | 0.050 | 0.055 |
| G1   | 17.57 | 17.78 | 17.91 | 0.692 | 0.700 | 0.705 |
| H1   | 19.6  |       |       | 0.772 |       |       |
| H2   |       |       | 20.2  |       |       | 0.795 |
| L    |       | 20.57 |       |       | 0.810 |       |
| L1   |       | 18.03 |       |       | 0.710 |       |
| L2   |       | 2.54  |       |       | 0.100 |       |
| L3   | 17.25 | 17.5  | 17.75 | 0.679 | 0.689 | 0.699 |
| L4   | 10.3  | 10.7  | 10.9  | 0.406 | 0.421 | 0.429 |
| L5   |       | 5.28  |       |       | 0.208 |       |
| L6   |       | 2.38  |       |       | 0.094 |       |
| L7   | 2.65  |       | 2.9   | 0.104 |       | 0.114 |
| S    | 1.9   |       | 2.6   | 0.075 |       | 0.102 |
| S1   | 1.9   |       | 2.6   | 0.075 |       | 0.102 |
| Dia1 | 3.65  |       | 3.85  | 0.144 |       | 0.152 |

## OUTLINE AND MECHANICAL DATA



**Multiwatt15 H**

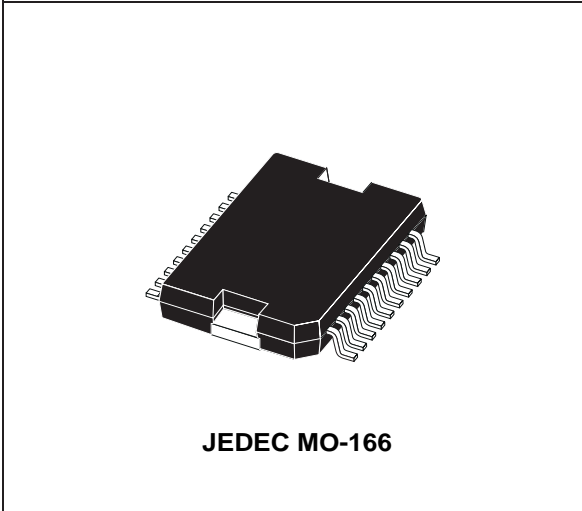




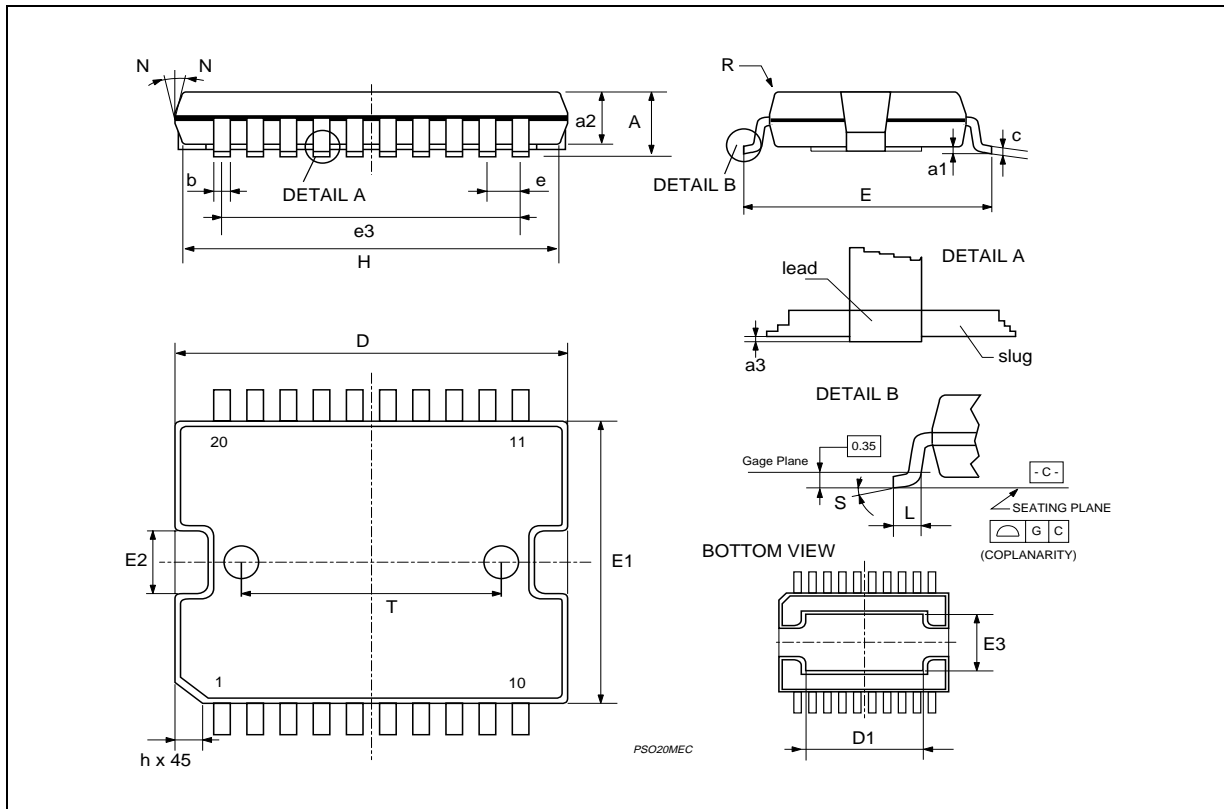
| DIM.   | mm         |       |      | inch  |       |       |
|--------|------------|-------|------|-------|-------|-------|
|        | MIN.       | TYP.  | MAX. | MIN.  | TYP.  | MAX.  |
| A      |            |       | 3.6  |       |       | 0.142 |
| a1     | 0.1        |       | 0.3  | 0.004 |       | 0.012 |
| a2     |            |       | 3.3  |       |       | 0.130 |
| a3     | 0          |       | 0.1  | 0.000 |       | 0.004 |
| b      | 0.4        |       | 0.53 | 0.016 |       | 0.021 |
| c      | 0.23       |       | 0.32 | 0.009 |       | 0.013 |
| D (1)  | 15.8       |       | 16   | 0.622 |       | 0.630 |
| D1     | 9.4        |       | 9.8  | 0.370 |       | 0.386 |
| E      | 13.9       |       | 14.5 | 0.547 |       | 0.570 |
| e      |            | 1.27  |      |       | 0.050 |       |
| e3     |            | 11.43 |      |       | 0.450 |       |
| E1 (1) | 10.9       |       | 11.1 | 0.429 |       | 0.437 |
| E2     |            |       | 2.9  |       |       | 0.114 |
| E3     | 5.8        |       | 6.2  | 0.228 |       | 0.244 |
| G      | 0          |       | 0.1  | 0.000 |       | 0.004 |
| H      | 15.5       |       | 15.9 | 0.610 |       | 0.626 |
| h      |            |       | 1.1  |       |       | 0.043 |
| L      | 0.8        |       | 1.1  | 0.031 |       | 0.043 |
| N      | 10° (max.) |       |      |       |       |       |
| S      | 8° (max.)  |       |      |       |       |       |
| T      |            | 10    |      |       | 0.394 |       |

(1) "D and F" do not include mold flash or protrusions.  
 - Mold flash or protrusions shall not exceed 0.15 mm (0.006").  
 - Critical dimensions: "E", "G" and "a3"

**OUTLINE AND MECHANICAL DATA**



**PowerSO20**



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See page 21.



Full-Featured E Series Multifunction DAQ

| Family   | Bus                | Analog Inputs | Input Resolution | Max Sampling Rate | Input Range    | Analog Outputs | Output Resolution | Output Rate | Output Range | Digital I/O | Counter/Timers | Triggers        |
|----------|--------------------|---------------|------------------|-------------------|----------------|----------------|-------------------|-------------|--------------|-------------|----------------|-----------------|
| NI 6071E | PCI, PXI           | 64 SE/32 DI   | 12 bits          | 1.25 MS/s         | ±0.05 to ±10 V | 2              | 12 bits           | 1 MS/s      | ±10 V        | 8           | 2, 24-bit      | Analog, digital |
| NI 6070E | PCI, PXI, FireWire | 16 SE/8 DI    | 12 bits          | 1.25 MS/s         | ±0.05 to ±10 V | 2              | 12 bits           | 1 MS/s      | ±10 V        | 8           | 2, 24-bit      | Analog, digital |
| NI 6062E | PCMCIA             | 16 SE/8 DI    | 12 bits          | 500 kS/s          | ±0.05 to ±10 V | 2              | 12 bits           | 850 kS/s    | ±10 V        | 8           | 2, 24-bit      | Analog, digital |
| NI 6052E | PCI, PXI, FireWire | 16 SE/8 DI    | 16 bits          | 333 kS/s          | ±0.05 to ±10 V | 2              | 16 bits           | 333 kS/s    | ±10 V        | 8           | 2, 24-bit      | Analog, digital |
| NI 6040E | PCI, PXI           | 16 SE/8 DI    | 12 bits          | 500 kS/s          | ±0.05 to ±10 V | 2              | 12 bits           | 1 MS/s      | ±10 V        | 8           | 2, 24-bit      | Analog, digital |
| NI 6033E | PCI                | 64 SE/32 DI   | 16 bits          | 100 kS/s          | ±0.1 to ±10 V  | 0              | -                 | -           | -            | 8           | 2, 24-bit      | Analog, digital |
| NI 6032E | PCI                | 16 SE/8 DI    | 16 bits          | 100 kS/s          | ±0.1 to ±10 V  | 0              | -                 | -           | -            | 8           | 2, 24-bit      | Analog, digital |
| NI 6031E | PCI, PXI           | 64 SE/32 DI   | 16 bits          | 100 kS/s          | ±0.1 to ±10 V  | 2              | 16 bits           | 100 kS/s    | ±10 V        | 8           | 2, 24-bit      | Analog, digital |
| NI 6030E | PCI, PXI           | 16 SE/8 DI    | 16 bits          | 100 kS/s          | ±0.1 to ±10 V  | 2              | 16 bits           | 100 kS/s    | ±10 V        | 8           | 2, 24-bit      | Analog, digital |
| NI 6020E | NI USB             | 16 SE/8 DI    | 12 bits          | 100 kS/s          | ±0.05 to ±10 V | 2              | 12 bits           | 20 S/s      | ±10 V        | 8           | 2, 24-bit      | Digital         |

Table 1. NI Full-Featured E Series Model Guide (See page 228 for detailed specifications.)

## Overview and Applications

NI Full-Featured E Series devices are the fastest and the most accurate multiplexed data acquisition devices available. They are ideal for applications ranging from continuous high-speed data logging to control applications to high voltage signal or sensor measurements when used with NI signal conditioning. Synchronize the operations of multiple devices using the RTSI bus or PXI trigger bus and easily integrate other hardware such as motion control and machine vision to create an entire measurement and control system.

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## Highly Accurate Hardware Design

NI Full-Featured E Series DAQ devices include the following features and technologies:

**Temperature Drift Protection Circuitry** – Designed with components that minimize the effect of temperature changes on measurements to less than 0.0006% of reading per °C.

**Resolution-Improvement Technologies** – Carefully designed noise floor maximizes resolution.

**Onboard Self-Calibration** – Precise voltage reference included for calibration and measurement accuracy. Self-calibration is completely software controlled, with no potentiometers to adjust.

**NI DAQ-STC** – Timing and control ASIC designed to provide more flexibility, lower power consumption, and a higher immunity to noise and jitter than off-the-shelf counter/timer chips.

Data Acquisition and Signal Conditioning

# Full-Featured E Series Multifunction DAQ

## 12 or 16-Bit, up to 1.25 MS/s, up to 64 Analog Inputs

**NI MITE** – ASIC designed to optimize data transfer for multiple simultaneous operations using bus mastering with three scatter-gather DMA channels for maximum performance of concurrent I/O operations.

**NI PGIA** – Measurement and instrument class amplifier that guarantees settling times at all gains. Typical commercial off-the-shelf amplifier components do not meet the settling time requirements for high-gain measurement applications.

**PFI Lines** – Eight programmable function input (PFI) lines that can be used for software-controlled routing of interboard and intraboard digital and timing signals.

**RTSI or PXI Trigger Bus** – Used to share timing and control signals between devices and synchronize operations.

**RSE Mode** – In addition to differential and nonreferenced single-ended modes, NI full-featured E Series devices offer referenced single-ended (RSE) mode for use with floating signal sources in applications with channel counts higher than eight.

**Onboard Temperature Sensor** – Included for monitoring the operating temperature of the device to ensure that it is operating within the specified range.

**Analog and Digital Triggering** – Only full-featured E Series devices provide the ability to set a trigger based on the level of an analog signal, in addition to the ability to trigger off an edge of a digital signal.

**More Input Ranges** – Up to 15 input ranges for optimal resolution, even for signals smaller than 50 mV.

### High-Performance, Easy-to-Use Driver Software

NI-DAQ is the robust driver software that makes it easy to access the functionality of your data acquisition hardware, whether you are a beginning or advanced user. Helpful features include:

**Automatic Code Generation** – DAQ Assistant is an interactive guide that steps you through configuring, testing, and programming measurement tasks, and generating the necessary code automatically for use in LabVIEW, LabWindows/CVI, or Measurement Studio.

**Cleaner Code Development** – Basic and advanced software functions have been combined into one easy-to-use yet powerful set to help you build cleaner code and move from basic to advanced applications without replacing functions.

**High-Performance Driver Engine** – Software-timed single-point input (typically used in control loops) with NI-DAQ achieves rates of up to 50 kHz. NI-DAQ also delivers maximum I/O system throughput with a multithreaded driver.

**Test Panels** – With NI-DAQ, you can test all of your device functionality before you begin development.

**Scaled Channels** – Easily scale your voltage data into the proper engineering units using the NI-DAQ Measurement Ready virtual channels by choosing from a list of common sensors and signals or creating your own custom scale.

**LabVIEW Integration** – All NI-DAQ functions use the waveform data type, which carries acquired data and timing information directly into more than 400 LabVIEW built-in analysis routines for display of results in engineering units on a graph.

### Worldwide Support and Services

NI provides you with a wealth of resources to help you get your application up and running more quickly, including:

**Technical Support** – Purchase of NI hardware or software gives you access to application engineers all over the world as well as Web resources with more than 3,000 measurement examples and more than 9,000 KnowledgeBase entries. – [ni.com/support](http://ni.com/support)

**NI Factory Installation Services (FIS)** – Software and hardware installed in PXI and PXI/SCXI systems, tested and ready to use – [ni.com/advisor](http://ni.com/advisor)

**Calibration** – Includes NIST-traceable basic calibration certificates, services for ANSI/NCSL-Z540 and periodic calibration – [ni.com/calibration](http://ni.com/calibration)

**Extended Warranty** – Meet project life-cycle requirements and maintain optimal performance in a cost-effective way – [ni.com/services](http://ni.com/services)

**Data Acquisition Training** – Instructor-led courses – [ni.com/training](http://ni.com/training)

**Professional Services** – Feasibility, consulting, and integration through our Alliance Partners – [ni.com/alliance](http://ni.com/alliance)

**For more information on NI services and support, please visit [ni.com/services](http://ni.com/services)**

**For information on device support in NI-DAQ 7, visit [ni.com/dataacquisition](http://ni.com/dataacquisition)**

# Full-Featured E Series Multifunction DAQ

## 12 or 16-Bit, up to 1.25 MS/s, up to 64 Analog Inputs

Full-Featured E Series Multifunction DAQ

| Models                        |             | Full-Featured E Series                 |          |                    |          | Low-Cost E Series  |                              | Basic              |
|-------------------------------|-------------|--|----------|--------------------|----------|--------------------|------------------------------|--------------------|
|                               |             | NI 6030E, NI 6031E, NI 6032E, NI 6033E | NI 6052E | NI 6070E, NI 6071E | NI 6040E | NI 6034E, NI 6036E | NI 6023E, NI 6024E, NI 6025E | PCI-6013, PCI-6014 |
| Measurement Sensitivity* (mV) |             | 0.0023                                 | 0.0025   | 0.009              | 0.008    | 0.0036             | 0.008                        | 0.004              |
| Nominal Range (V)             |             | Absolute Accuracy (mV)                 |          |                    |          |                    |                              |                    |
| Positive FS                   | Negative FS |  |          |                    |          |                    |                              |                    |
| 10                            | -10         | 1.147                                  | 4.747    | 14.369             | 15.373   | 7.56               | 16.504                       | 8.984              |
| 5                             | -5          | 2.077                                  | 0.876    | 5.193              | 5.697    | 1.79               | 5.263                        | 2.003              |
| 2.5                           | -2.5        | —                                      | 1.190    | 3.605              | 3.859    | —                  | —                            | —                  |
| 2                             | -2          | 0.836                                  | —        | —                  | —        | —                  | —                            | —                  |
| 1                             | -1          | 0.422                                  | 0.479    | 1.452              | 1.556    | —                  | —                            | —                  |
| 0.5                           | -0.5        | 0.215                                  | 0.243    | 0.735              | 0.789    | 0.399              | 0.846                        | 0.471              |
| 0.25                          | -0.25       | —                                      | 0.137    | 0.379              | 0.405    | —                  | —                            | —                  |
| 0.2                           | -0.2        | 0.102                                  | —        | —                  | —        | —                  | —                            | —                  |
| 0.1                           | -0.1        | 0.061                                  | 0.064    | 0.163              | 0.176    | —                  | —                            | —                  |
| 0.05                          | -0.05       | —                                      | 0.035    | 0.091              | 0.100    | 0.0611             | 0.106                        | 0.069              |
| 10                            | 0           | 0.976                                  | 1.232    | 6.765              | 7.269    | —                  | —                            | —                  |
| 5                             | 0           | 1.992                                  | 2.119    | 5.391              | 5.645    | —                  | —                            | —                  |
| 2                             | 0           | 0.802                                  | 0.850    | 2.167              | 2.271    | —                  | —                            | —                  |
| 1                             | 0           | 0.405                                  | 0.428    | 1.092              | 1.146    | —                  | —                            | —                  |
| 0.5                           | 0           | 0.207                                  | 0.242    | 0.558              | 0.583    | —                  | —                            | —                  |
| 0.2                           | 0           | 0.098                                  | 0.111    | 0.235              | 0.247    | —                  | —                            | —                  |
| 0.1                           | 0           | 0.059                                  | 0.059    | 0.127              | 0.135    | —                  | —                            | —                  |

Note: Accuracies are valid for measurements following an internal calibration. Measurement accuracies are listed for operational temperatures within ±1 °C of internal calibration temperature and ±10 °C of external or factory-calibration temperature. One-year calibration interval recommended. The Absolute Accuracy at Full Scale calculations were performed for a maximum range input voltage (for example, 10 V for the ±10 V range) after one year, assuming 100 pt averaging of data.\*Smallest detectable voltage change in the input signal at the smallest input range.

Table 2. E Series Analog Input Absolute Accuracy Specifications

| Models            |             | Full-Featured E Series                 |          |                    |          | Low-Cost E Series |                      | Basic            |
|-------------------|-------------|--|----------|--------------------|----------|-------------------|----------------------|------------------|
|                   |             | NI 6030E, NI 6031E, NI 6032E, NI 6033E | NI 6052E | NI 6070E, NI 6071E | NI 6040E | PCI-6036E         | PCI-6024E, NI 6025E, | NI 6013, NI 6014 |
| Nominal Range (V) |             | Absolute Accuracy (mV)                 |          |                    |          |                   |                      |                  |
| Positive FS       | Negative FS |  |          |                    |          |                   |                      |                  |
| 10                | -10         | 1.43                                   | 1.405    | 8.127              | 8.127    | 2.417             | 8.127                | 3.835            |
| 10                | 0           | 1.201                                  | 1.176    | 5.685              | 5.685    | —                 | —                    | —                |

Table 3. E Series Analog Output Absolute Accuracy Specifications

### Recommended Accessories

Signal conditioning is required for sensor measurements or voltage inputs greater than 10 V. National Instruments SCXI is a versatile, high-performance signal conditioning platform, intended for high-channel-count applications. NI SCC products provide portable, flexible signal conditioning options on a per-channel basis. Both signal conditioning platforms are designed to increase the performance and reliability of your DAQ System, and are up to 10X more accurate than terminal blocks (please visit [ni.com/sigcon](http://ni.com/sigcon) for more details). Refer to the table below for more information:

| Sensor/Signals (>10 V) |                                    |                     |      |
|------------------------|------------------------------------|---------------------|------|
| System Description     | DAQ Device                         | Signal Conditioning | Page |
| High performance       | PCI-60xxE, PXI-60xxE, DAQPad-60xxE | SCXI                | 270  |
| Low-cost, portable     | PCI-60xxE, PXI-60xxE, DAQPad-60xxE | SCC                 | 251  |

| Signals (<10 V) <sup>1</sup> |                                  |                |            |      |
|------------------------------|----------------------------------|----------------|------------|------|
| System Description           | DAQ Device                       | Terminal Block | Cable      | Page |
| Shielded                     | PCI-60xxE/DAQPad-60xxE           | SCB-68         | SH6868-EP  | 214  |
| Shielded                     | PXI-60xxE                        | TB-2705        | SH6868-EP  | 214  |
| Shielded                     | PCI-6071E/PCI-6033E/PCI-6031E    | SCB-100        | SH100100   | 214  |
| Shielded                     | PXI-6071E/PXI-6031E              | Two TBX-68s    | SH1006868  | 214  |
| Shielded                     | DAQPad-60xxE                     | SCB-68         | SHC6868-EP | 214  |
| Low-Cost                     | PCI-60xxE/PXI-60xxE/DAQPad-60xxE | CB-68LP        | R6868      | 214  |
| Low-Cost                     | DAQCard-60xxE                    | CB-68LP        | RC6868     | 214  |

<sup>1</sup>Terminal Blocks do not provide signal conditioning (ie. filtering, amplification, isolation, etc.), which may be necessary to increase the accuracy of your measurements.

Table 4. Recommended Accessories

### Ordering Information

|                                    |                |
|------------------------------------|----------------|
| NI PXI-6071E .....                 | 777676-01      |
| NI PCI-6071E .....                 | 777515-01      |
| NI PXI-6070E .....                 | 777060-01      |
| NI PCI-6070E .....                 | 777305-01      |
| NI DAQPad-6070E for FireWire ..... | (See page 207) |
| NI DAQCard-6062E .....             | (See page 207) |
| NI PXI-6052E .....                 | 777962-01      |
| NI PCI-6052E .....                 | 777745-01      |
| NI DAQPad-6052E for FireWire ..... | (See page 207) |
| NI PXI-6040E .....                 | 777484-01      |
| NI PCI-6040E .....                 | 777383-01      |
| NI PCI-6033E .....                 | 777516-01      |
| NI PCI-6032E .....                 | 777422-01      |
| NI PXI-6031E .....                 | 777636-01      |
| NI PCI-6031E .....                 | 777514-01      |
| NI PXI-6030E .....                 | 777555-01      |
| NI PCI-6030E .....                 | 777384-01      |
| NI DAQPad-6020E for USB .....      | (See page 207) |

Includes NI-DAQ driver software and calibration certificate.

For more information on warranty and value-added services, see page 20.

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Data Acquisition and Signal Conditioning

# 16-Bit E Series Multifunction DAQ Specifications

## Specifications – NI 6052E and NI 603xE

These specifications are typical for 25 °C unless otherwise noted.

### Analog Input

Accuracy specifications ..... See page 228.

### Input Characteristics

|   | Number of Channels   |
|---|--|
| 6052E<br>6030E<br>6032E<br>6034E<br>6036E | 16 single-ended or 8 differential (software selectable per channel)  |
| 6031E<br>6033E                            | 64 single-ended or 32 differential (software-selectable per channel) |

Resolution..... 16 bits, 1 in 65,536

|                                  | Maximum Sampling Rate |
|----------------------------------|-----------------------|
| 6052E                            | 333 kS/s              |
| 6034E<br>6036E                   | 200 kS/s              |
| 6030E<br>6031E<br>6032E<br>6033E | 100 kS/s              |

Input signal ranges

| Device | Range Software Selectable | Bipolar Input Range | Unipolar Input Range |           |
|--------|---------------------------|---------------------|----------------------|-----------|
| 6052E  | 20 V                      | ±10 V               | –                    |           |
|        | 10 V                      | ±5 V                | 0 to 10 V            |           |
|        | 5 V                       | ±2.5 V              | 0 to 5 V             |           |
|        | 2 V                       | ±1 V                | 0 to 2 V             |           |
|        | 1 V                       | ±500 mV             | 0 to 1 V             |           |
|        | 500 mV                    | ±250 mV             | 0 to 500 mV          |           |
|        | 200 mV                    | ±100 mV             | 0 to 200 mV          |           |
|        | 100 mV                    | ±50 mV              | 0 to 100 mV          |           |
|        | 6030E                     | 20 V                | ±10 V                | –         |
|        |                           | 10 V                | ±5 V                 | 0 to 10 V |
| 5 V    |                           | –                   | 0 to 5 V             |           |
| 4 V    |                           | ±2 V                | –                    |           |
| 2 V    |                           | ±1 V                | 0 to 2 V             |           |
| 1 V    |                           | ±500 mV             | 0 to 1 V             |           |
| 500 mV |                           | –                   | 0 to 500 mV          |           |
| 400 mV |                           | ±200 mV             | –                    |           |
| 200 mV |                           | ±100 mV             | 0 to 200 mV          |           |
| 100 mV |                           | –                   | 0 to 100 mV          |           |
| 6034E  | 20 V                      | ±10 V               | –                    |           |
|        | 10 V                      | ±5 V                | –                    |           |
|        | 1 V                       | ±500 mV             | –                    |           |
| 6036E  | 10 V                      | ±5 V                | –                    |           |
|        | 1 V                       | ±500 mV             | –                    |           |
|        | 100 mV                    | ±50 mV              | –                    |           |

Input coupling..... DC

Maximum working voltage (signal + common mode) ..... Each input should remain within ±11 V of ground

Overvoltage protection

Powered on..... ±25 V

Powered off ..... ±15 V

### Inputs Protected

|   |                                |
|---|--------------------------------|
| 6052E<br>6030E<br>6032E<br>6034E<br>6036E | AI<0..15>, AI SENSE            |
| 6031E<br>6033E                            | AI<0..63>, AI SENSE, AI SENSE2 |

FIFO buffer size ..... 512 samples, (1024 samples for DAQCard)

Data transfers

PCI, PXI ..... DMA, interrupts, programmed I/O

DAQCard ..... Interrupts, programmed I/O

DMA modes

PCI, PXI ..... Scatter-gather (single transfer, demand transfer)

Configuration memory size ..... 512 words

### Transfer Characteristics

Relative accuracy (dithered)

| Device                           | Typical   | Maximum |
|----------------------------------|-----------|---------|
| 6052E<br>6034E<br>PCI-6036E      | ±1.5 LSB  | ±3 LSB  |
| 6030E<br>6031E<br>6032E<br>6033E | ±0.75 LSB | ±1 LSB  |
| DAQCard-6036E                    | ±3.0 LSB  | ±6 LSB  |

DNL

| Device                                | Typical  | Maximum    |
|---------------------------------------|----------|------------|
| 6052E<br>603xE (except DAQCard-6036E) | ±0.5 LSB | ±1 LSB     |
| DAQCard-6036E                         | ±1.0 LSB | +4, -2 LSB |

No missing codes

DAQCard 6036E ..... 15 bits, guaranteed

Others ..... 16 bits, guaranteed

### Amplifier Characteristics

Input impedance

| Device         | Normal Powered On              | Powered Off | Overload |
|----------------|--------------------------------|-------------|----------|
| 6052E<br>603xE | 100 GΩ in parallel with 100 pF | 820 Ω       | 820 Ω    |

Input bias and offset current

| Device                           | Bias Current | Offset Current |
|----------------------------------|--------------|----------------|
| 6052E<br>6034E<br>PCI-6036E      | ±200 pA      | ±100 pA        |
| 6030E<br>6031E<br>6032E<br>6033E | ±1 nA        | ±2 nA          |
| DAQCard-6036E                    | ±800 pA      | ±100 pA        |

# 16-Bit E Series Multifunction DAQ Specifications

## Specifications – NI 6052E and NI 603xE (continued)

CMRR, DC to 60 Hz

| Device | Range            | CMRR         |               |
|--------|------------------|--------------|---------------|
|        |                  | Bipolar (dB) | Unipolar (dB) |
| 6052E  | 20 V             | 92           | –             |
|        | 10 V             | 97           | 97            |
|        | 5 V              | 101          | 101           |
|        | 2 V              | 104          | 104           |
|        | 100 mV to 1 V    | 105          | 105           |
| 6030E  | 20 V             | 92           | –             |
| 6031E  | 10 V             | 97           | 92            |
| 6032E  | 5 V              | –            | 97            |
| 6033E  | 4 V              | 101          | –             |
|        | 2 V              | 104          | 101           |
|        | 1 V              | 105          | 104           |
|        | 100 mV to 500 mV | 105          | 105           |
| 6034E  | 20 V             | 85           | –             |
| 6036E  | 10 V             | 85           | –             |
|        | 1 V              | 96           | –             |
|        | 100 mV           | 96           | –             |

## Dynamic Characteristics

Bandwidth

| Device                     | Range      | Small Signal (-3 dB) |
|----------------------------|------------|----------------------|
| 6052E                      | All ranges | 480 kHz              |
| 6030E, 6031E, 6032E, 6033E | All ranges | 255 kHz              |
| 6034E, 6036E               | All ranges | 413 kHz              |

System noise (LSB<sub>rms</sub>, including quantization)

| Device        | Range         | Bipolar | Unipolar |
|---------------|---------------|---------|----------|
| 6052E         | 2 to 20 V     | 0.95    | 0.95     |
|               | 1 V           | 1.1     | 1.1      |
|               | 500 mV        | 1.3     | 1.3      |
|               | 200 mV        | 2.7     | 2.7      |
|               | 100 mV        | 5.0     | 5.0      |
| 6030E         | 2 to 20 V     | 0.6     | 0.8      |
| 6031E         | 1 V           | 0.7     | 0.8      |
| 6032E         | 400 to 500 mV | 1.1     | 1.1      |
| 6033E         | 200 mV        | 2.0     | 2.0      |
|               | 100 mV        | –       | 3.8      |
| 6034E         | 10 to 20 V    | 0.8     | –        |
| PCI-6036E     | 1 V           | 1.0     | –        |
|               | 100 mV        | 6.2     | –        |
| DAQCard-6036E | 10 to 20 V    | 1.5     | –        |

Settling time to full-scale step

| Device        | Range         | Accuracy             |                   |                   |                   |                   |
|---------------|---------------|----------------------|-------------------|-------------------|-------------------|-------------------|
|               |               | ±0.00076% (±0.5 LSB) | ±0.0015% (±1 LSB) | ±0.0031% (±2 LSB) | ±0.0061% (±4 LSB) | ±0.024% (±16 LSB) |
| 6052E         | 2 to 20 V     | –                    | 10 µs max         | 5 µs max          | 4 µs max          | 3 µs max          |
|               | 1 V           | –                    | 15 µs max         | 5 µs max          | 4 µs max          | 3 µs max          |
|               | 200 to 500 mV | –                    | 15 µs max         | 10 µs max         | 4 µs max          | 3 µs max          |
|               | 100 mV        | –                    | 15 µs typical     | 10 µs typical     | 4 µs max          | 3 µs max          |
| 6030E         | All           | 40 µs max            | 20 µs max         | –                 | 10 µs max         | –                 |
| 6032E         | All           | 50 µs max            | 25 µs max         | –                 | 10 µs max         | –                 |
| 6031E         | All           | 50 µs max            | 25 µs max         | –                 | 10 µs max         | –                 |
| 6033E         | All           | 50 µs max            | 25 µs max         | –                 | 10 µs max         | –                 |
| 6034E         | 1 to 20 V     | –                    | –                 | 5 µs max          | –                 | –                 |
| 6036E         | 100 mV        | –                    | –                 | –                 | 5 µs typical      | –                 |
| DAQCard-6036E | 10 V          | –                    | –                 | 5 µs max          | –                 | –                 |

Crosstalk

| Device | Adjacent Channels | All Other Channels |
|--------|-------------------|--------------------|
| 6052E  | -75 dB            | -90 dB             |
| 603xE  |                   |                    |

## Analog Output

### Output Characteristics

| Number of Channels  |                   |
|---------------------|-------------------|
| 6052E               | 2 voltage outputs |
| 6030E               |                   |
| 6031E               |                   |
| 6036E               |                   |
| 6032E, 6033E, 6034E | None              |

| Resolution |                      |
|------------|----------------------|
| 6052E      | 16 bits, 1 in 65,536 |
| 6036E      |                      |
| 6030E      |                      |
| 6031E      |                      |

| Maximum Update Rate |                           |
|---------------------|---------------------------|
| 6052E               | 333 kS/s                  |
| PCI-6036E           | 10 kS/s, system dependent |
| 6030E               | 100 kS/s                  |
| 6031E               |                           |
| DAQCard-6036E       | 1 kS/s, system dependent  |

Type of DAC..... Double buffered, multiplying

| FIFO Buffer Size    |               |
|---------------------|---------------|
| 6052E, 6030E, 6031E | 2,048 samples |
| 6036E               | None          |

Data transfers

PCI, PXI ..... DMA, interrupts, programmed I/O  
DAQCard ..... Interrupts, programmed I/O

DMA modes

PCI, PXI ..... Scatter-gather (single transfer, demand transfer)

### Transfer Characteristics

| Relative Accuracy |                                   |
|-------------------|-----------------------------------|
| 6052E             | ±0.35 LSB typical, ±1 LSB maximum |
| 6030E             | ±0.5 LSB typical, ±1 LSB maximum  |
| 6031E             |                                   |
| 6036E             | ±2 LSB maximum                    |

DNL..... ±1.0 LSB maximum

| Monotonicity |                     |
|--------------|---------------------|
| 6052E        | 16 bits, guaranteed |
| 6036E        |                     |
| 6030E        |                     |
| 6031E        |                     |

### Voltage Output

| Ranges |   |
|--------|---|
| 6052E  | ±10 V, 0 to 10 V, ±EXTREF, 0 to EXTREF; software selectable |
| 6030E  |   |
| 6031E  | ±10 V, 0 to 10 V; software selectable                       |
| 6036E  | ±10 V   |

Output coupling ..... DC

Output impedance ..... 0.1 Ω maximum

Current drive ..... ±5 mA maximum

Protection ..... Short-circuit to ground

| Power-On State |              |
|----------------|--------------|
| 6052E          | 0 V (±20 mV) |
| 6030E          |              |
| 6031E          |              |
| PCI-6036E      | 0 V (±44 mV) |
| DAQCard-6036E  | 0 V (±60 mV) |

# 16-Bit E Series Multifunction DAQ Specifications

## Specifications – NI 6052E and NI 603xE (continued)

External reference input (6052E only)

|                             |                                     |
|-----------------------------|-------------------------------------|
| Range.....                  | ±11 V                               |
| Overvoltage protection..... | ±25 V powered on, ±15 V powered off |
| Input impedance.....        | 10 kΩ                               |
| Bandwidth (-3 dB).....      | 3 kHz                               |
| Slew rate.....              | 0.3 V/μs                            |

### Dynamic Characteristics

Settling time and slew rate

| Device        | Settling Time For Full-Scale Step | Slew Rate |
|---------------|-----------------------------------|-----------|
| 6052E         | 3.5 μs to ±1 LSB accuracy         | 15 V/μs   |
| 6030E         | 10 μs to ±1 LSB accuracy          | 5 V/μs    |
| 6031E         |                                   |           |
| PCI-6036E     | 5 μs to ±1 LSB accuracy           | 15 V/μs   |
| DAQCard-6036E | 5 μs to ±4.5 LSB accuracy         | 5 V/μs    |

### Noise

|               |                                       |
|---------------|---------------------------------------|
| 6052E         | 60 μV <sub>rms</sub> , DC to 1 MHz    |
| 6030E         |                                       |
| 6031E         |                                       |
| PCI-6036E     | 110 μV <sub>rms</sub> , DC to 400 kHz |
| DAQCard-6036E | 160 μV <sub>rms</sub> , DC to 400 kHz |

Glitch energy (at mid-scale transition)

| Device    | Magnitude | Duration |
|-----------|-----------|----------|
| 6052E     | ±10 mV    | 1 μs     |
| PCI-6036E | ±10 mV    | 1 μs     |

### Digital I/O

|                         |                        |
|-------------------------|------------------------|
| Number of channels..... | 8 input/output         |
| Compatibility.....      | 5 V/TTL/CMOS           |
| Power-on state.....     | Input (high impedance) |
| Data transfers.....     | Programmed I/O         |

| Level  | Minimum | Maximum |
|--|---------|---------|
| Input low voltage                                | 0.0 V   | 0.8 V   |
| Input high voltage                               | 2.0 V   | 5.0 V   |
| Output low voltage (I <sub>out</sub> = 5 mA)     | –       | 0.4 V   |
| Output high voltage (I <sub>out</sub> = -3.5 mA) | 4.35 V  | –       |

### Timing I/O

#### General-Purpose Up/Down Counter/Timers

|                                    |  |
|------------------------------------|--|
| Number of channels                 |  |
| Up/down counter/timers.....        | 2  |
| Frequency Scaler.....              | 1  |
| Resolution                         |  |
| Up/down counter/timers.....        | 24 bits  |
| Frequency Scaler.....              | 4 bits   |
| Compatibility.....                 | 5 VTTL/CMOS  |
| Digital logic levels               |  |
| Base clocks available              |  |
| Up/down counter/timers.....        | 20 MHz and 100 kHz   |
| Frequency Scaler.....              | 10 MHz and 100 kHz   |
| Base clock accuracy.....           | ±0.01%   |
| Maximum external source frequency  |  |
| Up/down counter/timers.....        | 20 MHz   |
| External source selections.....    | PFI <0..9>, RTSI <0..6>, analog trigger; software selectable |
| External gate selections.....      | PFI <0..9>, RTSI <0..6>, analog trigger; software selectable |
| Minimum source pulse duration..... | 10 ns, edge-detect mode                                      |
| Minimum gate pulse duration.....   | 10 ns, edge-detect mode                                      |
| Data transfers                     |  |
| PCI/PXI Up/down counter/timer..... | DMA (scatter-gather), interrupts, programmed I/O             |
| DAQCard Up/down counter/timer..... | Interrupts, programmed I/O                                   |
| Frequency Scaler.....              | Programmed I/O   |

## Triggers

### Analog Triggers

|       | Number of Triggers |
|-------|--------------------|
| 6052E | 1                  |
| 6030E |                    |
| 6031E |                    |
| 6032E |                    |
| 6033E |                    |
| 6034E | None               |
| 6036E |                    |

Purpose

|                                     |                                     |
|-------------------------------------|-------------------------------------|
| Analog input.....                   | Start and stop trigger, gate, clock |
| Analog output.....                  | Start trigger, gate, clock          |
| General-purpose counter/timers..... | Source, gate                        |

### Source

|       |                                |
|-------|--------------------------------|
| 6052E | AI<0..15>, PFI 0/AI START TRIG |
| 6030E |                                |
| 6032E |                                |
| 6031E | AI<0..63>, PFI 0/AI START TRIG |
| 6033E |                                |

Level

|   |             |
|---|-------------|
| Internal source, AI<0..15/63>.....        | ±full-scale |
| External source, PFI 0/AI START TRIG..... | ±10 V       |

Slope..... Positive or negative; software-selectable

Resolution..... 12 bits, 1 in 4,096

Hysteresis..... Programmable

Bandwidth (-3 dB)

| Device                             | Internal Source | External Source     |
|------------------------------------|-----------------|---------------------|
|                                    | AI<0..15/63>    | PFI 0/AI START TRIG |
| 6052E                              | 700 kHz         | 700 kHz             |
| PCI-6030E, PCI-6031E, 6032E, 6033E | 255 kHz         | 4 MHz               |
| PXI-6030E, PXI-6031E               | 255 kHz         | 255 kHz             |

Accuracy..... ±1% of full-scale range maximum

### Digital Triggers (all devices)

Purpose

|                                     |                                     |
|-------------------------------------|-------------------------------------|
| Analog input.....                   | Start and stop trigger, gate, clock |
| Analog output.....                  | Start trigger, gate, clock          |
| General-purpose counter/timers..... | Source, gate                        |

Source..... PFI <0..9>, RTSI <0..6>

Compatibility..... 5 VTTL

Response..... Rising or falling edge

Pulse width..... 10 ns minimum



# 16-Bit E Series Multifunction DAQ Specifications

## Specifications – NI 6052E and NI 603xE (continued)

### External Input for Digital or Analog Trigger (PFI 0/AI START TRIG)

(6052E, 6033E, 6032E, 6031E, 6030E only)

|                       |                                 |
|-----------------------|---------------------------------|
| Impedance .....       | 10 k $\Omega$                   |
| Coupling .....        | DC                              |
| Protection            |                                 |
| Digital trigger ..... | -0.5 to V <sub>cc</sub> + 0.5 V |
| Analog trigger        |                                 |
| On/off/disabled ..... | $\pm 35$ V                      |

### Calibration

|                                |                                    |
|--------------------------------|------------------------------------|
| Recommended warm-up time ..... | 15 minutes; 30 minutes for DAQCard |
| Calibration Interval .....     | 1 year                             |
| Onboard calibration reference  |                                    |

#### DC Level

| Device                                  | DC Level                | Notes   |
|---|-------------------------|---|
| 6052E, 6030E,<br>6031E, 6032E,<br>6033E | 5.000 V ( $\pm 1.0$ mV) | Over full operating temperature,<br>actual value stored in EEPROM |
| 6034E, 6036E                            | 5.000 V ( $\pm 3.5$ mV) |   |

#### Temperature Coefficient

| Device                                  | Temperature Coefficient         |
|---|---------------------------------|
| 6052E, 6030E,<br>6031E, 6032E,<br>6033E | $\pm 0.6$ ppm/ $^{\circ}$ C max |
| 6034E, 6036E                            | $\pm 5.0$ ppm/ $^{\circ}$ C max |

#### Long-Term Stability

| Device                                  | Long-Term Stability             |
|---|---------------------------------|
| 6052E, 6030E,<br>6031E, 6032E,<br>6033E | $\pm 6.0$ ppm/ $\sqrt{1000}$ h  |
| 6034E, 6036E                            | $\pm 15.0$ ppm/ $\sqrt{1000}$ h |

### RTSI

|               |   |
|---------------|---|
| Trigger lines |   |
| PCI .....     | 7 |
| DAQPad .....  | 4 |

### PXI Trigger Bus (PXI only)

|                     |   |
|---------------------|---|
| Trigger lines ..... | 6 |
| Star trigger .....  | 1 |

### Bus Interface

|                |                                       |
|----------------|---------------------------------------|
| PCI, PXI ..... | Master, slave                         |
| DAQCard .....  | Slave                                 |
| DAQPad .....   | Master, slave, asynchronous, 400 Mb/s |

### Power Requirements<sup>1</sup>

| Device                        | +5 VDC ( $\pm 5\%$ ) | Power Available at I/O Connector |
|-------------------------------|----------------------|----------------------------------|
| PCI-6052E, PXI-6052E          | 1.3 A                | +4.65 to +5.25 VDC, 1 A          |
| 6030E, 6031E,<br>6032E, 6033E | 1.5 A                | +4.65 to +5.25 VDC, 1 A          |
| 6034E<br>PCI-6036E            | 0.9 A                | +4.65 to +5.25 VDC, 1 A          |
| DAQCard-6036E                 | 300 mA               | +4.65 to +5.25 VDC, 0.75 A       |

DAQPad-6052E ..... 20W @ 9-24 VDC

### Physical<sup>1</sup>

#### Dimensions (not including connectors)<sup>1</sup>

|               |  |
|---------------|--|
| PCI .....     | 17.5 by 10.6 cm (6.9 by 4.2 in.)               |
| PXI .....     | 16.0 by 10.0 cm (6.3 by 3.9 in.)               |
| DAQCard ..... | Type II PC Card                                |
| DAQPad .....  | 30.7 by 25.4 by 4.3 cm (12.1 by 10 by 1.7 in.) |

#### I/O Connectors

| Device  | I/O Connectors  |
|---|---|
| PCI-6052E<br>6030E<br>6032E<br>6034E<br>PCI-6036E | 68-pin male SCSI-II type  |
| 6031E<br>6033E                                    | 100-pin female 0.050 D-type   |
| DAQCard-6036E<br>DAQPad-6052E                     | 68-position VHDCI female<br>68-pin male SCSI-II type, or<br>15 BNCs and 30 removable<br>screw terminals |

### Environment

|                                  |                          |
|----------------------------------|--------------------------|
| Operating temperature            |                          |
| 6052E, 6036E, 6034E .....        | 0 to 55 $^{\circ}$ C     |
| 6030E, 6031E, 6032E, 6033E ..... | 0 to 50 $^{\circ}$ C     |
| Storage temperature .....        | -20 to 70 $^{\circ}$ C   |
| Relative humidity .....          | 10 to 90%, noncondensing |

### Certifications and Compliances

#### CE Mark Compliance $\text{CE}$

<sup>1</sup>See page 134 for RT Series device power requirements and physical parameters.



# Multifunction DAQ Cable and Accessory Selection Guides

## NI Cable Design Advantages

The SH68-68-EP cable is the most commonly used E Series and S Series cable. The cable is designed to work specifically with the NI Multifunction DAQ devices to preserve signal integrity through these technologies:

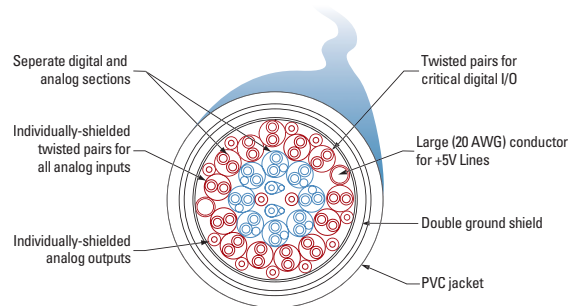


Figure 1. SH68-68-EP Cable

A variety of cabling and accessory options are available for your needs. Use the following tables to choose the most appropriate cables and accessories. To determine which Multifunction DAQ device best fits your needs, please see page 189.



Figure 2. NI offers a wide variety of cable and accessory options, such as the SH68-68-EP cable and the BNC-2110 terminal block.

| Platform                    | Shielding  | Connect to ...                               | Cable                                    | Adapter     | Accessory                                       |
|-----------------------------|------------|--|--|-------------|---|
| <b>PCI/PXI/USB/FireWire</b> |            |  |  |             |   |
|                             | Shielded   | SCC portable signal conditioning per channel | SH68-68-EP                               | –           | SC-2345 and modules, page 251                   |
|                             | Shielded   | SCXI high-performance signal conditioning    | SCXI-1349                                | –           | SCXI Chassis and Modules, page 270              |
|                             | Shielded   | Screw terminals <sup>1</sup>                 | SH68-68-EP or SH68-68R1-EP               | –           | SCB-68  |
|                             | Shielded   | BNC terminal block                           | SH68-68-EP                               | –           | BNC-2110, BNC-2120, BNC-2090                    |
|                             | Shielded   | 50-pin connector                             | SH6850                                   | –           | CB50, custom or 3rd party                       |
|                             | Shielded   | Configurable connectivity box                | SH68-68-EP                               | –           | CA-1000, page 351                               |
|                             | Unshielded | Screw terminals <sup>1</sup>                 | R6868                                    | –           | TBX-68, CB-68LP, CB-68LPR, DAQ signal accessory |
|                             | Unshielded | 50-pin connector                             | R6850                                    | –           | CB50, custom or 3rd party                       |
| <b>PXI only</b>             |            |  |  |             |   |
|                             | Shielded   | Front-mounted screw terminals                | N/A                                      | –           | TB-2705   |
| <b>PCMCIA</b>               |            |  |  |             |   |
|                             | Shielded   | Screw terminals <sup>1</sup>                 | SHC68-68-EP or SHC68U-68-EP <sup>2</sup> | –           | SCB-68, CA-1000                                 |
|                             | Shielded   | 50-pin connector                             | SHC68-68-EP or SHC68U-68-EP <sup>2</sup> | 68M-50F MIO | CB50, custom or 3rd party                       |
|                             | Unshielded | Screw terminals <sup>1</sup>                 | RC68-68                                  | –           | TBX-68, CB-68LP, CB-68LPR, DAQ signal accessory |
|                             | Unshielded | 50-pin connector                             | RC68-68                                  | 68M-50F MIO | CB50, custom or 3rd party                       |

<sup>1</sup>Unshielded cables can connect to shielded accessories and vice-versa. <sup>2</sup>In adjacent PCMCIA slots, both cables types are required because the same cable would cause mechanical hindrance.

Table 1. Cable Connection Specifications for 16-Channel E Series Devices and Basic Multifunction DAQ (except NI 6025E, which is on the next page)

# Multifunction DAQ Cable and Accessory Selection Guides

|                  |    |    |                  |
|------------------|----|----|------------------|
| AI 0-            | 34 | 68 | AI 0+            |
| AI 1+            | 33 | 67 | AI 0 GND         |
| AI 1 GND         | 32 | 66 | AI 1-            |
| AI 2-            | 31 | 65 | AI 2+            |
| AI 3+            | 30 | 64 | AI 2 GND         |
| AI 3 GND         | 29 | 63 | AI 3-            |
| NC               | 28 | 62 | NC               |
| NC               | 27 | 61 | NC               |
| NC               | 26 | 60 | NC               |
| NC               | 25 | 59 | NC               |
| NC               | 24 | 58 | NC               |
| NC               | 23 | 57 | NC               |
| AO 0             | 22 | 56 | NC               |
| AO 0             | 21 | 55 | AO GND           |
| EXT REF          | 20 | 54 | AO GND           |
| P0.4             | 19 | 53 | D GND            |
| D GND            | 18 | 52 | P0.0             |
| P0.1             | 17 | 51 | P0.5             |
| P0.6             | 16 | 50 | D GND            |
| D GND            | 15 | 49 | P0.2             |
| +5 V             | 14 | 48 | P0.7             |
| D GND            | 13 | 47 | P0.3             |
| D GND            | 12 | 46 | AI HOLD          |
| PFI 0/AI START   | 11 | 45 | EXT STROBE       |
| PFI 1/REF TRIG   | 10 | 44 | D GND            |
| D GND            | 9  | 43 | PFI 2/AI CONV    |
| +5 V             | 8  | 42 | PFI 3/CTR 1 SRC  |
| D GND            | 7  | 41 | PFI 4/CTR 1 GATE |
| PFI 5/AO SAMP    | 6  | 40 | CTR 1 OUT        |
| PFI 6/AO START   | 5  | 39 | D GND            |
| D GND            | 4  | 38 | PFI 7/AI SAMP    |
| PFI 9/CTR 0 GATE | 3  | 37 | PFI 8/CTR 0 SRC  |
| CTR 0 OUT        | 2  | 36 | D GND            |
| F OUT            | 1  | 35 | D GND            |

Figure 2. S Series Devices Connector

<sup>1</sup>No connects for boards that do not support AO or use an external reference with the SH1006868 cable.

|                      |    |    |                     |
|----------------------|----|----|---------------------|
| AI 8                 | 34 | 68 | AI 0                |
| AI 1                 | 33 | 67 | AI GND              |
| AI GND               | 32 | 66 | AI 9                |
| AI 10                | 31 | 65 | AI 2                |
| AI 3                 | 30 | 64 | AI GND              |
| AI GND               | 29 | 63 | AI 11               |
| AI 4                 | 28 | 62 | AI SENSE            |
| AI GND               | 27 | 61 | AI 12               |
| ACH13                | 26 | 60 | AI 5                |
| ACH6                 | 25 | 59 | AI GND              |
| AIGND                | 24 | 58 | AI 14               |
| ACH15                | 23 | 57 | AI 7                |
| AO 0 <sup>1</sup>    | 22 | 56 | AI GND              |
| AO 1 <sup>1</sup>    | 21 | 55 | AO GND              |
| EXT REF <sup>1</sup> | 20 | 54 | AO GND              |
| P0.4                 | 19 | 53 | D GND               |
| D GND                | 18 | 52 | P0.0                |
| P0.1                 | 17 | 51 | P0.5                |
| P0.6                 | 16 | 50 | D GND               |
| D GND                | 15 | 49 | P0.2                |
| +5 V                 | 14 | 48 | P0.7                |
| D GND                | 13 | 47 | P0.3                |
| D GND                | 12 | 46 | AI HOLD             |
| PFI 0/AI START       | 11 | 45 | EXT STROBE          |
| PFI 1/REF TRIG       | 10 | 44 | D GND               |
| D GND                | 9  | 43 | PFI 2/AI CONV       |
| +5 V                 | 8  | 42 | PFI 3/AI CTR 1 SRC  |
| D GND                | 7  | 41 | PFI 4/AI CTR 1 GATE |
| PFI 5/AO SAMP        | 6  | 40 | CTR 1 OUT           |
| PFI 6/AO START       | 5  | 39 | D GND               |
| D GND                | 4  | 38 | PFI 7/AI SAMP       |
| PFI 9/CTR 0 GATE     | 3  | 37 | PFI 8/CTR 0 SRC     |
| CTR 0 OUT            | 2  | 36 | D GND               |
| F OUT                | 1  | 35 | D GND               |

Figure 3. I/O Connector for 16-Channel E Series and Basic Multifunction DAQ Devices, except NI 6025E

|                  |    |     |            |
|------------------|----|-----|------------|
| AI GND           | 1  | 51  | AI 16      |
| AI GND           | 2  | 52  | AI 24      |
| AI 0             | 3  | 53  | AI 17      |
| AI 8             | 4  | 54  | AI 25      |
| AI 1             | 5  | 55  | AI 18      |
| AI 9             | 6  | 56  | AI 26      |
| AI 2             | 7  | 57  | AI 19      |
| AI 10            | 8  | 58  | AI 27      |
| AI 3             | 9  | 59  | AI 20      |
| AI 11            | 10 | 60  | AI 28      |
| AI 4             | 11 | 61  | AI 21      |
| AI 12            | 12 | 62  | AI 29      |
| AI 5             | 13 | 63  | AI 22      |
| AI 13            | 14 | 64  | AI 30      |
| AI 6             | 15 | 65  | AI 23      |
| AI 14            | 16 | 66  | AI 31      |
| AI 7             | 17 | 67  | AI 32      |
| AI 15            | 18 | 68  | AI 40      |
| AI SENSE         | 19 | 69  | AI 33      |
| AO 0             | 20 | 70  | AI 41      |
| AO 1             | 21 | 71  | AI 34      |
| EXT REF          | 22 | 72  | AI 42      |
| AO GND           | 23 | 73  | AI 35      |
| D GND            | 24 | 74  | AI 43      |
| P0.0             | 25 | 75  | AI SENSE 2 |
| P0.4             | 26 | 76  | AI GND     |
| P0.1             | 27 | 77  | AI 36      |
| P0.5             | 28 | 78  | AI 44      |
| P0.2             | 29 | 79  | AI 37      |
| P0.6             | 30 | 80  | AI 45      |
| P0.3             | 31 | 81  | AI 38      |
| P0.7             | 32 | 82  | AI 46      |
| D GND            | 33 | 83  | AI 39      |
| +5 V             | 34 | 84  | AI 47      |
| +5 V             | 35 | 85  | AI 48      |
| AI HOLD          | 36 | 86  | AI 56      |
| EXT STROBE       | 37 | 87  | AI 49      |
| PFI 0/AI START   | 38 | 88  | AI 57      |
| PFI 1/REF TRIG   | 39 | 89  | AI 50      |
| PFI 2/AI CONV    | 40 | 90  | AI 58      |
| PFI 3/CTR 1 SRC  | 41 | 91  | AI 51      |
| PFI 4/CTR 1 GATE | 42 | 92  | AI 59      |
| CTR 1 OUT        | 43 | 93  | AI 52      |
| PFI 5/AO SAMP    | 44 | 94  | AI 60      |
| PFI 6/AO START   | 45 | 95  | AI 53      |
| PFI 7/AI SAMP    | 46 | 96  | AI 61      |
| PFI 8/CTR 0 SRC  | 47 | 97  | AI 54      |
| PFI 9/CTR 0 GATE | 48 | 98  | AI 62      |
| CTR 0 OUT        | 49 | 99  | AI 55      |
| F OUT            | 50 | 100 | AI 63      |

Figure 4. I/O Connector for 64-Channel E Series Devices

|                  |    |     |      |
|------------------|----|-----|------|
| AI GND           | 1  | 51  | P2.7 |
| AI GND           | 2  | 52  | GND  |
| AI 0             | 3  | 53  | P2.6 |
| AI 8             | 4  | 54  | GND  |
| AI 1             | 5  | 55  | P2.5 |
| AI 9             | 6  | 56  | GND  |
| AI 2             | 7  | 57  | P2.4 |
| AI 10            | 8  | 58  | GND  |
| AI 3             | 9  | 59  | P2.3 |
| AI 11            | 10 | 60  | GND  |
| AI 4             | 11 | 61  | P2.2 |
| AI 12            | 12 | 62  | GND  |
| AI 5             | 13 | 63  | P2.1 |
| AI 13            | 14 | 64  | GND  |
| AI 6             | 15 | 65  | P2.0 |
| AI 14            | 16 | 66  | GND  |
| AI 7             | 17 | 67  | P1.7 |
| AI 15            | 18 | 68  | GND  |
| AI SENSE         | 19 | 69  | P1.6 |
| AO 0             | 20 | 70  | GND  |
| AO 1             | 21 | 71  | P1.5 |
| NC               | 22 | 72  | GND  |
| AO GND           | 23 | 73  | P1.4 |
| D GND            | 24 | 74  | GND  |
| P0.0             | 25 | 75  | P1.3 |
| P0.4             | 26 | 76  | GND  |
| P0.1             | 27 | 77  | P1.2 |
| P0.5             | 28 | 78  | GND  |
| P0.2             | 29 | 79  | P1.1 |
| P0.6             | 30 | 80  | GND  |
| P0.3             | 31 | 81  | P1.0 |
| P0.7             | 32 | 82  | GND  |
| D GND            | 33 | 83  | P0.7 |
| +5 V             | 34 | 84  | GND  |
| +5 V             | 35 | 85  | P0.6 |
| AI HOLD          | 36 | 86  | GND  |
| EXT STROBE       | 37 | 87  | P0.5 |
| PFI 0/AI START   | 38 | 88  | GND  |
| PFI 1/REF TRIG   | 39 | 89  | P0.4 |
| PFI 2/AI CONV    | 40 | 90  | GND  |
| PFI 3/CTR 1 SRC  | 41 | 91  | P0.3 |
| PFI 4/CTR 1 GATE | 42 | 92  | GND  |
| CTR 1 OUT        | 43 | 93  | P0.2 |
| PFI 5/AO SAMP    | 44 | 94  | GND  |
| PFI 6/AO START   | 45 | 95  | P0.1 |
| PFI 7/AI SAMP    | 46 | 96  | GND  |
| PFI 8/CTR 0 SRC  | 47 | 97  | P0.0 |
| PFI 9/CTR 0 GATE | 48 | 98  | GND  |
| CTR 0 OUT        | 49 | 99  | +5 V |
| F OUT            | 50 | 100 | GND  |

Figure 5. I/O Connector for the NI 6025E Device

## E Series Devices (NI 6031E, NI 6033E, NI 6071E, NI 6025E)

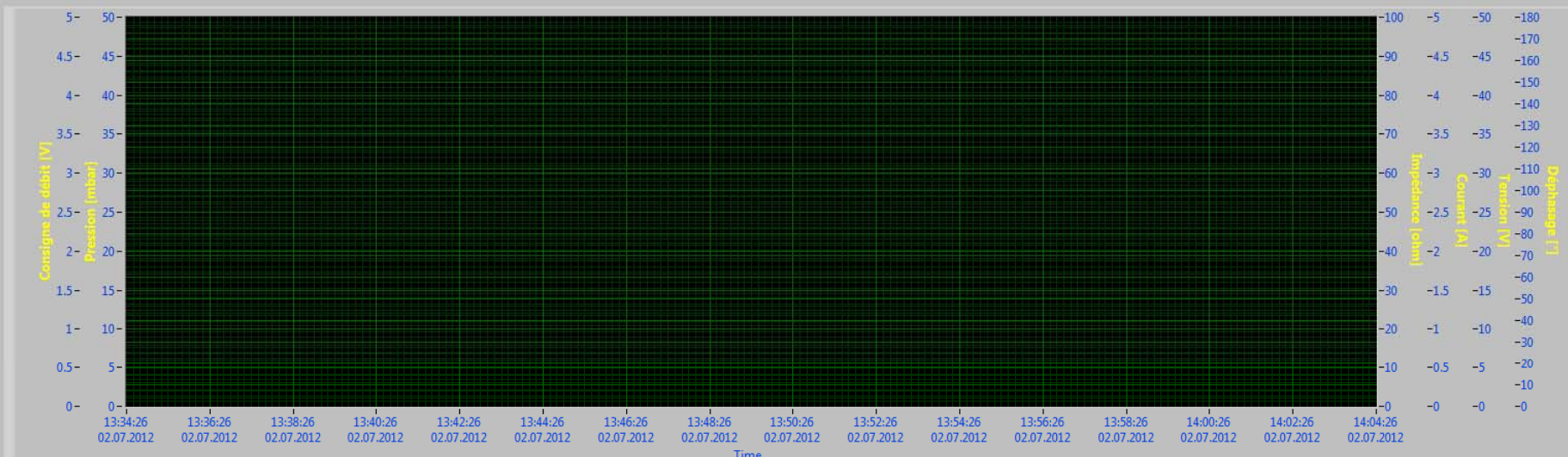
| Platform | Shielding  | Connect to ...               | Cable     | Cable Leg | Adapter          | Accessory                                       |
|----------|------------|------------------------------|-----------|-----------|------------------|---|
| PCI, PXI | Shielded   | Screw terminals              | SH100100  | –         | –                | SCB-100   |
|          | Shielded   | Screw terminals              | SH1006868 | MIO:      | –                | SCB-68  |
|          | Shielded   |                              | SH1006868 | Extended: | –                | SCB-68  |
|          | Shielded   | Screw terminals <sup>1</sup> | SH1006868 | MIO:      | –                | TBX-68, CB-68LP, CB-68LPR, DAQ signal accessory |
|          | Shielded   | Screw terminals <sup>1</sup> | SH1006868 | Extended: | –                | TBX-68, CB-68LP, CB-68LPR                       |
|          | Shielded   | BNC terminal block           | SH1006868 | MIO:      | –                | BNC-2110, BNC-2120, BNC-2090                    |
|          | Shielded   |                              | SH1006868 | Extended: | –                | BNC-2115  |
|          | Shielded   | 50-pin connectors            | SH1006868 | MIO:      | 68M-50F MIO      | Custom or 3rd party                             |
|          | Shielded   |                              | SH1006868 | Extended: | 68M-50F Extended | Custom or 3rd party                             |
|          | Unshielded | 50-pin connector             | R1005050  | MIO:      | –                | Custom or 3rd party                             |
|          | Unshielded |                              | R1005050  | Extended: | –                | Custom or 3rd party                             |

<sup>1</sup>Shielded cable with unshielded accessories

Table 2. Cable Connection Specifications for 64-Channel E Series Devices and the NI 6025E

|          |                  | Canal             | Dénomination                      | Description  | Signal |
|----------|------------------|-------------------|-----------------------------------|--|--------|
| USB-NI   | <b>Digital</b>   |                   |                                   |  |        |
|          |                  | DO.0              | Gmain                             | Connecté sur le relais Nr.1 pour alimentation 0/24V  | 0 ou 1 |
|          |                  | DO.1              | GV1                               | Connecté sur le relais Nr.2 pour alimentation 0/24V  | 0 ou 1 |
|          |                  | DO.2              | GV2                               | Connecté sur le relais Nr.3 pour alimentation 0/24V  | 0 ou 1 |
|          |                  | DO.3              | GV3                               | Connecté sur le relais Nr.4 pour alimentation 0/24V  | 0 ou 1 |
|          |                  | DO.4              | GV4                               | Connecté sur le relais Nr.5 pour alimentation 0/24V  | 0 ou 1 |
|          |                  | DO.5              | Pompe extérieure                  | Connecté sur le relais Nr.6 pour alimentation 0/24V  | 0 ou 1 |
|          |                  | DO.6              | Vanne intérieure                  | Connecté sur le relais Nr.7 pour alimentation 0/24V  | 0 ou 1 |
|          |                  | DI/DO.7           | Pompe intérieure                  | Connecté sur le relais Nr.8 pour alimentation 0/24V  | 0 ou 1 |
|          |                  | DI/DO.8           | Vanne extérieure                  | Connecté sur le relais Nr.9 pour alimentation 0/24V  | 0 ou 1 |
|          |                  | DI/DO.9           | Lancer Installation               | Connecté sur le relais Nr.10 pour alimentation 0/24V | 0 ou 1 |
|          |                  | <b>Analog IN</b>  |                                   |  |        |
|          |                  | AI.0              | Pext                              | Pression de la chambre extérieure                    | 0-10V  |
|          |                  | AI.1              | Pint                              | Pression de la chambre intérieure                    | 0-10V  |
|          |                  | AI.2              | MFC 1                             | Mesure du Débit                                      | 0-5V   |
|          |                  | AI.3              | MFC 2                             | Mesure du Débit                                      | 0-5V   |
|          |                  | <b>Analog OUT</b> |                                   |  |        |
|          |                  | AO.0              | MFC 1                             | Consigne de Débit                                    | 0-5V   |
|          |                  | AO.1              | MFC 2                             | Consigne de Débit                                    | 0-5V   |
| NI-PCI 1 | <b>Analog IN</b> |                   |                                   |  |        |
|          |                  | AI.0              | MFC 3                             | Mesure du Débit                                      | 0-5V   |
|          |                  | AI.1              | MFC 4                             | Mesure du Débit                                      | 0-5V   |
|          |                  | <b>Analog OUT</b> |                                   |  |        |
|          |                  | AO.0              | MFC 3                             | Consigne de Débit                                    | 0-5V   |
|          | AO.1             | MFC 4             | Consigne de Débit                 | 0-5V   |        |
| NI-PCI 2 | <b>Digital</b>   |                   |                                   |  |        |
|          |                  | D0.0              | Sens                              | Choix du sens moteur 1                               | 0 ou 1 |
|          |                  | D0.1              | Enable                            | Enable Moteur 1                                      | 0 ou 1 |
|          |                  | D0.2              | Enable                            | Enable VCO 1   | 0 ou 1 |
|          |                  | D0.3              | Sens                              | Choix sens Moteur 2                                  | 0 ou 1 |
|          |                  | D0.4              | Enable                            | Enable Moteur 2                                      | 0 ou 1 |
|          |                  | D0.5              |                                   | Enable VCO 2   | 0 ou 1 |
|          |                  | <b>Analog OUT</b> |                                   |  |        |
|          | AO.0             | VCO 1             | Tension pour varier fréquence VCO | 0-5V   |        |
|          | AO.1             | VCO 2             | Tension pour varier fréquence VCO | 0-5V   |        |

## Graphique Réacteur à Plasma



Variable\_List

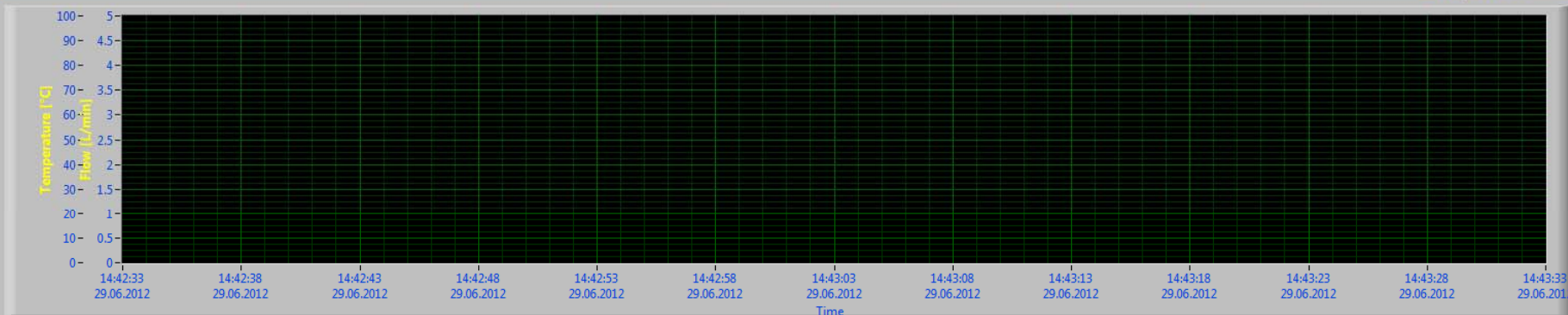
Real\_Time\_Value

Débit MFC 4

- \\.\Data\Compteur moteur du bas
- \\.\Data\Courant
- \\.\Data\Débit MFC 2
- \\.\Data\Débit MFC 3
- \\.\Data\Débit MFC 4
- \\.\Data\Débit MFC1
- \\.\Data\Déphasage
- \\.\Data\Impédance
- \\.\Data\Pression extérieure
- \\.\Data\Pression intérieure
- \\.\Data\Tension

| Date | Cursor1 | Cursor2 | Actual Value |
|------|---------|---------|--------------|
| Time |         |         |              |
|      |         |         |              |
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|      |         |         |              |

# Historique Réacteur à Plasma



Historical Display Length

1 minute

Historical\_Value

Variable\_List\_Historical

- \\.\Data\Compteur moteur du bas
- \\.\Data\Courant
- \\.\Data\Débit MFC 2
- \\.\Data\Débit MFC 3
- \\.\Data\Débit MFC 4
- \\.\Data\Débit MFC1
- \\.\Data\Déphasage
- \\.\Data\Impédance
- \\.\Data\Pression extérieure
- \\.\Data\Pression intérieure
- \\.\Data\Tension

| Date    | Cursor1 | Cursor2 | Actual Value |
|---------|---------|---------|--------------|
| Time    |         |         |              |
| Courant |         |         |              |
|         |         |         |              |
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|         |         |         |              |
|         |         |         |              |

Courant

Output data file (use dialog)

C:\Data\_PAC\_TestBench.xls

Intervalle\_sauvegarde [s]

10

Export Selected Traces to Excel File

OR

Export ALLTraces to Excel File

Display Historical Data