Lehigh University
Lehigh Preserve

ATLSS Reports | Civil and Environmental Engineering

6-1-1996

ATLSS Strain Gage Conditioners: Operation, Specifications, and Use

Christopher C. Higgins

Follow this and additional works at: http://preserve.lehigh.edu/engr-civil-environmental-atlss-reports

Recommended Citation
Higgins, Christopher C., "ATLSS Strain Gage Conditioners: Operation, Specifications, and Use" (1996). ATLSS Reports. ATLSS report number 96-11:.
http://preserve.lehigh.edu/engr-civil-environmental-atlss-reports/218

This Technical Report is brought to you for free and open access by the Civil and Environmental Engineering at Lehigh Preserve. It has been accepted for inclusion in ATLSS Reports by an authorized administrator of Lehigh Preserve. For more information, please contact preserve@lehigh.edu.

ADVANCED TECHNOLOGY FOR
LARGE
STRUCTURAL SYSTEMS

Lehigh University

ATLSS STRAIN GAGE CONDITIONERS:

OPERATION, COMPONENT SPECIFICATIONS, AND USE

by

Christopher Higgins
Graduate Research Assistant

ATLSS Report No. 96-11

June 1996

ATLSS Engineering Research Center
Lehigh University
117 ATLSS Dr., Imbt Laboratories
Bethlehem, PA 18015-4729
(610) 758-3525

An NSF Sponsored Engineering Research Center

Table of Contents

Abstract

This manual describes the theory of operation, product specifications, and use of the strain gage conditioners (SGCs) developed for structural testing applications in the ATLSS Laboratories.

The SGC was developed for use with 120 Ω strain gages in a quarter bridge configuration with user selectable fixed gains of 1, 10, 100, 1000, and 2000. Bridge voltages can be varied from +2.00 V to +5.00 V. The bridge operates in null mode which permits balancing of the bridge for use of the full span of the data acquisition system (± 10.00 V). Balancing the bridge is facilitated by two LEDs which indicate the bridge balance point. The circuit also includes an on-board passive low-pass filter with a cut-off frequency of 158 Hz. These specifications satisfy the typical strain gage requirements encountered in the ATLSS Laboratories.

1.0 Background

1.1 Theory of Operation

Strain gages are sensors which exhibit a change in electrical resistance when elongated or shortened. The resistance change is due primarily to a change in length of the very thin foil within the gage as well as transverse dilation of the foil. When the strain gage is shortened, the very thin foil within the gage shortens and the foil width increases resulting in a decrease of the gage resistance. Similarly, when the strain gage is elongated, the very thin foil within the gage lengthens and the foil width decreases resulting in a resistance increase. A strain gage bonded to a material which experiences a change in strain due to an applied load or temperature change, results in a resistance change in the gage. By calibrating the resistance change of the strain gage, the magnitude of the strain can be determined. The actual magnitude of resistance change is typically very small and difficult to directly measure with accuracy. Fortunately, there is a well known electrical circuit which permits more sensitive measurement of a resistance change for a component in the circuit network, called a Wheatstone bridge. As shown in Fig. 1, four resistors are necessary for the Wheatstone bridge. One or more arms of the bridge can be made-up of strain gages. When a single strain gage is used in the bridge, it is called a quarter bridge as shown in Fig. 2a. Two active strain gages make a half bridge (Fig. 2b), and four active gages make a full bridge (Fig. 2c).

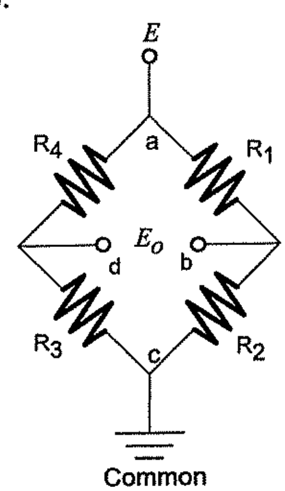


Fig.1 - Typical Wheatstone Bridge.

The SGCs at ATLSS were developed for use only in a quarter bridge configuration. In addition to the single strain gage, three fixed value resistors, called bridge-completion resistors, are required to form the quarter-bridge network. The bridge also requires an external excitation voltage, E, called the driving voltage. When one arm of the bridge (the strain gage) changes resistance, a voltage change occurs between points b and d (Fig. 1) which is related to the change in the strain by the formula:

$$\frac{E_o}{E} = \left[\frac{F \cdot \mu\varepsilon \times 10^{-6}}{4} \right] \qquad [1]$$

Where E_o (V) is the output voltage from the bridge between points b and d , E (V) is the driving voltage, F is the gage factor, and $\mu\varepsilon$ is the measured microstrain. The voltage change, E_o, is something a data acquisition system can measure electronically. However, the actual magnitude of the voltage change is again quite small when considering the typical values used for the elements of the Wheatstone bridge used in the structures laboratory. To increase the resolution of the strain measurement, it is possible (and usually necessary) to gain or amplify the signal. Gaining the signal increases the magnitude of the original signal.

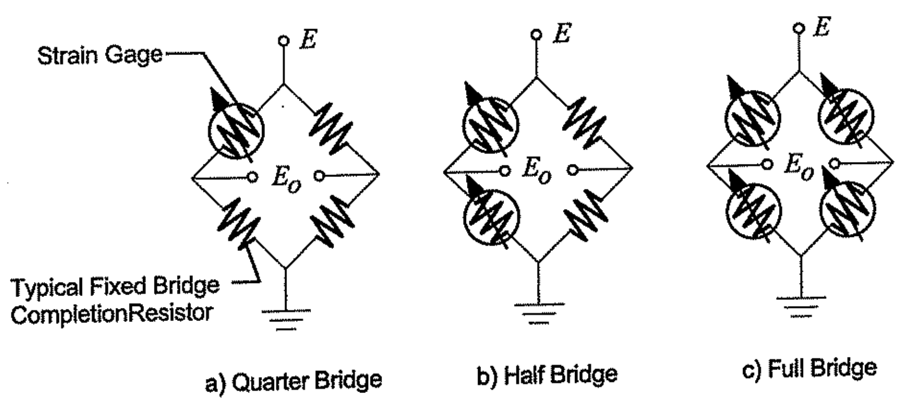


Fig. 2 - Examples of Wheatstone bridges with active arm strain gages.

1.2 System Overview

As discussed earlier, measurement of strain on a test specimen requires several components including a strain gage, an electrical circuit called a Wheatstone bridge which permits accurate measurement of the strain gage resistance change, a power supply to provide the driving voltage to the bridge, a circuit to gain the signal from the bridge, and a filtering circuit to reduce unwanted noise (discussed later). The SGC developed for ATLSS includes all of these features.

2.0 External Power Supply

Voltage to drive the bridge and power the electronics within the SGCs is provided by an external power supply illustrated in Fig. 3. The power supply is a regulated triple output linear supply with specifications shown in Appendix A. The three voltage outputs provide DC excitation of +12.0 V and -12.0 V for the ICs and the third output, +5.00 V, is used to drive the Wheatstone bridge and can be varied from +2.00 to +5.00 V by a trimpot on each SGC circuit board. Pin configurations for power connections between the power supply and SGC rack are shown in Fig. 4. The power supply is self contained, grounded, and capable of providing power to four racks of SGCs (32 individual cards). A cooling fan is recommended when powering multiple racks, especially for long duration tests, or in hot weather, as the supplies will become very warm. Fine adjustments can be made to the power supply output voltages by opening the supply enclosure and turning the adjustment potentiometers. This would be rarely necessary as absolute precision of the output voltages is not required by the SGC circuit. If the $\pm$ 12.0 V supply is above $\pm$ 11.0 V and the +5.00 V supply is above +4.50 V, the supplies do not require adjustment.

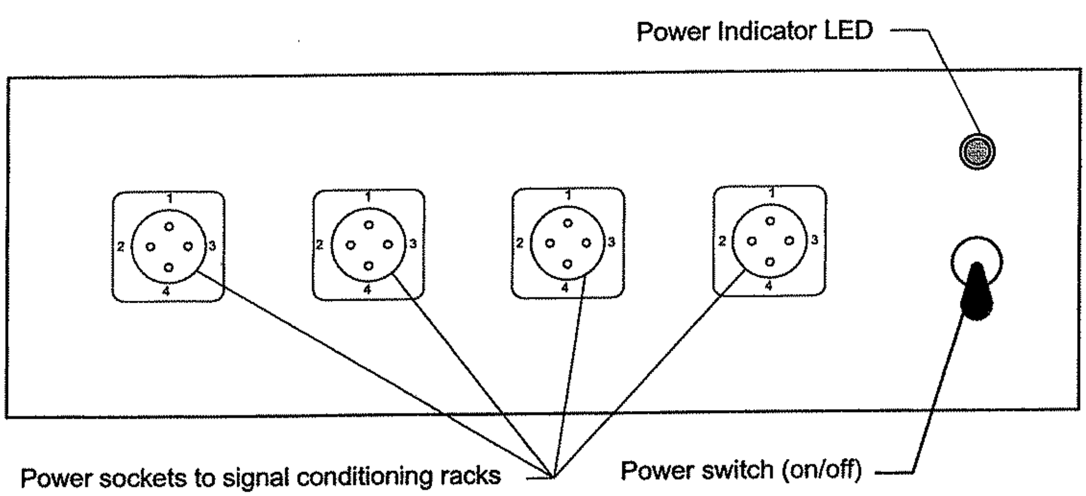
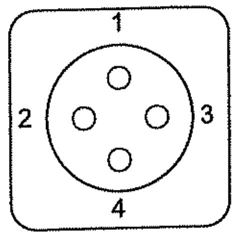


Fig. 3 - External power supply configuration.



Pin Configuration

1:	+12 Volts
2:	-12 Volts
3:	+5 Volts
4:	Common

Note: Sockets located on power supplies and racks
Pins located on cables which connect the power supply to the SGC rack.

Fig. 4 - Power connection between signal conditioning rack and power supply.

3.0 Strain Gage Conditioning Card (SGC)

3.1 Overview of Strain Gage Conditioning Card

The SGC card is the green circuit board with the necessary components for strain gage measurement. The circuit diagram is shown in Fig. 5. Eight SGC cards are housed in a rack-mountable enclosure and a single SGC card is required for each strain gage. Each of the SGC cards contains three precision (1% tolerance) resistors to complete the Wheatstone bridge, a fuse to prevent short circuiting the bridge, one IC for amplifying the signal, a passive single pole low-pass filter circuit, an IC for optical bridge balance, and two trimpots for bridge voltage and balancing adjustment.

Input and output wiring to the SGC is provided by screw terminals on the back of the card cage with the wiring configuration illustrated in Fig. 6. The SGC input requires a three wire hook-up for each strain gage (typical strain gage wiring) as illustrated in Fig. 7. Output to a data acquisition system is provided as a high (+ positive) and low (- negative) signal. The low signal for all cards is referenced to the power supply common, and thus the SGC can be used for single-ended data acquisition systems. Racks of SGC cards in cabinet enclosures have screw terminals wired to plugs for rapid connect/disconnect to test set-ups. Connector pin configurations are shown in Fig. 8.

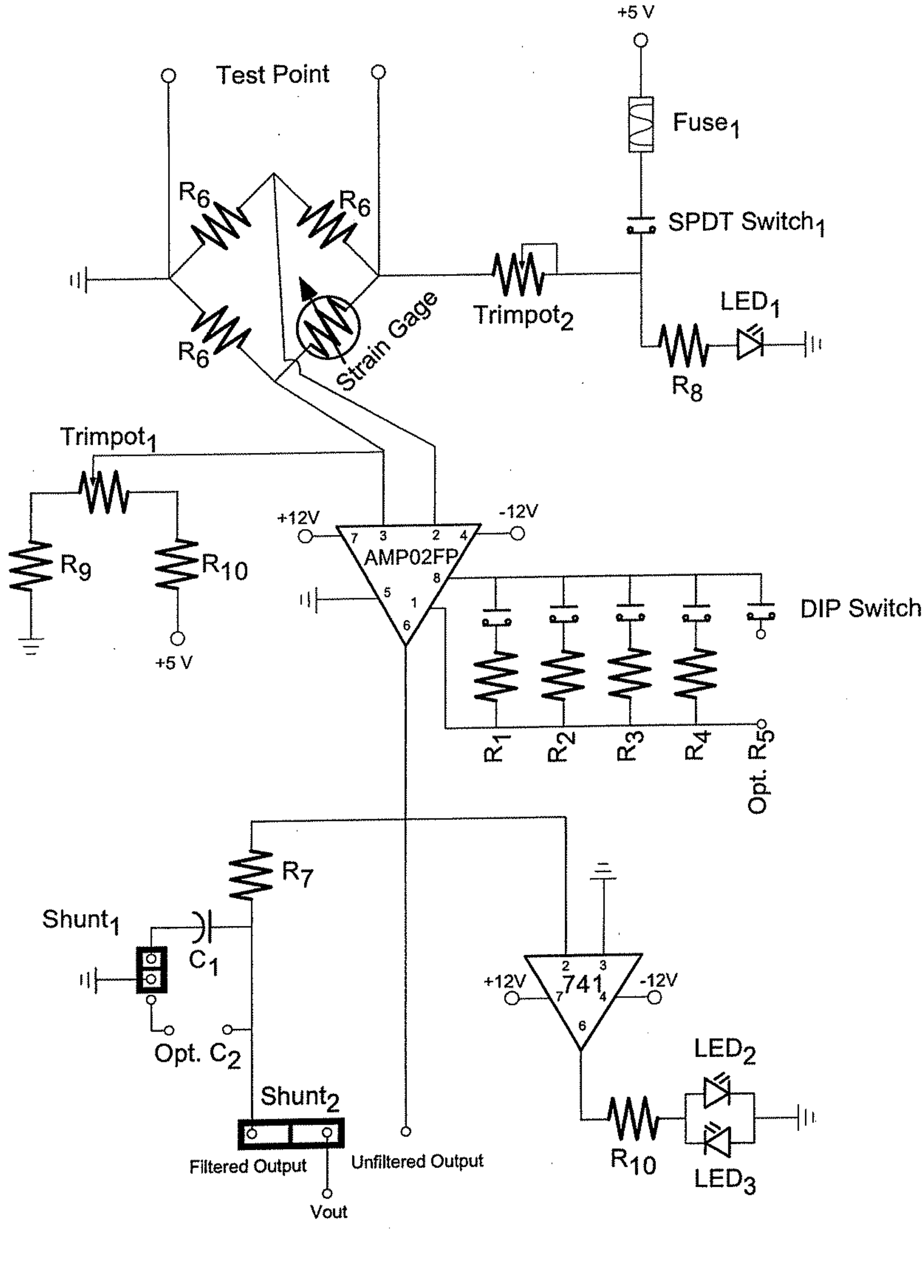


Fig. 5 - Circuit diagram.

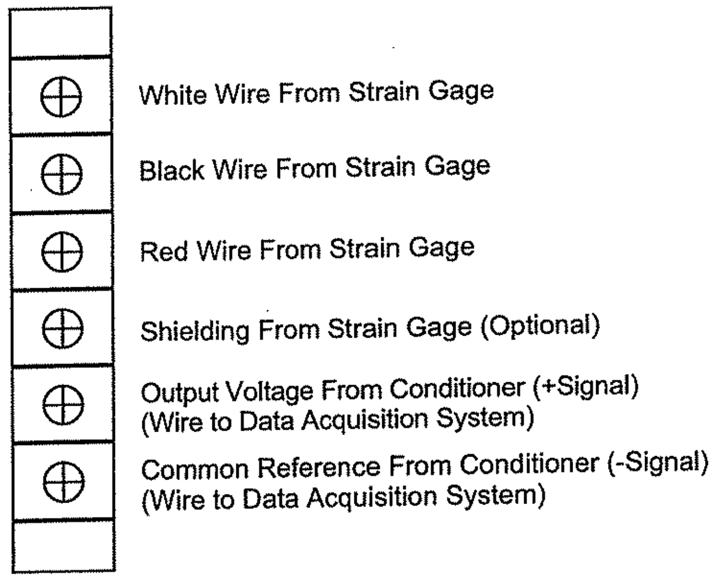


Fig. 6 - Screw terminal for input to and output from SGCs.

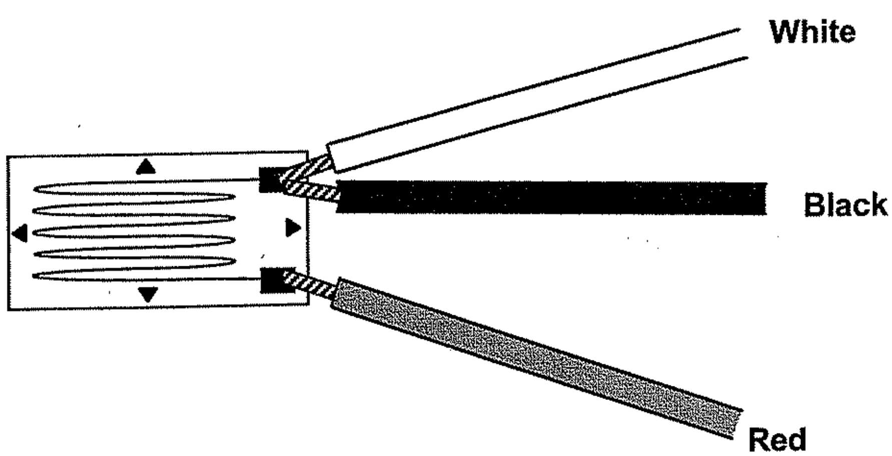
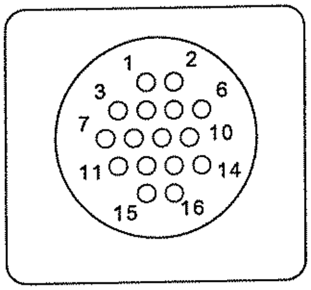


Fig. 7 - Wiring standard for strain gages.

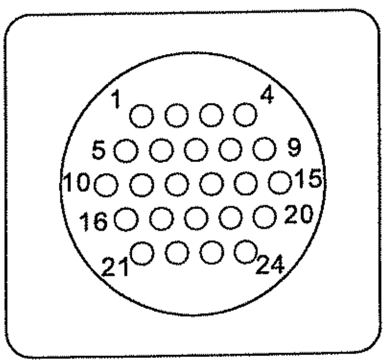


Pin Configuration

1:	+Signal (Gage #1)	9:	+Signal (Gage #5)
2:	Common (Gage #1)	10:	Common (Gage #5)
3:	+Signal (Gage #2)	11:	+Signal (Gage #6)
4:	Common (Gage #2)	12:	Common (Gage #6)
5:	+Signal (Gage #3)	13:	+Signal (Gage #7)
6:	Common (Gage #3)	14:	Common (Gage #7)
7:	+Signal (Gage #4)	15:	+Signal (Gage #8)
8:	Common (Gage #4)	16:	Common (Gage #8)

Output from signal conditioning rack to data acquisition system.

/



Pin Configuration

1:	White Wire (Gage #1)	13:	White Wire (Gage #5)
2:	Black Wire (Gage #1)	14:	Black Wire (Gage #5)
3:	Red Wire (Gage #1)	15:	Red Wire (Gage #5)
4:	White Wire (Gage #2)	16:	White Wire (Gage #6)
5:	Black Wire (Gage #2)	17:	Black Wire (Gage #6)
6:	Red Wire (Gage #2)	18:	Red Wire (Gage #6)
7:	White Wire (Gage #3)	19:	White Wire (Gage #7)
8:	Black Wire (Gage #3)	20:	Black Wire (Gage #7)
9:	Red Wire (Gage #3)	21:	Red Wire (Gage #7)
10:	White Wire (Gage #4)	22:	White Wire (Gage #8)
11:	Black Wire (Gage #4)	23:	Black Wire (Gage #8)
12:	Red Wire (Gage #4)	24:	Red Wire (Gage #8)

Note standard wiring convention used to describe wire locations.

Input from strain gages to signal conditioning rack.

Fig. 8 - Connector configuration for input and output from rack-mounted SGCs.

3.2 Bridge Driving Voltage and Adjustment

The Wheatstone bridge on the SGC card is powered by the +5.00 V output from the triple output power supply. There is however, voltage loss along the wires which connect the power supply and SGC card. This results in voltage less than +5.00 V when measured at the card. To account for this reduction in supply voltage, a trimpot is provided on the SGC card to permit accurate adjustment of the bridge driving voltage as illustrated in Fig. 9. While it is not possible to increase the bridge voltage higher than +5.00 V, it is possible to adjust the bridge voltage downward to a suitable round number for simplified calculation of the circuit parameters. Typically, the bridge voltage is set to +4.00 V. This permits adequate signal to noise ratio while providing sufficient temperature dissipation for most 120 Ω strain gages (See strain gage manufacturers specifications for specific dissipation requirements). The bridge voltage can be adjusted as low as +2.00 V. Adjustment of the bridge voltage is made by turning the trimpot located at the face panel as shown in Fig. 10. The bridge voltage is measured with a standard digital multimeter (DMM) at the face panel as shown in Fig. 10.

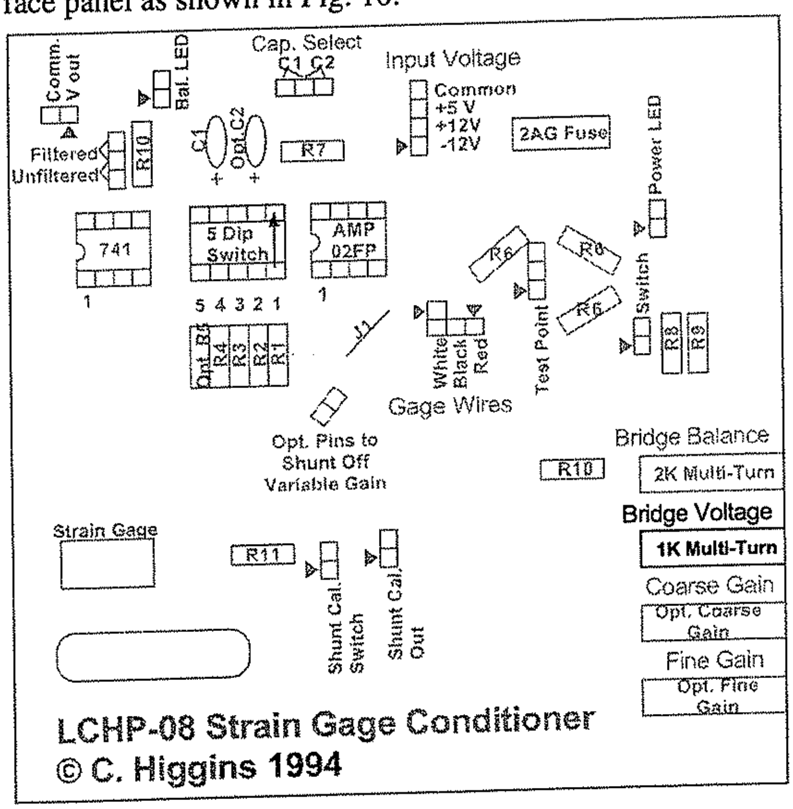


Fig. 9 - Location of bridge voltage trimpot on SGC card.

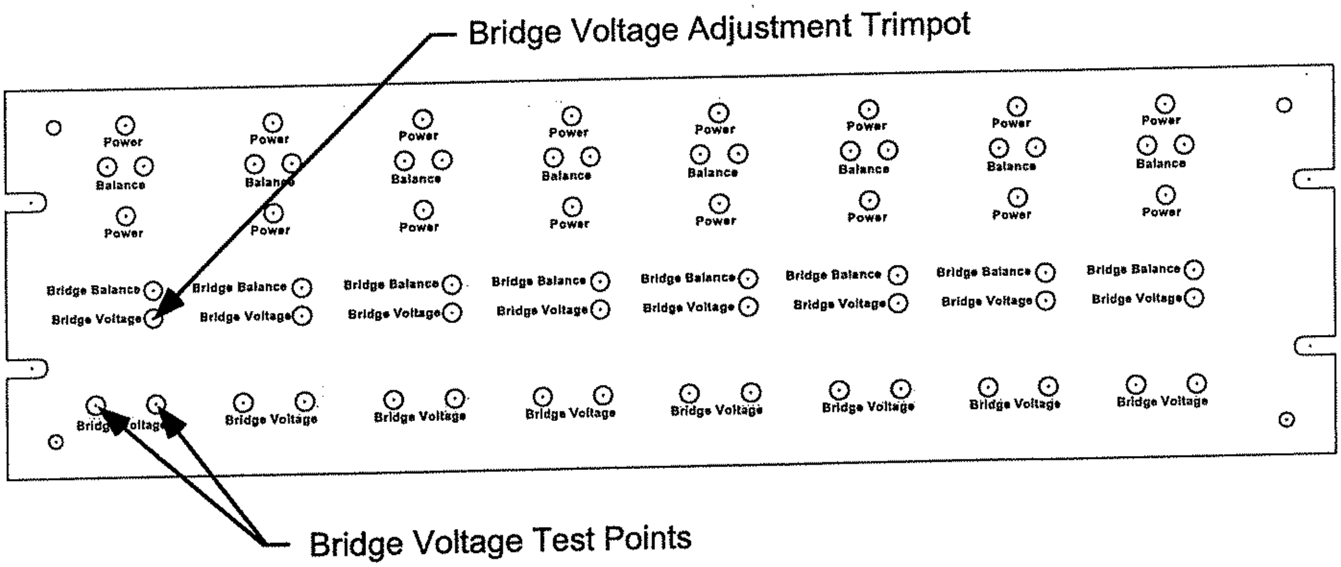


Fig. 10 - Location of bridge voltage trimpot on face panel.

3.3 Bridge Balancing

Output from the SGC card to the data acquisition system is not actually zero when the strain gage is unstrained. This is a result of the wire resistances which attach the strain gage to the SGC card, offset voltages from the ICs, imperfect matching of the bridge completion resistors, variation of the actual strain gage resistance, and other sources. The SGC permits the output to be zeroed so that when the strain gage is unstrained, the output to the data acquisition system is set to zero (or nulled). This is called null mode. When the bridge is properly nulled, there is approximately 0.00 V measured by the data acquisition system which permits the full range of the strain gage to be used. If the bridge is not nulled, the complete range ($\pm$ 10.00 V) of the data acquisition system will not be fully utilized. For example, if the unnulled output from the SGC to the data acquisition system is +3.00 V when there is no strain, then only +7.00 additional volts can be measured by the data acquisition system before going out of range or off scale. The system used only 70% of the available range capability. By nulling the output from the SGC, 100% range efficiency (or close to it) can be obtained from the data acquisition system.

Adjustment of the bridge balance is made by turning the trimpot located on the SGC card as shown in Fig. 11. The trimpot is accessed through the face panel and balancing is facilitated by two red LEDs also located on the face panel as shown in Fig. 12. The red LEDs are driven by a typical 741 operational amplifier (op amp) located on the SGC card as shown in Fig. 11. One LED will switch on while the other will switch off when the bridge is near the balance point. The trimpot should be turned in the opposite direction of the illuminated LED to reach the balance point. It is very difficult to get both LEDs to illuminate (perfect balance) as this is an inherently unstable condition. It is typically adequate to turn the trimpot just enough to have the LEDs change which one is illuminated. If the output must be balanced to absolute zero, a DMM can be used to measure the output from the SGC card as shown in Fig. 6 and the bridge balancing trimpot adjusted until 0.0 V is obtained on the meter.

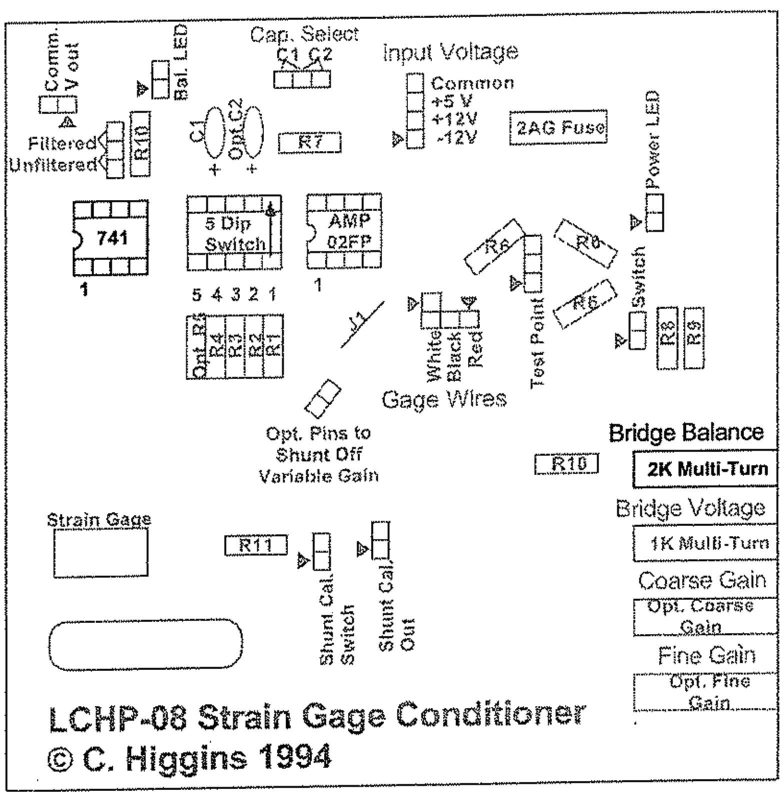


Fig. 11 - Location of bridge balance trimpot on SGC card.

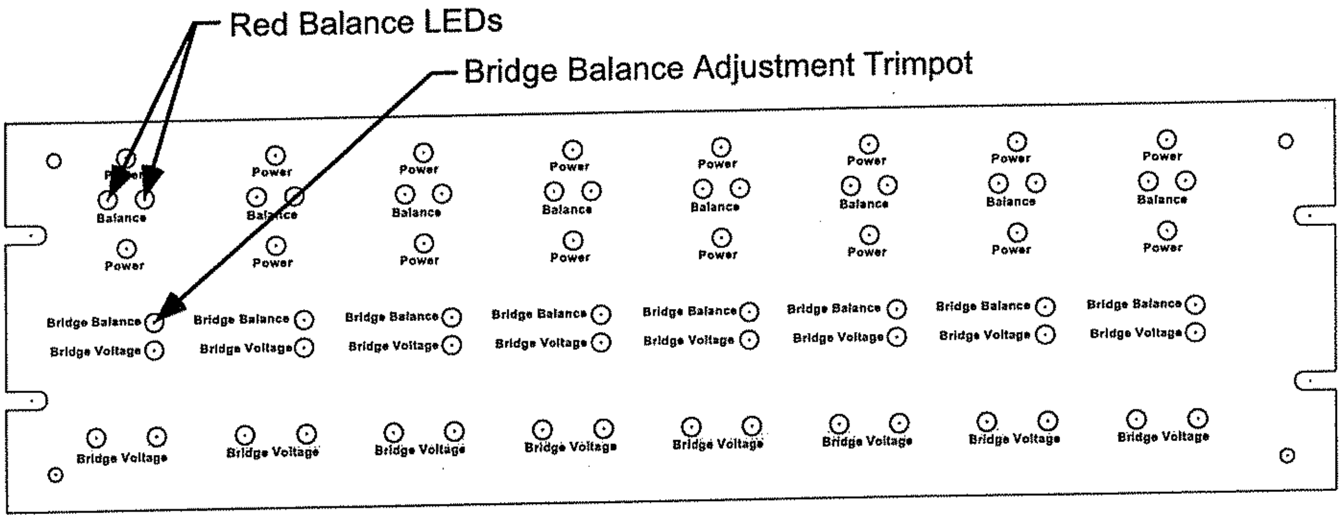


Fig. 12 - Location of bridge balance trimpot on face panel.

3.4 Bridge Output Gain

As mentioned earlier, it is often necessary to increase the magnitude of the signal from the Wheatstone bridge. This is necessary so that a data acquisition system can be used to measure a strain change accurately. Typical data acquisition systems are 12 bit systems which permit measurement of data at a resolution of ± 5 mV. This means that the system can only measure signal changes in increments of ± 5 mV and cannot distinguish changes less than this value. A typical 2.0% maximum elongation, 120 Ω strain gage, using a driving voltage of 4.00 V, with a gage factor of 2.00, has a maximum bridge output voltage of only 0.04 V (Eq. 1). This value would permit only 8 data points to be collected by a 12 bit data acquisition system during the entire experiment. If the signal from the Wheatstone bridge is gained, the output voltage increases and results in greater resolution of strain for the data acquisition system. If in the previous example, a gain of 100 was used, the maximum output voltage to the data acquisition system would be 4.00 V and would permit acquisition of up to 800 data points. This results in a much better description of the strain behavior for the test specimen.

Gain for the SGC is provided by an IC called an instrumentation amplifier located on the circuit board as shown in Fig 13. An instrumentation amplifier is a precision component with desirable electrical operating characteristics and is especially suited for amplification of low level signals. The instrumentation amplifier selected for the SGC circuit, manufactured by Precision Monolithics Inc. (PMI), is in an eight pin epoxy package, possessing low input and output offset voltage, high common mode rejection ratio (CMR), gain accuracy of 0.5% at 1000 gain, low temperature coefficient, large band width at high gain, and fast slew rate. Gain is set by a single feedback resistor. Specifications for the instrumentation amplifier are contained in Appendix A. Pin connections for the PMI instrumentation amplifier are typical for eight pin packages and instrumentation amplifiers from other manufacturers may be substituted if necessary. Feedback resistors to the instrumentation amplifier are precision 1% tolerance components to provide actual gains very close to the nominally calculated gain.

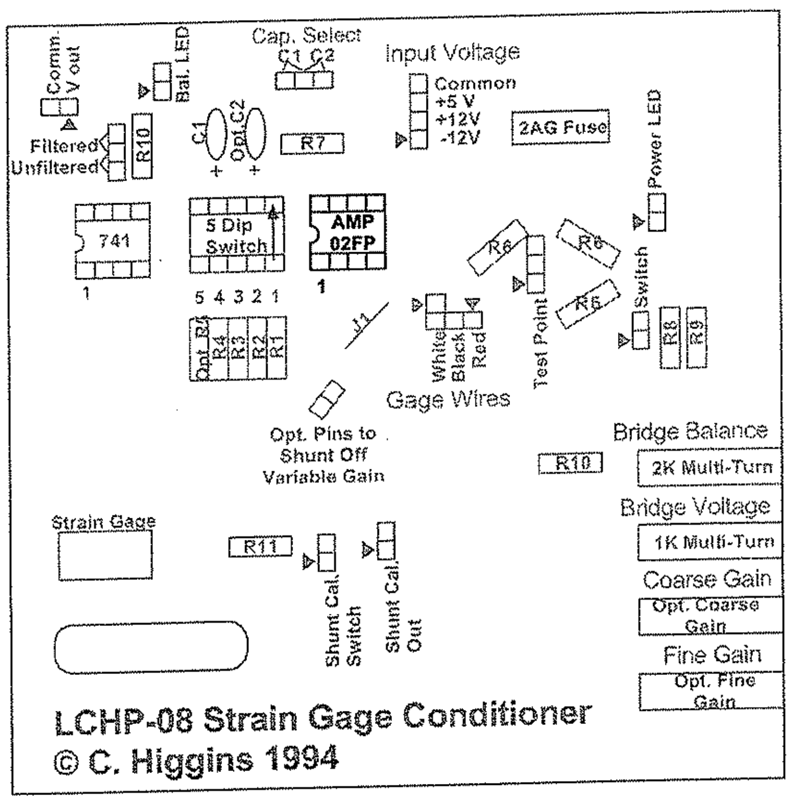


Fig. 13 - Location of instrumentation amplifier on SGC card.

There are four preset gain settings selectable on the SGC card. The gain is set by depressing one of the DIP switches as illustrated in Fig. 14. The DIP switch is the component located between the two ICs as illustrated in Fig. 15. Table 1 contains the switch settings and corresponding gain, as well as typical data ranges and resolution for a 12 bit data acquisition system.

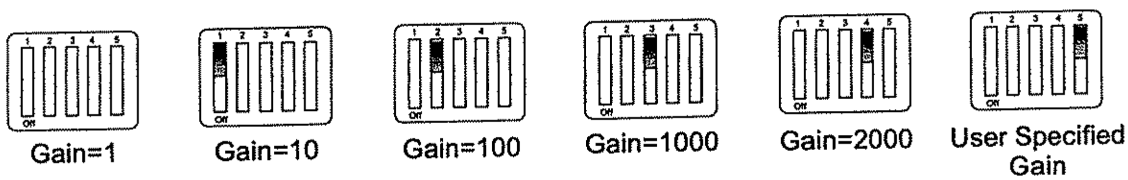


Fig. 14 - DIP switch gain settings.

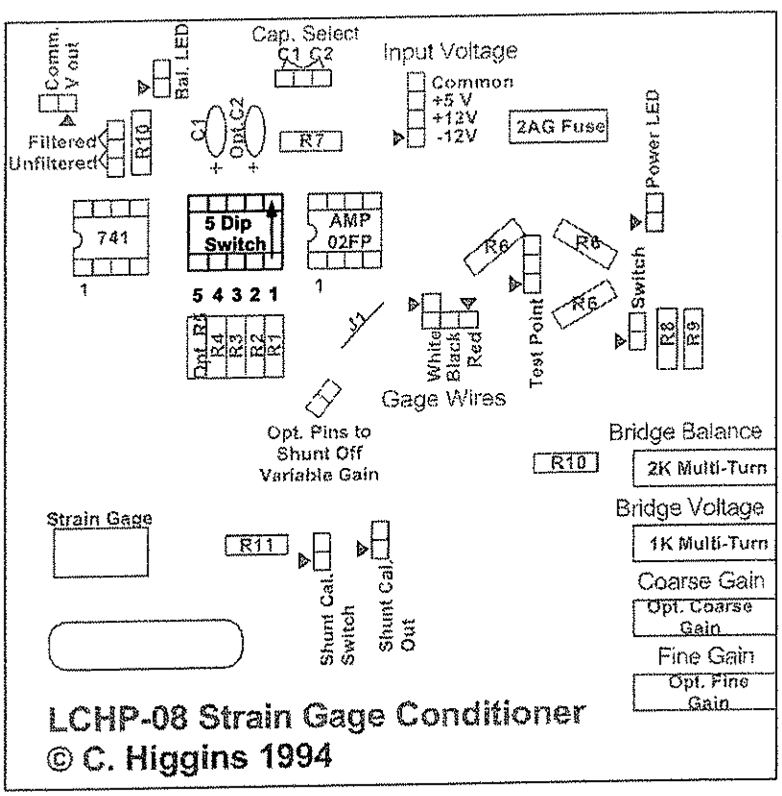


Fig. 15 - Location of DIP switch on SGC card.

Table 1

DIP Switch Position	Nominal Gain	X_{Factor} * (με/V)	Max. Recordable Strain (@ ± 10 V)* (με)	Strain Resolution for a 12 bit Data Acquisition* (με)
None	1	479620.0	4796200.0	2398.10
1	10	47962.0	479620.0	239.81
2	100	4796.2	47962.0	23.98
3	1000	479.6	4796.2	2.40
4	2000	239.8	2398.1	1.20
5	User Installed			

*Note : Values were calculated for gage factor of 2.085, and driving voltage of 4.00 V.

Maximum recordable strain at 10.00 V for a typical 12 bit data acquisition system is calculated as follows:

$$MaxStrain_{\pm 10V} = \left[\frac{4 \cdot 1000000}{F \cdot E \cdot Gain}\right] \cdot 10 \qquad [2]$$

Where *F* is the gage factor, *E* is the driving voltage, and *Gain* is the selected DIP switch gain value. Resolution of strain for a 12 bit data acquisition system is calculated as follows:

$$\mu SR_{12bit} = \left[\frac{4 \cdot 1000}{F \cdot E \cdot Gain}\right] \cdot 5 \qquad [3]$$

To convert the output voltage from the SGC to engineering units such as microstrain (με), a conversion factor is required. Rearrangement of Eq. 1 including gain results in Eq. 4.

$$X_{Factor} = \left[\frac{4 \cdot 1000000}{F \cdot E \cdot Gain}\right] \qquad [4]$$

Where X_{Factor} (με/V) is the conversion factor from voltage to microstrain. In other words, the acquired voltage is multiplied by X_{Factor} to calculate με. As an example, if the gage factor is 2.085, driving voltage is 3.00 V, and gain is 100, then 6,394.88 με/V will be output from the signal conditioner to the data acquisition system.

3.5 Low-Pass Filter

Electrical noise is inherent in all electronic components and as a result, sensors used to measure structural response include noise in addition to the actual signal of interest. The noise encountered typically includes both random noise and noise associated with 60 Hz and harmonics of 60 Hz (a result of AC power lines). One of the best ways to limit AC noise pick-up is to use shielded cable and ground the shielding. Another way to minimize noise is to use data averaging. That is, take multiple samples and average them into one sample. This method is particularly useful in reducing random noise. Unfortunately, data averaging is typically not possible for higher frequency dynamic tests due to the high acquisition speeds required for these tests.

An electronic method used to reduce noise is the application of a filter. There are numerous types of filters and filter configurations. One of the simplest filters used to remove high frequency noise is a passive low-pass filter. Signals in a structures laboratory are typically signals very close to 0 Hz (DC signals). DC means there is no oscillating component or time varying component, typical for a static test, however this may not be the case for fatigue or dynamic tests. Noise has time varying components at frequencies above 0 Hz. Thus, to remove noise from the sensor signal, a filter should allow low frequency components (signal) to pass unchanged while removing higher frequency components riding on the signal (noise).

The passive filter on the SGC is a simple single pole resistor-capacitor (R-C) filter as shown in Fig. 16a (resistor is 1 kΩ and capacitor is 1.0 μF). A Bode plot of the filter response is shown in Fig. 17 and the frequency response is shown in Fig. 18.

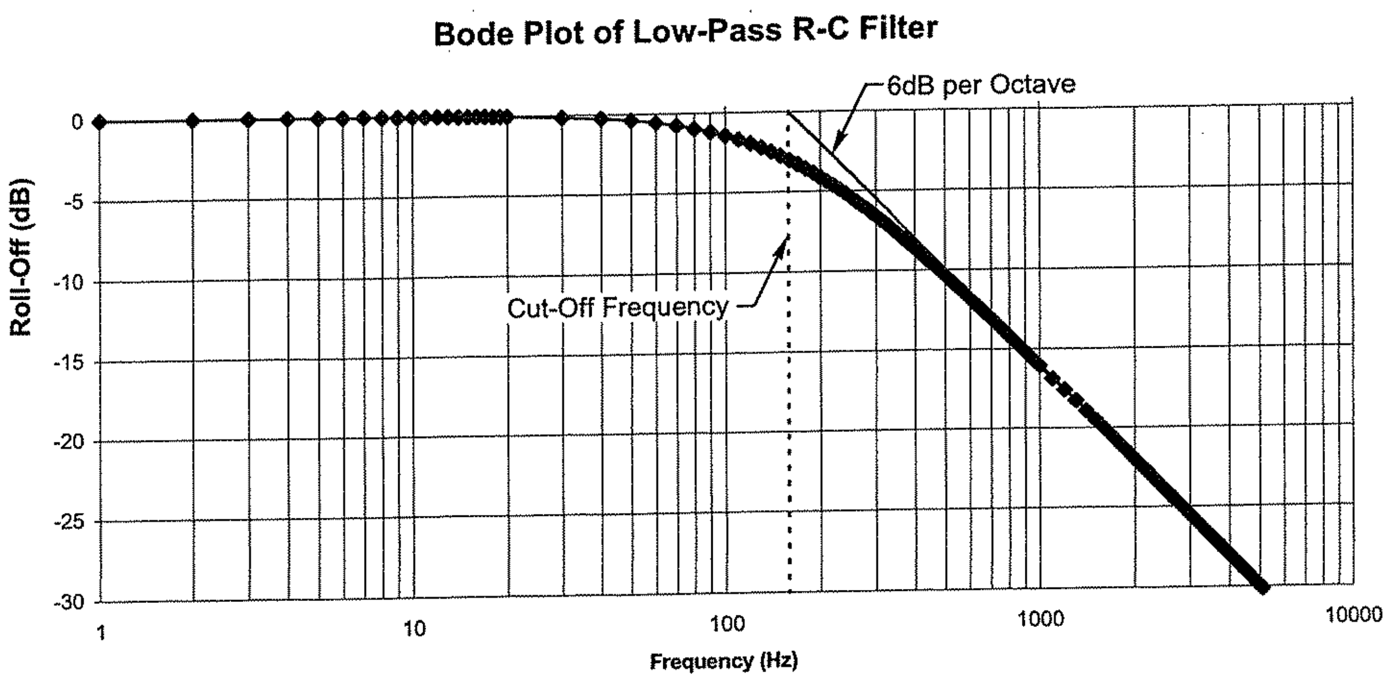


Fig. 17 - Bode plot of frequency response.

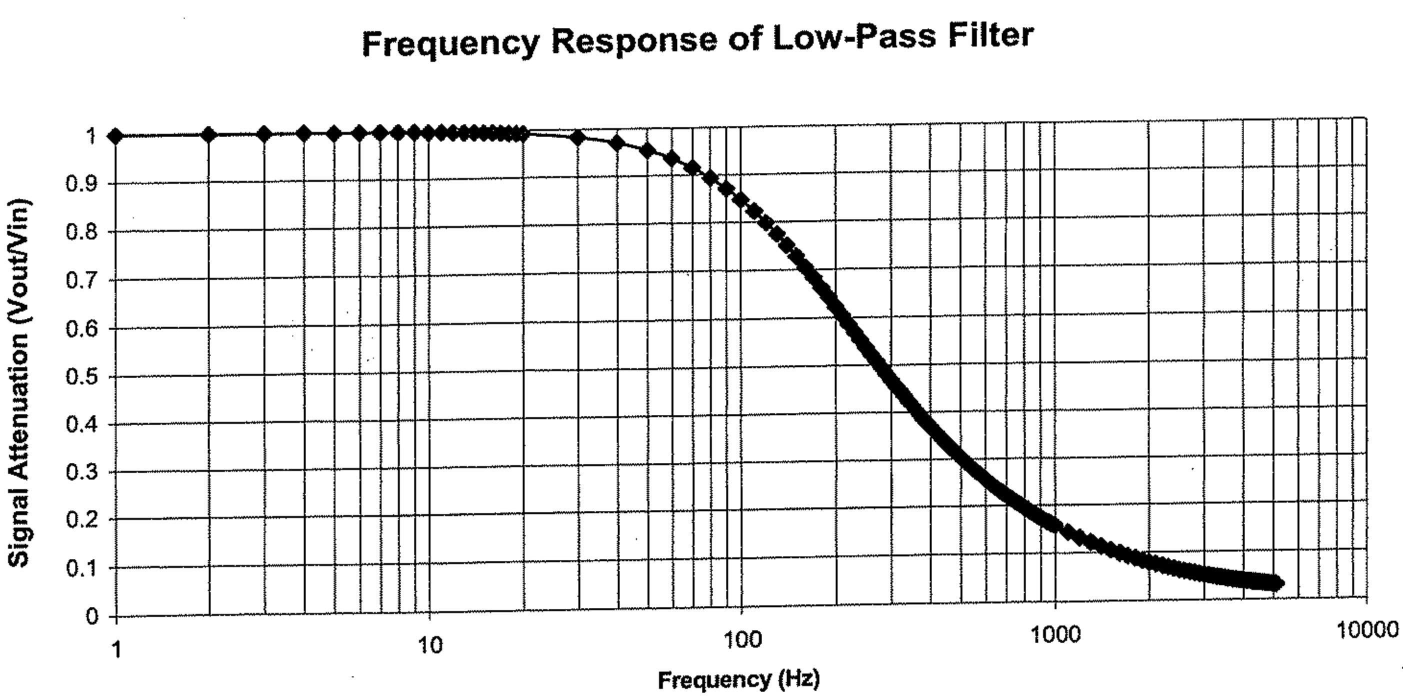


Fig. 18 - Frequency response of low-pass filter.

The cut-off frequency (determined at 3dB) is 158 Hz. As a result, most of the amplitude for frequencies below 158 Hz are passed. To determine the amount of attenuation or amplitude loss at any particular frequency f (Hz), Eq. 5 can be used:

$$\frac{V_{out}}{V_{in}} = \left[\frac{1}{\sqrt{4 \cdot C^2 \cdot R^2 \cdot \pi^2 \cdot f^2 + 1}} \right] \quad [5]$$

Where C (F) is the capacitance and R (Ω) is the resistance of the filter components. The filter response for the SGC is such that for experiments with frequencies above 10 Hz, there is little or no signal attenuation. This permits application of the SGC to fatigue tests operating in the lower frequency range. Though it is recommended the filter be used, it can be switched off if necessary by simply moving a single shunt to the position illustrated in Fig. 16b.

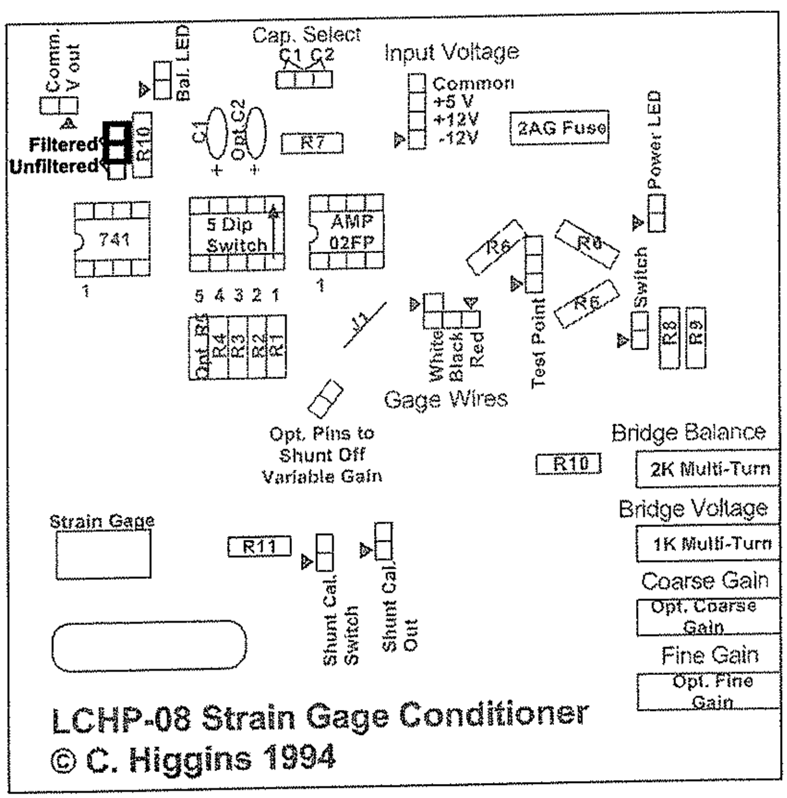


Fig. 16a - Position of shunt to switch filter on.

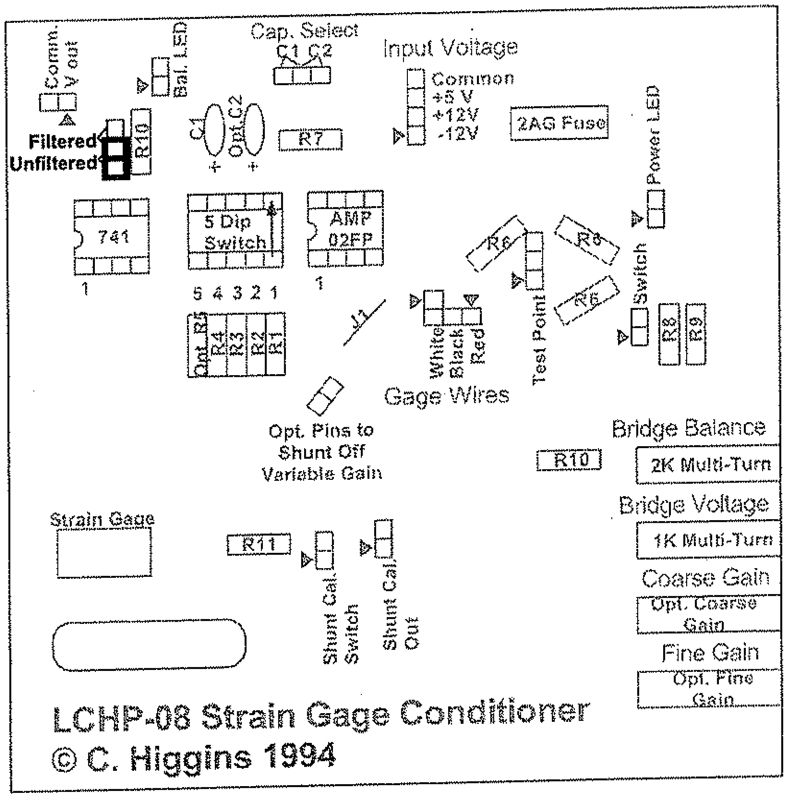


Fig. 16b - Position of shunt to switch filter off.

4.0 Use of Strain Gage Conditioning Card

4.1 Introduction

This section describes the typical application of the SGC and a step-by-step procedure to facilitate use of the conditioners.

4.2 Step-By-Step Procedure

4.2.1) Bond and wire strain gages using the three wire hook-up as illustrated in Fig. 7.

4.2.2) Check strain gage to ensure it is not grounded to the test specimen by measuring the resistance between the gage and the specimen with a DMM (a resistance measured between the gage and the specimen indicates the gage is grounded to the specimen).

4.2.3) Check gage resistance at the ends of the hook-up wire with a DMM before attaching wires to the SGC. Resistance between the white and black wires should be very small, and the resistance between the red and black wires and red and white wires should be approximately 120 Ω.

4.2.4) Ensure gain setting is properly selected on each SGC. See previous section for discussion of gain settings.

4.2.5) Ensure filter is selected on each SGC.

4.2.6) Wire the gage to the SGC as illustrated in Fig. 6.

4.2.7) Plug power supply in and turn power supply on. Green LED on power supply will illuminate. One red balance LED will illuminate on each of the eight SGCs in the powered rack.

4.2.8) Switch on power to the bridge for each gage. The switch is located on the front panel of the rack. A yellow LED will illuminate.

4.2.9) Permit the conditioners to warm-up adequately (see cautionary notes).

4.2.10) Measure the bridge voltage at the red and black test points with a DMM. Adjust the voltage as required (+4.00 V is typical) by turning the bridge voltage trimpot. When driving multiple racks of SGC with one power supply, this procedure should be performed multiple times to ensure proper voltage to all channels.

Start at one channel, adjust all bridge voltages and go back to the first channel and repeat. Repeat as many times as necessary until the voltages don't change. If a powered channel is turned off, the voltage on other channels may be affected and the balancing process should be repeated. This process sounds time consuming, but the system converges quickly to stable accurate bridge voltage levels.

4.2.11) Balance the bridge. The bridge balance trimpot should be turned in the opposite direction of the illuminated LED to reach the balance point. It is very difficult to get both LEDs to illuminate (perfect balance). It is typically adequate to turn the trimpot just enough to have the LEDs change which one is illuminated. If the output must be balanced to perfect zero, a DMM can be used to measure the output from the SGC card as shown in Fig. 6 and the bridge balancing trimpot adjusted until 0.00 V is obtained on the meter.

4.2.12) The system is ready for use.

4.3 Troubleshooting

<u>4.3.1 Both red balance LEDs always on:</u> This is a sure indication of a ground loop. Ground loops are always difficult to track down. Check to be sure no gages are grounded to the specimen and there are no crossed wires (high wired to low or vise versa) at the data acquisition system. Check the power supplies for all devices wired to the data acquisition system and ensure they are properly grounded and the reference commons are properly wired.

<u>4.3.2 One red LED is always on even when the bridge voltage is off:</u> This is normal operation of the SGC. When the external power supply is on and a rack of SGC is plugged in, the ICs on the card are automatically powered even when the bridge is not. It is one of these ICs that drives the balance LEDs.

4.3.3 The signal is noisy: Check to be sure there is a common reference connected to the data acquisition system. Insure the filter is selected. Follow the procedure in the previous section to turn filter on if necessary. Be sure to attach the shielding of the stain gage wires to ground. If use of the SGC filter is not desired, then consider filtering by external data averaging or other methods.

4.3.4 Yellow power LED does not come on when power is switched on

but one red LED is on: This is typically caused by a blown fuse on the SGC. Turn off the power to the bridge and disconnect the external power supply. Remove the existing fuse and replace with a new one. Be sure there are no bare wires shorting out the bridge at the end of the wires at the strain gage.

and no red LEDs are on: Ensure the power supply is plugged in and turned on. At least one red LED on each SGC should be illuminated when proper power is provided to the rack. Ensure there is proper power being provided by the power supply by measuring with a DMM (see pin designations discussed previously). If the supply short circuited, it can be reset by switching the power supply off and back on.

4.3.5 The gage appears grounded to the specimen when checked with a DMM: Unplug the power supply and re-check the gage. If the gage is still grounded, check the gage and repair as necessary. If the gage does not appear grounded then it is fine. The reason for the apparent grounding is that the power supply is tied to earth ground through the AC socket and the common is referenced to earth ground. Therefore, when a strain gage is hooked-up to the powered SGC there is a normal and measurable electrical path between earth ground and the strain gage. The gage should not be grounded to the specimen before being wired to the SGC and should be carefully checked before being connected to the conditioner.

4.3.6 Bridge will not balance: This is typical of a mistakenly wired gage or a bad strain gage. If there is an improper three wire hook-up or the gage resistance is very different from specified (much different than 120 Ω) then the SGC will not balance. Check wiring and strain gage. Disconnect the stain gage wires from the SGC and ensure proper resistance of the gage by measuring with a DMM. Repair or replace the gage and check wiring configuration.

5.0 Cautionary Notes

5.1 Sign convention of the output

The sign convention of the SGC output is positive for compressive strain and negative for tensile strain. To change the sign to the more conventional positive for tension, simply use a negative sign for the X_{Factor} used by the data acquisition program when converting voltage to engineering units of microstrain.

5.2 Gain Selection

Be sure to select the highest practical gain such that good resolution is achieved while the strain reading does not go out of range of the data acquisition. See Table 1 for examples of gain ranges and limitations.

5.3 Temperature sensitivity

All electrical components are sensitive to temperature changes. The operating characteristics of most electrical components change with temperature. To ensure proper performance and eliminate output voltage drift due to temperature changes, warm-up the SGC and strain gages a *minimum* of one hour and preferably overnight. This time permits all components to reach an equilibrium temperature. Better performance is achieved when sufficient time is permitted for warm-up, and the SGC can operate continuously for many days/weeks without damage.

5.4 Temperature Compensation

Typical gages are temperature compensating over normal operating temperatures. The SGC does not provide internal temperature compensating gages as part of the circuit. Therefore, if extreme operating temperatures are used for an experiment, a separate strain gage should be bonded to an unstressed piece of material which is at the same temperature as the stressed test specimen. The temperature effect can be removed during post-processing of the data by removing the thermal strain measured on the unstressed material. See individual strain gage manufacturer literature for information regarding specific gage temperature compensation performance and to determine if an external temperature gage is necessary.

5.5 Shunt Calibration

While the actual gain of the SGC card is very close to the nominal gain value, shunt calibration of each SGC card is suggested to obtain the most accurate measurement of strain on the laboratory floor. A shunt calibration device is available to verify the gain accuracy of the SGCs. Each card should be calibrated for the specific gain value to be used in the actual experiment. A written step-by-step procedure, developed by Perry S. Green, is provided in Appendix B to illustrate the process required for shunt calibration of the SGC cards. Gain linearity for the instrumentation amplifier is not assured for gains over 1000, therefore gain accuracy should always be calibrated for very high gains.

6.0 Advanced Options of Strain Gage Conditioning Cards

6.1 User Installed Filtering

The on-board passive low-pass filter can be modified to provide a frequency response different than the default filter. Installation of a capacitor into position C_2 and movement of the capacitor selection shunt as illustrated in Figs. 19a and 19b is required to change the filter. The capacitor value should be selected according to Eq. 6.

$$C = \sqrt{\frac{1}{4} \cdot \frac{1}{1000^2 \cdot \pi^2 \cdot f_{cut}^2}} \qquad [6]$$

Where f_{cut} (Hz) is the desired cut-off frequency (3dB attenuation at f_{cut}), and C (F) is the necessary capacitor value. High quality, tight tolerance (5% or better), nonpolarized 50WV capacitors such as Panasonic V-Series stacked metalized film capacitors would be required.

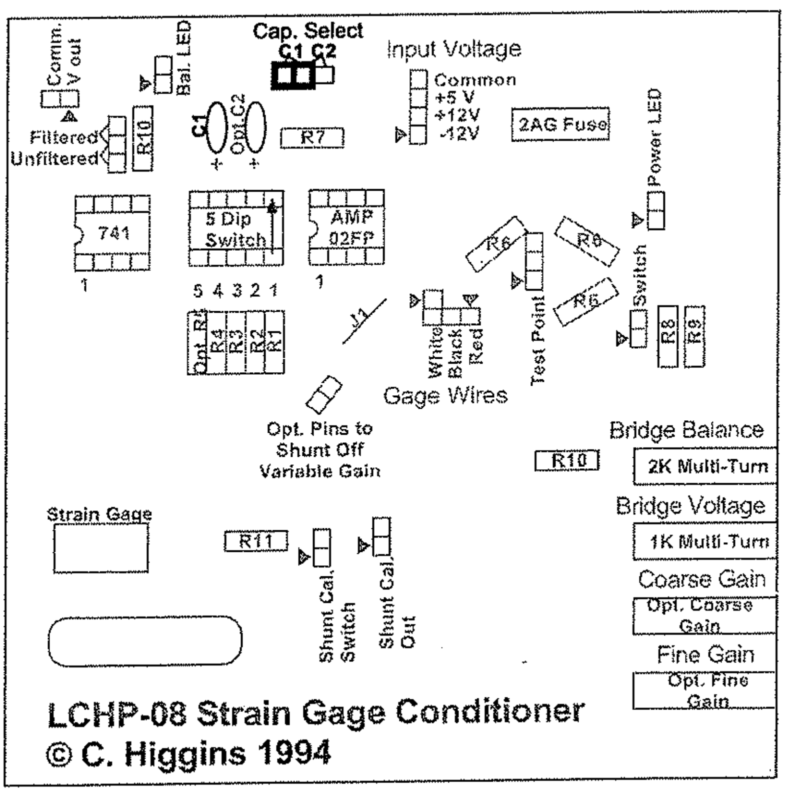


Fig. 19a - Position of shunt to select capacitor 1 for filter.

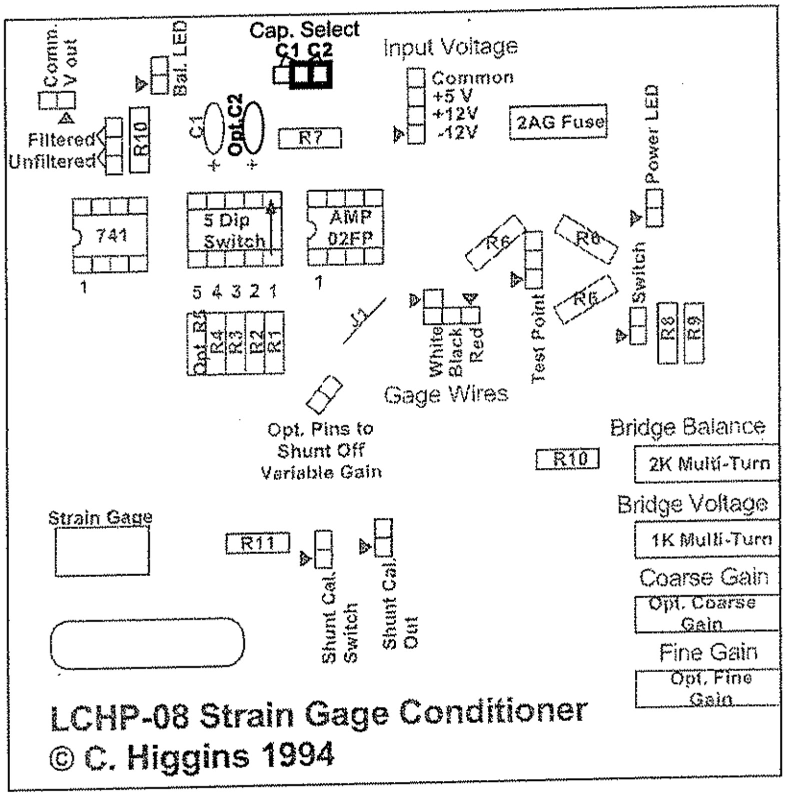


Fig. 19b - Position of shunt to select capacitor 2 for filter.

6.2 User Installed Gains

Amplification of the bridge output can be modified to provide a gain value different than the default values. Installation of a new resistor into position R_5 and selection of position 5 on the DIP switch as illustrated in Fig. 20 is all that is required to provide a unique user gain value. The resistor value should be determined according to Eq. 7.

$$R_{Gain_5} = \sqrt{\frac{50000\Omega}{Gain - 1}} \qquad [7]$$

Where *Gain* is the required gain, and R_{Gain_5} (Ω) is the necessary resistor value. High quality, tight tolerance (1% or better), 1/4 Watt resistors are required for accurate gains.

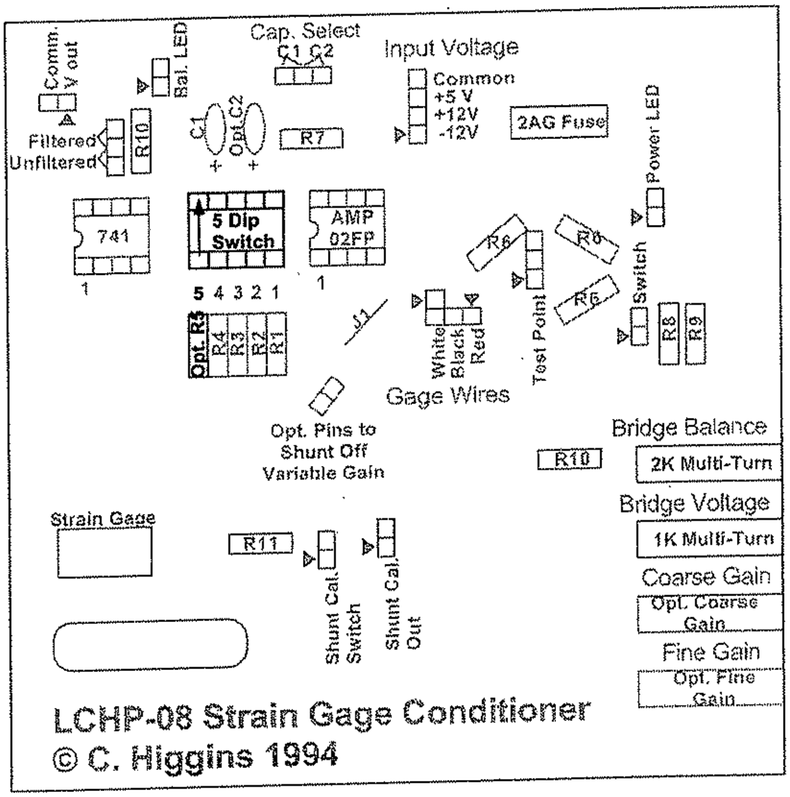


Fig. 20 - Location of additional resistor required for user installed gain.

6.3 Variable Gain

It is possible to change the SGC from fixed gain to variable gain. Installation of two trimpots, a jumper wire into position 5, and selection of position 5 on the DIP switch are required as illustrated in Fig. 21. Additionally, on the back of the SGC card, one small copper trace must be removed as shown in Fig. 22. This option is one which should be carefully considered before installing. When variable gain is used, shunt calibration (a time consuming procedure) is required before each use of the SGC card.

The trimpots for the variable gain should be 3/4 in. rectangular, cermet, multi-turn (10 or more) sealed trimming potentiometers (Bourns Model 3006 or equivalent). One trimpot should provide coarse gain adjustment (larger resistance value) and the other should provide fine gain adjustment (smaller resistance value). Modification of the face panel is also required as illustrated in Fig. 23.

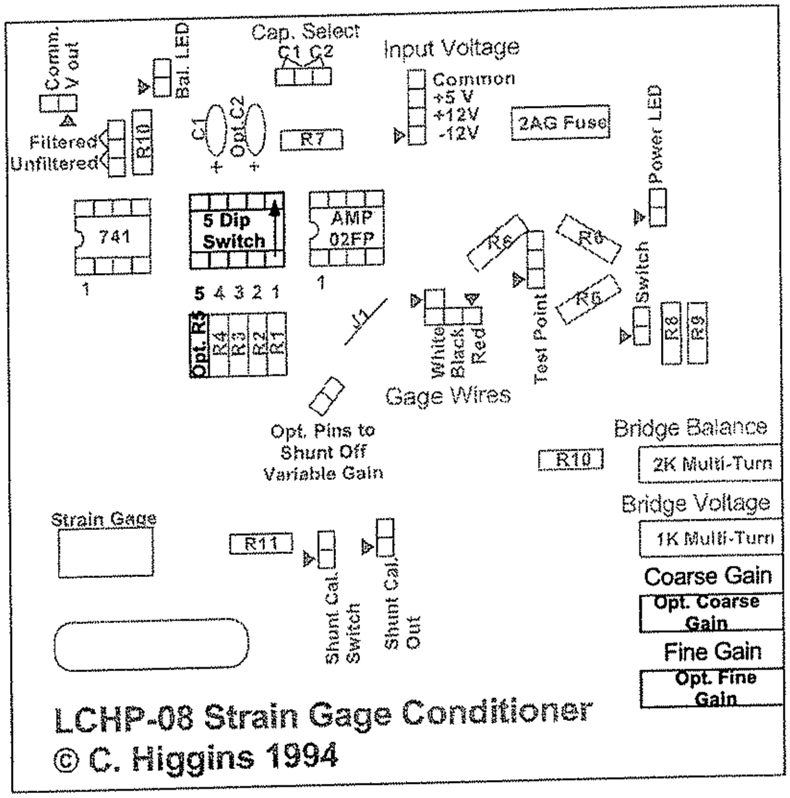


Fig. 21 - Location of additional trimpots and jumper required for variable gain.

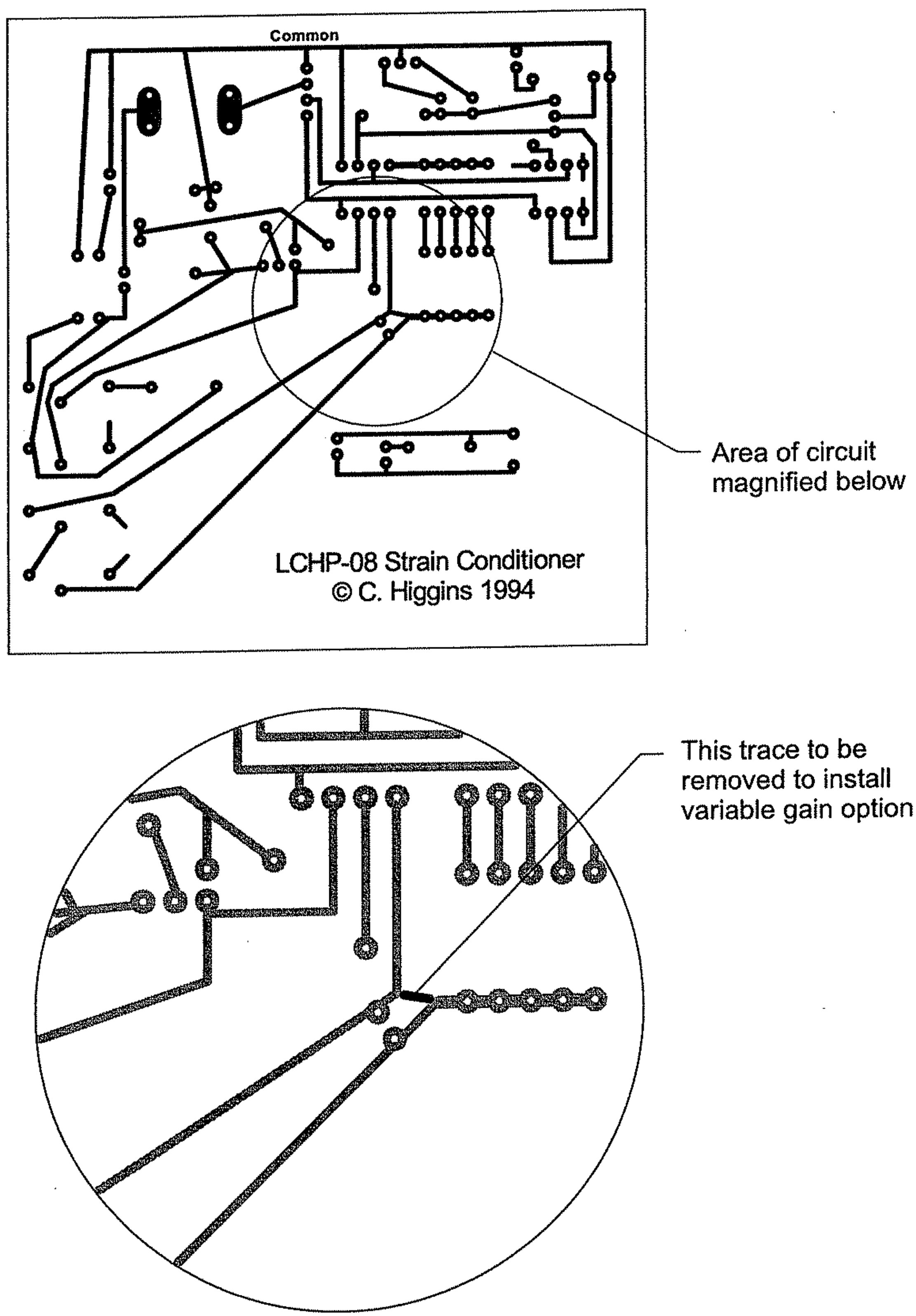


Fig. 22 - Copper trace which must be removed to install variable gain.

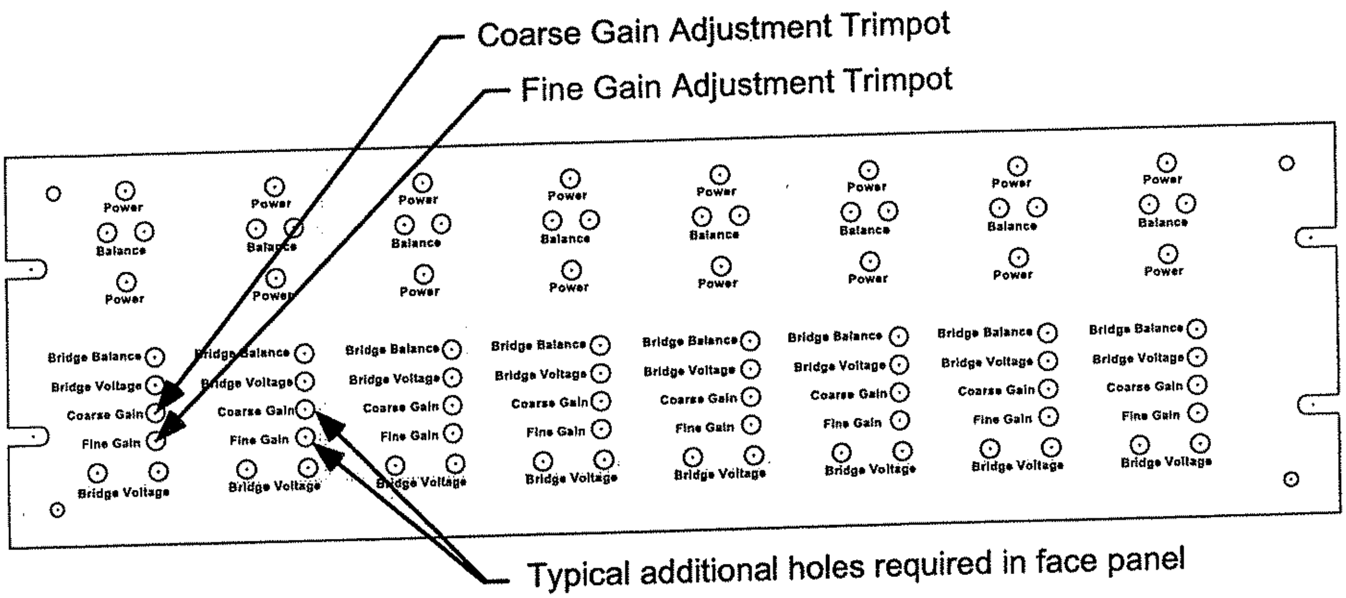


Fig. 23 - Location of additional holes required in face panel for variable gain option.

6.4 Internal Shunt Calibration

Single point internal shunt calibration is possible with the SGC. A strain gage, precision resistor, and two switches are required. This is a very difficult option to install, as additional holes must be drilled in the face panel to permit installation of the switches. See Fig. 24 for the salient features of this option. If variable gain modifications are made to the SGC cards, internal shunt calibration would be a logical option to permit accurate determination of the actual circuit gain set by the variable gain trimpots

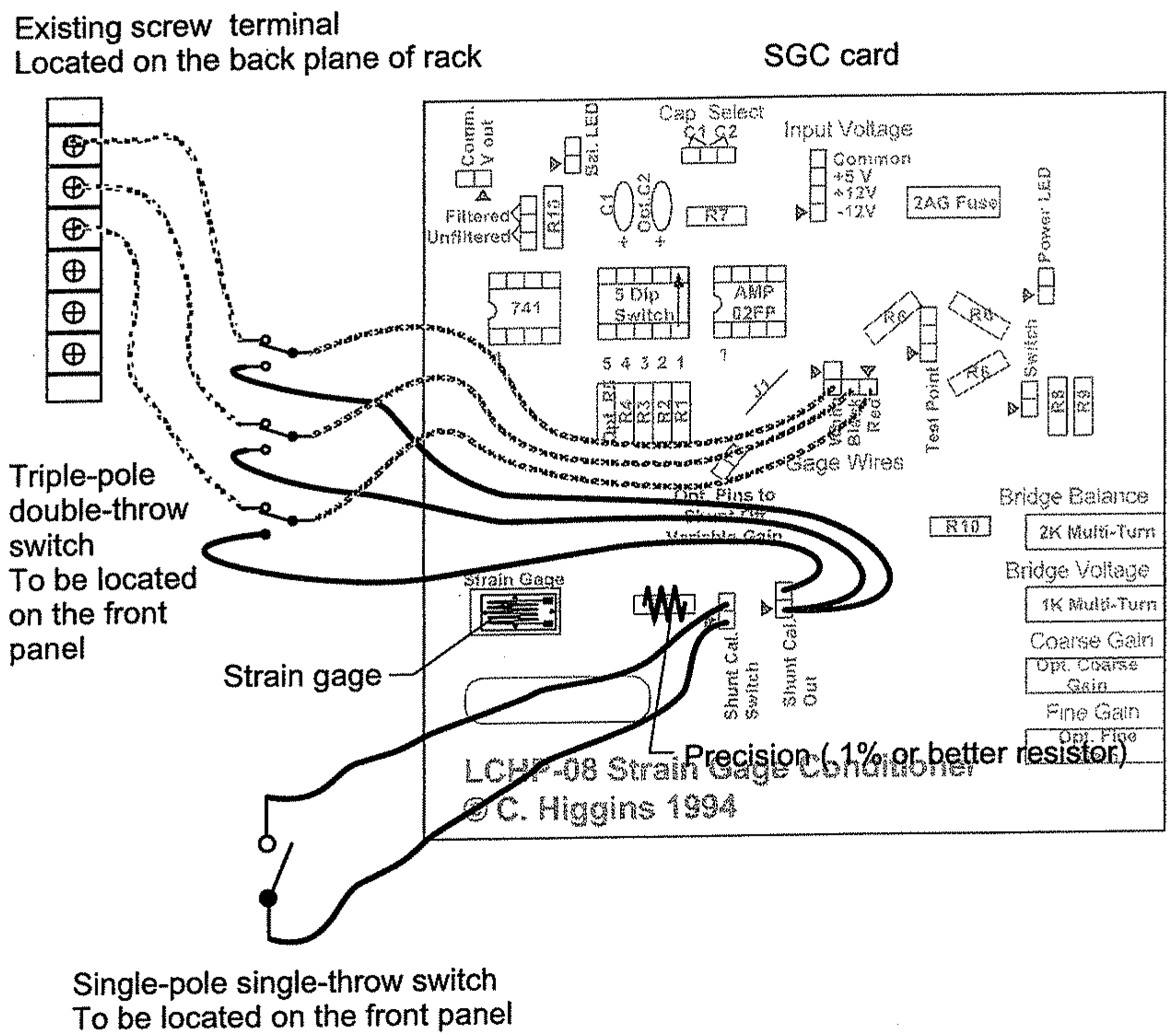


Fig. 24 - Salient features of internal shunt calibration option.

References

[1] Boylestad, R. L. (1987) Introductory Circuit Analysis, Merrill Publishing Company, Columbus, OH.

[2] Johnson, J. H. (1994) Build Your Own Low-Cost Data Acquisition and Display Devices, McGraw-Hill Inc., New York, NY.

[3] Measurements Group, Inc. (1993) General Reference Binder, Measurements Group Inc., Raleigh, NC.

[4] Mimms, F. M. (1986) Engineer's Mini-Notebook Optoelectronic Circuits, Radio Shack, USA.

[5] Mimms, F. M. (1986) Engineer's Mini-Notebook Op Amp IC Circuits, Radio Shack, USA.

[6] Wobscall, D. (1987) Circuit Design for Electronic Instrumentation, McGraw-Hill Inc., New York, NY.

APPENDIX A

Component Specifications

Specified SGC Component Values

Identification	Specified Value	Rating	Tolerance
Resistors			
R1	5.49 K Ω	1/4 Watt	1%
R2	499.0 Ω	1/4 Watt	1%
R3	49.9 Ω	1/4 Watt	1%
R4	24.9 Ω	1/4 Watt	1%
R5	User selectable	1/4 Watt	1%
R6	121 Ω	1/4 Watt	1%
R7	1.0 K Ω	1/4 Watt	1%
R8	510 Ω	1/4 Watt	5%
R9	1.0 K Ω	1/4 Watt	5%
R10	2.2 K Ω	1/4 Watt	5%
R11	User selectable	1/4 Watt	0.1%
Capacitors			
C1	1 μ F	50 V	5%
C2	User selectable	50 V	5%
Trimpots			
Trimpot1	2 K Ω	3/4 Watt	15 turn cermet
Trimpot2	1 K Ω	3/4 Watt	15 turn cermet
LEDs			
LED1	Yellow	T-1 3/4	
LED2	Red	T-1 3/4	
LED3	Red	T-1 3/4	
Fuse			
Fuse1	2AG	1/8 Amp	

Complete Parts List

Item	Vendor	Vendor Id	Cost per Unit	No. Req'd
SGC BOARD				
Circuit Board	Lehighton		19.00	1
LED Yellow	Digi-Key	HLMP-4719QT-ND	0.19	1
LED Red (2)	Digi-Key	HLMP-4700QT-ND	0.19	2
LED Holders	Digi-Key	LU4002-ND	0.05	3
Header Pins Single Row .1 in. sq	Digi-Key	2440-6213TG-ND	0.03	23
1% Bridge Resistors 121 Ohm	Digi-Key	121XBK-ND	0.02	3
1 % Gain Resistors 25 Ohm	Digi-Key	24.9XBK-ND	0.04	1
1 % Gain Resistors 50 Ohm	Digi-Key	49.9XBK-ND	0.04	1
1 % Gain Resistors 500 Ohm	Digi-Key	499XBK-ND	0.04	1
1 % Gain Resistors 5500 Ohm	Digi-Key	5.49KXBK-ND	0.04	1
1 % Filter Resistors 1KOhm	Digi-Key	1.00KXBK-ND	0.04	1
1 microFarad 50 V Capacitor	Digi-Key	P4675-ND	0.71	1
5 % Resistor 2.2KOhm	PA Peters	CF 1/4	0.01	2
5 % Resistor 1KOhm	PA Peters	CF 1/4	0.01	1
5 % Resistor 500 Ohm	PA Peters	CF 1/4	0.01	1
Shunts	PA Peters	PPE-PLS-MJ-02	0.04	2
Jumper Wires 0.4 in	Digi-Key	923345-04	0.02	1
741 Op-Amps	PA Peters	741	0.72	1
AMP02FP Inst. Amp	Allied	630-2270	5.25	1
Op-Amp Sockets	PA Peters	PPE-SCS-8	0.04	2
5 Position Dip Switch	PA Peters	AMP-3-435640-6	0.75	1
SPDP Switch	PA Peters	PHI-10002	0.99	1
Tip Jack Black	Digi-Key	J118-ND	0.34	1
Tip Jack Red	Digi-Key	J117-ND	0.34	1
Fuse Clips	PA Peters	LF-111501	0.09	2
Fuse 1/8 Amp 2AG	PA Peters	LF 225.125	0.48	1
15 Turn 2 KOhm Trimpot	PA Peters	3006P-2K	1.05	1
15 Turn 1 KOhm Trimpot	PA Peters	3006P-1K	1.05	1
2 circuit Housings	PA Peters	AMP 640440-2	0.07	6
3 circuit Housings	PA Peters	AMP 640440-3	0.15	2
4 circuit Housings	PA Peters	AMP 640440-4	0.19	1
Shielded 3 cond. Wire 22 gage	Newark	50F3477WMO	0.21	1
Shielded 4 cond. Wire 22 gage	Newark	50F3478WMO	0.77	1
Twisted 2 cond. Wire 22 gage	Newark	87F4391WM	0.45	1
RACK HARDWARE				
Enclosure (rack of 8)	Vector	CCK12S/90	90.14	1
Face Plate	H.T. Lyons	1/8 x 5-1/4 x19 in.	4.10	1
6 Term. Beau Barrior Block	PA Peters	72206	1.35	8
POWER SUPPLY				
Power Supply	PA Peters	SLT-12-31010-12	78.52	1
Enclosure	Circuit Specialist	LA-7	13.28	1
A/C Power Cord	PA Peters	AEC SK-086	1.90	1
Cables (4 Cond. 18 gage)	Newark	50F3460WA0	6.00	4
Amp Connector Receptical	PA Peters	AMP 206429-1	1.19	8
Amp Connector Plug	PA Peters	AMP 206429-1	1.41	8
Amp Crimp Pins	PA Peters	AMP 66361-2	0.15	32
Amp Crimp Sockets	PA Peters	AMP 66360-2	0.15	32
Amp Cable Clamps	PA Peters	AMP 206358-1	1.80	8

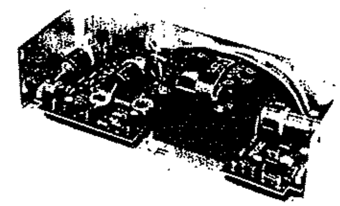
A.1 Triple output power supply.

A UNIT OF GENERAL SIGNAL GS

SOLA

POWER SUPPLY GROUP

LINEAR OPEN FRAME DC POWER SUPPLIES



SILVER LINE

Models:
SLT-12-31010-12

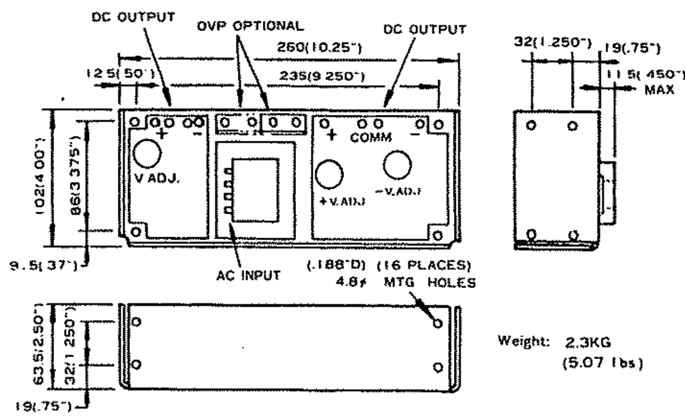
FEATURES:

- Tight regulation: 0.05% Line; 0.05% Load
- Full Output Ratings to +50° C
- Built in OVP on 5 Volt Outputs
- OVP Option for 12V, 15V, and 24V
- Foldback Current Limiting Overload Protection with Automatic Recovery
- Multi-tap AC Inputs
- 100% Four-Hour Burn-In
- Limited Warranty for one Year
- UL Recognized
- CSA Certified
- TUV Certified

Input AC Connections:

FOR USE AT	CONNECT	APPLY AC TO:	Primary Fuse
100 VAC	1–3, 2–4	1 & 5	1.6A/125V
120 VAC	1–3, 2–4	1 & 4	1.6A/125V
220 VAC	2–3	1 & 5	0.8A/250V
230 VAC	2–3	1 & 4	0.8A/250V
240 VAC	2–3	1 & 4	0.8A/250V

Mechanical Dimensions: mm (Inches)



Weight: 2.3KG (5.07 lbs)

P/N 36169-05
Rev 4/88

4

A.1 Triple output power supply.

GENERAL SPECIFICATIONS:

Voltage/Current Ratings:

MODEL NUMBER	OUTPUT 1	OUTPUT 2	OUTPUT 3
SLT-12-31010-12[1]	+5V/3.0 A*	+12V/1.0A	-12V/1.0A

[1] +5 is isolated from other outputs.

Operating Temperature Range: 0 to +50°C (Derate to 40% at +70° C)

Temperature Coefficient (Typical): +/- 0.01%/°C

Stability: Within +/- 0.05% (For 24 hours after warm-up)

Vibration: Per MIL-STD-810C, Method 514

Shock: Per MIL-STD 810C, Method 516

EMI/RFI: Linear power supplies have inherently low conducted and radiated noise levels. For most system applications, these power supplies will meet the requirements of FCC Class "B" and VDE 0871 for Class "B" equipment without additional noise filtering.

Cooling: Forced air @20 CFM

INPUT SPECIFICATIONS:

Multi Input (all units): 100/120/220/230/240 VAC selectable +/- 10% except 230 is +15%, -6%

Frequency Range: 47-63 Hz (Typical is 60 Hz. derate output 10% at 50 Hz.)

2

Transient Response Time: 50 *u*SEC at 50% load changes for outputs rated up to 6 A
100 *u*SEC at 50% load changes for outputs rated 6 A and over

Fuse Requirements: Units are *not* fused internally. For safe operation, user must provide input line fuse as per values given in table.

OUTPUT SPECIFICATIONS:

Line Regulation: 0.05% for 10% change

Load Regulation: 0.05% for 50% change

Ripple: 3.0 mV maximum peak-to-peak

DC Output Adjustment Range: +/- 5% minimum

Overvoltage Protection: All 5 volt outputs include built-in OVP as standard (setting is 6.2 V +/- 0.4 V). OVP is optionally available on other outputs.

Remote Sensing: Refer to the * in the Voltage/Current Rating chart for the output(s) with remote sensing.

Overload Protection: 125 to 150% foldback current limit

Dielectric Withstand Voltage (min.): 3750 VAC input/output
1250 VAC input/safety ground
500 VAC output/safety ground

3

PMI

757/100 $8.79

AMP-02

HIGH ACCURACY 8-PIN INSTRUMENTATION AMPLIFIER

Precision Monolithics Inc.

FEATURES

- Low Offset Voltage .... 100µV Max
- Low Drift .... 2µV/°C Max
- Wide Gain Range .... 1 to 10,000
- High Common-Mode Rejection .... 115dB Min
- High Bandwidth (G = 1000) .... 200kHz Typ
- Gain Equation Accuracy .... 0.5% Max
- Single Resistor Gain Set
- Input Overvoltage Protection
- Low Cost
- Available In Die Form

APPLICATIONS

- Differential Amplifier
- Strain Gauge Amplifier
- Thermocouple Amplifier
- RTD Amplifier
- Programmable Gain Instrumentation Amplifier
- Medical Instrumentation
- Data Acquisition Systems

ORDERING INFORMATION †

T_A = +25°C V_{IOS} MAX (µV)	V_{OOS} MAX (mV)	PLASTIC 8-PIN	OPERATING TEMPERATURE RANGE
100	4	AMP02EP	XIND
200	8	AMP02FP	XIND

† Burn-in is available on commercial and industrial temperature range parts in CerDIP, plastic DIP, and TO-can packages. For ordering information, see PMI's Data Book, Section 2.

GENERAL DESCRIPTION

The AMP-02 is the first precision instrumentation amplifier available in an 8-pin package. Gain of the AMP-02 is set by a single external resistor, and can range from 1 to 10,000. No gain set resistor is required for unity gain. The AMP-02 includes an input protection network that allows the inputs to be taken 60V beyond either supply rail without damaging the device.

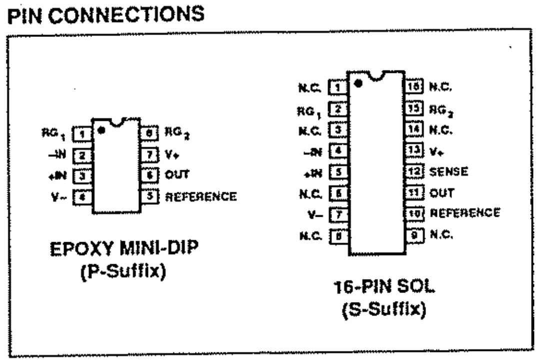
Laser trimming reduces the input offset voltage to under 100µV. Output offset voltage is below 4mV and gain accuracy is better than 0.5% for gain of 1000. PMI's proprietary thin-film resistor process keeps the gain temperature coefficient under 50 ppm/°C.

Due to the AMP-02's design, its bandwidth remains very high over a wide range of gain. Slew rate is over 4V/µs making the AMP-02 ideal for fast data acquisition systems.

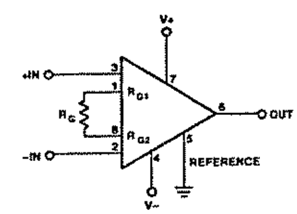
A reference pin is provided to allow the output to be referenced to an external DC level. This pin may be used for offset correction or level shifting as required. In the 8-pin package, sense is internally connected to the output.

For an instrumentation amplifier with the highest precision, consult the AMP-01 data sheet. For the highest input impedance and speed, consult the AMP-05 data sheet.

PIN CONNECTIONS



BASIC CIRCUIT CONNECTIONS



$$G = \frac{V_{OUT}}{(+IN) - (-IN)} = \left(\frac{50k\Omega}{R_G}\right) + 1$$

A.2 Instrumentation Amplifier.

ABSOLUTE MAXIMUM RATINGS

Supply Voltage .... ±18V
Common-Mode Input Voltage ...... [(V–) – 60V] to [(V+) + 60V]
Differential Input Voltage .... [(V–) – 60V] to [(V+) + 60V]
Output Short-Circuit Duration .... Continuous
Operating Temperature Range .... –40°C to +85°C
Storage Temperature Range .... –65°C to +150°C
Junction Temperature Range .... –65°C to +150°C
Lead Temperature (Soldering, 10 sec) .... +300°C

PACKAGE TYPE	Θ_{jA} (Note 2)	Θ_{jC}	UNITS
8-Pin Plastic DIP (P)	96	37	°C/W
16-Pin SOL (S)	92	27	°C/W

NOTE:
1. Absolute maximum ratings apply to both DICE and packaged parts, unless otherwise noted.
2. Θ_{jA} is specified for worst case mounting conditions, i.e., Θ_{jA} is specified for device in socket for P-DIP package; Θ_{jA} is specified for device soldered to printed circuit board for SOL package.

ELECTRICAL CHARACTERISTICS at $V_S = \pm15V$, $V_{CM} = 0V$, $T_A = +25°C$, unless otherwise noted.

PARAMETER	SYMBOL	CONDITIONS	AMP-02E MIN	AMP-02E TYP	AMP-02E MAX	AMP-02F MIN	AMP-02F TYP	AMP-02F MAX	UNITS
OFFSET VOLTAGE									
Input Offset Voltage	V_{IOS}	$T_A = +25°C$	–	20	100	–	40	200	µV
		$-40°C \le T_A \le +85°C$	–	50	200	–	100	350	
Input Offset Voltage Drift	TCV_{IOS}	$-40°C \le T_A \le +85°C$	–	0.5	2	–	1	4	µV/°C
Output Offset Voltage	V_{OOS}	$T_A = +25°C$	–	1	4	–	2	8	mV
		$-40°C \le T_A \le +85°C$	–	4	10	–	9	20	
Output Offset Voltage Drift	TCV_{OOS}	$-40°C \le T_A \le +85°C$	–	50	100	–	100	200	µV/°C
Power Supply Rejection	PSR	$V_S = \pm4.8V$ to $\pm18V$							dB
		G = 1000	115	128	–	110	115	–	
		G = 100	115	125	–	110	115	–	
		G = 10	100	110	–	95	100	–	
		G = 1	80	90	–	75	80	–	
		$V_S = \pm4.8V$ to $\pm18V$, $-40°C \le T_A \le +85°C$							dB
		G = 1000	110	120	–	105	110	–	
		G = 100	110	120	–	105	110	–	
		G = 10	95	110	–	90	95	–	
		G = 1	75	90	–	70	75	–	
INPUT CURRENT									
Input Bias Current	I_B	$T_A = +25°C$	–	2	10	–	4	20	nA
		$-40°C \le T_A \le +85°C$	–	12	30	–	20	40	
Input Bias Current Drift	TCI_B	$-40°C \le T_A$ +85°C	–	150	–	–	250	–	pA/°C
Input Offset Current	I_{OS}	$T_A = +25°C$	–	1.2	5	–	2	10	nA
		$-40°C \le T_A \le +85°C$	–	1.8	15	–	3	20	
Input Offset Current Drift	TCI_{OS}	$-40°C \le T_A \le +85°C$	–	9	–	–	15	–	pA/°C
INPUT									
Input Resistance	R_{IN}	Differential, G ≤ 1000	–	10	–	–	10	–	GΩ
		Common-Mode, G = 1000	–	16.5	–	–	16.5	–	
Input Voltage Range	IVR	$T_A = +25°C$ (Note 3)	±11	–	–	±11	–	–	V
		$-40°C \le T_A \le +85°C$	±11	–	–	±11	–	–	
Common-Mode Rejection	CMR	$V_{CM} = \pm11V$							dB
		G = 1000	115	120	–	110	115	–	
		G = 100	115	120	–	110	115	–	
		G = 10	100	115	–	95	110	–	
		G = 1	80	95	–	75	90	–	
		$V_{CM} = \pm11V$, $-40°C \le T_A \le +85°C$							dB
		G = 1000	110	120	–	105	115	–	
		G = 100	110	120	–	105	115	–	
		G = 10	95	110	–	90	105	–	
		G = 1	75	90	–	70	85	–	

A.2 Instrumentation Amplifier.

ELECTRICAL CHARACTERISTICS at $V_S = \pm15V$, $V_{CM} = 0V$, $T_A = +25°C$, unless otherwise noted. *Continued*

PARAMETER	SYMBOL	CONDITIONS	AMP-02E MIN	AMP-02E TYP	AMP-02E MAX	AMP-02F MIN	AMP-02F TYP	AMP-02F MAX	UNITS
GAIN									
Gain Equation Accuracy	$G = \frac{50k\Omega}{R_G} + 1$	G = 1000	–	–	0.50	–	–	0.70	%
		G = 100	–	–	0.30	–	–	0.50	
		G = 10	–	–	0.25	–	–	0.40	
		G = 1	–	–	0.02	–	–	0.05	
Gain Range	G		1	–	10k	1	–	10k	V/V
Nonlinearity		G = 1 to 1000	–	0.006	–	–	0.006	–	%
Temperature Coefficient	G_{TC}	$1 \le G \le 1000$ (Notes 1, 2)	–	20	50	–	20	50	ppm/°C
OUTPUT RATING									
Output Voltage Swing	V_{OUT}	$T_A = +25°C$, $R_L = 1k\Omega$	±12	±13	–	±12	±13	–	V
		$R_L = 1k\Omega$, $-40°C \le T_A \le +85°C$	±11	±12	–	±11	±12	–	
Positive Current Limit		Output-to-Ground Short	–	22	–	–	22	–	mA
Negative Current Limit		Output-to-Ground Short	–	32	–	–	32	–	mA
NOISE									
Voltage Density, RTI	e_n	$f_O = 1kHz$ G = 1000	–	9	–	–	9	–	$nV/\sqrt{Hz}$
		G = 100	–	10	–	–	10	–	
		G = 10	–	18	–	–	18	–	
		G = 1	–	120	–	–	120	–	
Noise Current Density, RTI	i_n	$f_O = 1kHz$, G = 1000	–	0.4	–	–	0.4	–	$pA/\sqrt{Hz}$
Input Noise Voltage	$e_{n\,p\text{-}p}$	0.1Hz to 10Hz G = 1000	–	0.4	–	–	0.4	–	$\mu V_{p\text{-}p}$
		G = 100	–	0.5	–	–	0.5	–	
		G = 10	–	1.2	–	–	1.2	–	
		G = 1	–	10	–	–	10	–	
DYNAMIC RESPONSE									
Small-Signal Bandwidth (–3dB)	BW	G = 1	–	1200	–	–	1200	–	kHz
		G = 10	–	300	–	–	300	–	
		G = 100	–	200	–	–	200	–	
		G = 1000	–	200	–	–	200	–	
Slew Rate	SR	G = 10, $R_L = 1k\Omega$	4	6	–	4	6	–	V/µs
Settling Time	t_S	To 0.01% ±10V Step G = 1 to 1000	–	10	–	–	10	–	µs

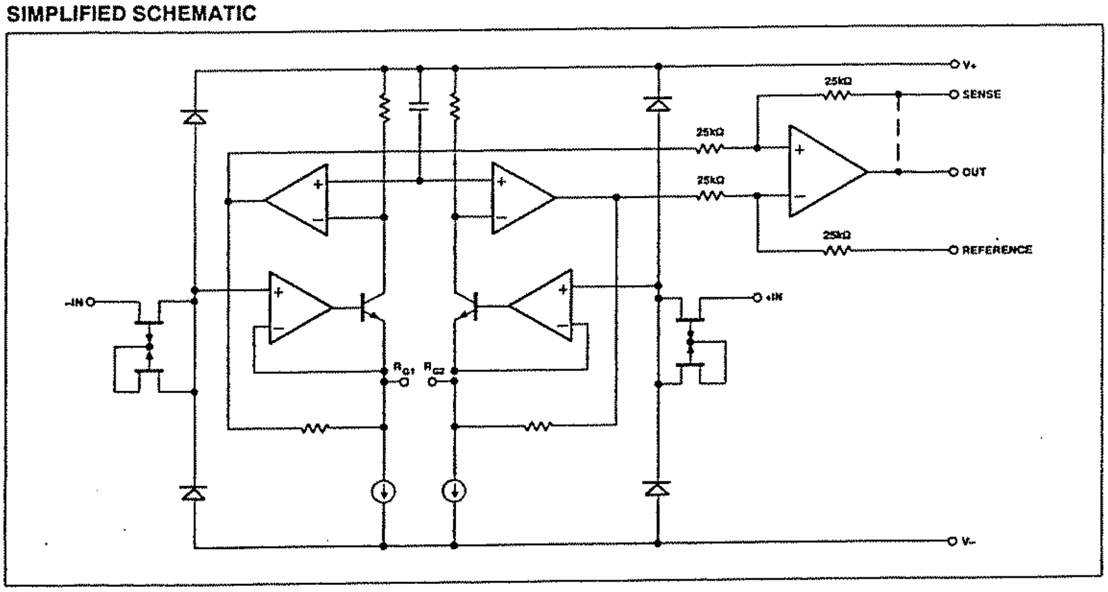
NOTES:
1. Guaranteed by design.
2. Gain tempco does not include the effects of external component drift.
3. Input voltage range guaranteed by common-mode rejection test.

A.2 Instrumentation Amplifier.

ELECTRICAL CHARACTERISTICS at $V_S = \pm15V$, $V_{CM} = 0V$, $T_A = +25°C$, unless otherwise noted. *Continued*

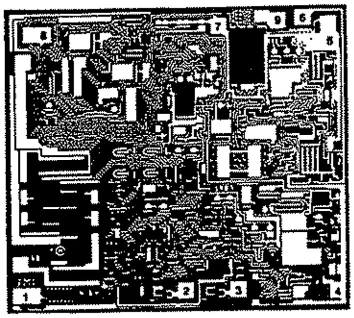
PARAMETER	SYMBOL	CONDITIONS	AMP-02E MIN	AMP-02E TYP	AMP-02E MAX	AMP-02F MIN	AMP-02F TYP	AMP-02F MAX	UNITS
SENSE INPUT									
Input Resistance	R_{IN}		–	25	–	–	25	–	kΩ
Voltage Range			–	±11	–	–	±11	–	V
REFERENCE INPUT									
Input Resistance	R_{IN}		–	50	–	–	50	–	kΩ
Voltage Range			–	±11	–	–	±11	–	V
Gain to Output			–	1	–	–	1	–	V/V
POWER SUPPLY									
Supply Voltage Range	V_S		±4.5	–	±18	±4.5	–	±18	V
Supply Current	I_{SY}	$T_A = +25°C$	–	5	6	–	5	6	mA
		$-40°C \le T_A \le +85°C$	–	5	6	–	5	6	

SIMPLIFIED SCHEMATIC



A.2 Instrumentation Amplifier.

DICE CHARACTERISTICS



DIE SIZE 0.103 x 0.116 inch, 11,948 sq. mils
(2.62 x 2.95 mm, 7.73 sq. mm)

1. RG_1
2. –IN
3. +IN
4. V–
5. REFERENCE
6. OUT
7. V+
8. RG_2
9. SENSE

Connect Substrate to V–

For additional DICE ordering information, refer to PMI's Data Book, Section 2.

WAFER TEST LIMITS at V_S = ±15V, V_{CM} = 0V, T_A = +25°C, unless otherwise noted.

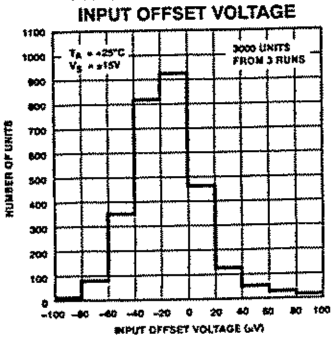
PARAMETER	SYMBOL	CONDITIONS	AMP-02GBC LIMITS	UNITS
Input Offset Voltage	V_{IOS}		200	µV MAX
Output Offset Voltage	V_{OOS}		8	mV MAX
Power Supply Rejection	PSR	V_S = ±4.8V to ±18V		dB MIN
		G = 1000	110	
		G = 100	110	
		G = 10	95	
		G = 1	75	
Input Bias Current	I_B		20	nA MAX
Input Offset Current	I_{OS}		10	nA MAX
Input Voltage Range	IVR	Guaranteed by CMR Tests	±11	V MIN
Common-Mode Rejection	CMR	V_{CM} = ±11V		dB MIN
		G = 1000	110	
		G = 100	110	
		G = 10	95	
		G = 1	75	
Gain Equation Accuracy		$G = \frac{50k\Omega}{R_G} + 1$, G = 1000	0.7	% MAX
Output Voltage Swing	V_{OUT}	R_L = 1kΩ	±12	V MIN
Supply Current	I_{SY}		6	mA MAX

NOTE:
Electrical tests are performed at wafer probe to the limits shown. Due to variations in assembly methods and normal yield loss, yield after packaging is not guaranteed for standard product dice. Consult factory to negotiate specifications based on dice lot qualifications through sample lot assembly and testing.

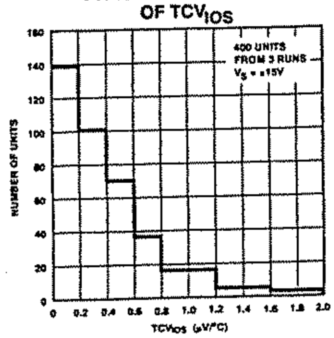
A.2 Instrumentation Amplifier.

TYPICAL PERFORMANCE CHARACTERISTICS

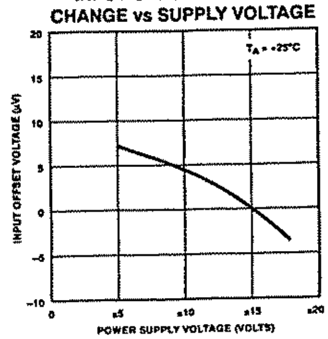
TYPICAL DISTRIBUTION OF INPUT OFFSET VOLTAGE



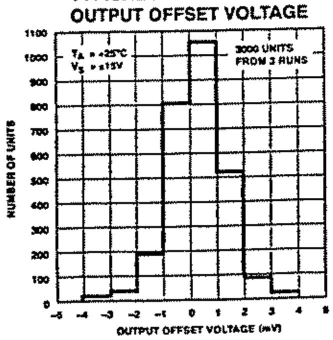
TYPICAL DISTRIBUTION OF TCV_{IOS}



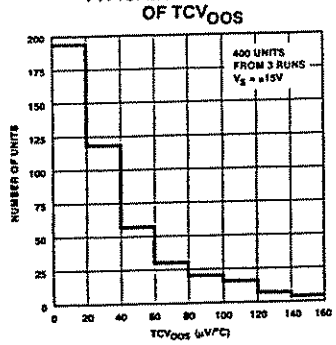
INPUT OFFSET VOLTAGE CHANGE vs SUPPLY VOLTAGE



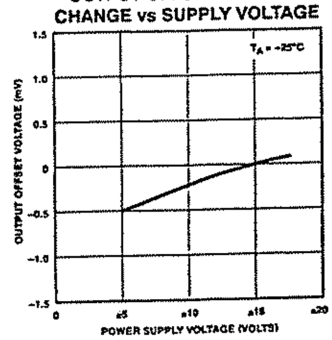
TYPICAL DISTRIBUTION OF OUTPUT OFFSET VOLTAGE



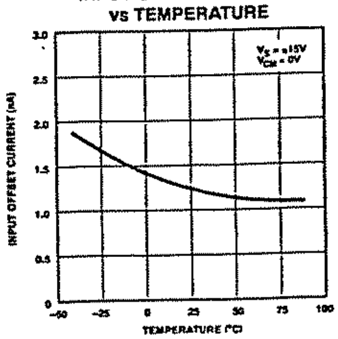
TYPICAL DISTRIBUTION OF TCV_{OOS}



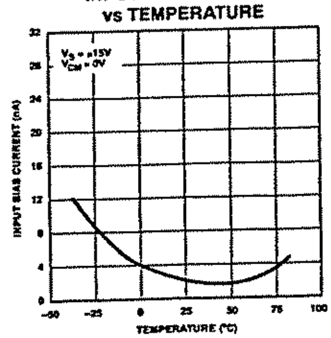
OUTPUT OFFSET VOLTAGE CHANGE vs SUPPLY VOLTAGE



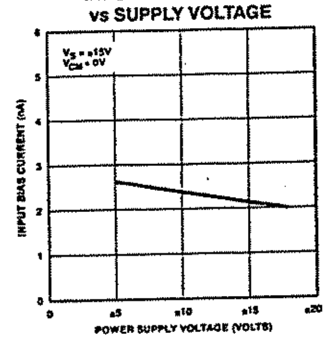
INPUT OFFSET CURRENT vs TEMPERATURE



INPUT BIAS CURRENT vs TEMPERATURE



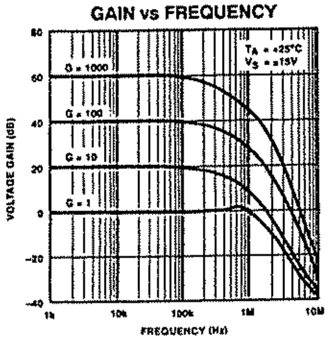
INPUT BIAS CURRENT vs SUPPLY VOLTAGE



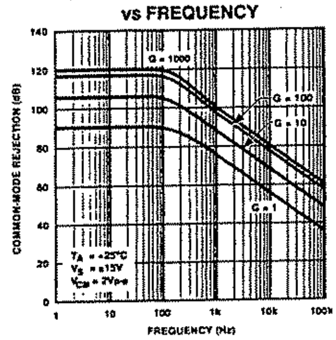
A.2 Instrumentation Amplifier.

TYPICAL PERFORMANCE CHARACTERISTICS *Continued*

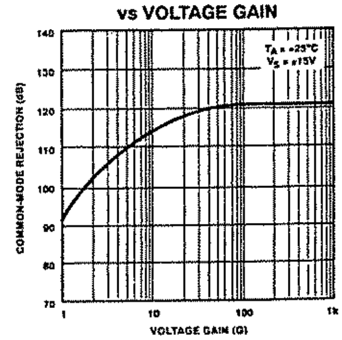
CLOSED-LOOP VOLTAGE GAIN vs FREQUENCY



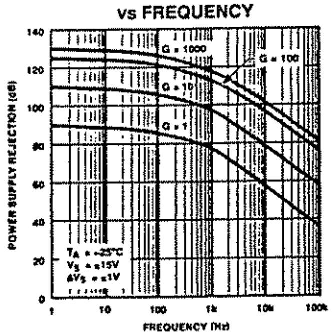
COMMON-MODE REJECTION vs FREQUENCY



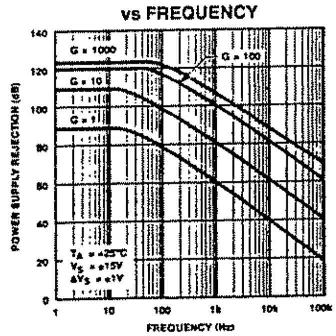
COMMON-MODE REJECTION vs VOLTAGE GAIN



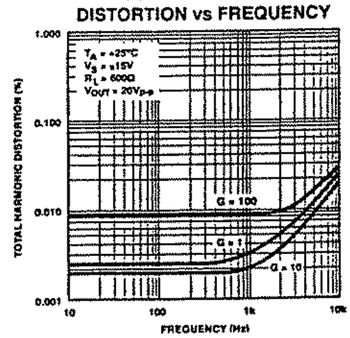
POSITIVE PSR vs FREQUENCY



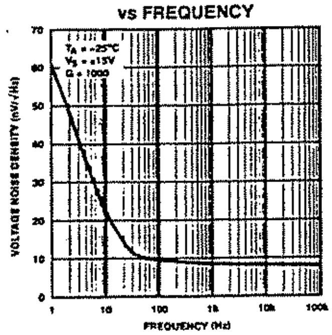
NEGATIVE PSR vs FREQUENCY



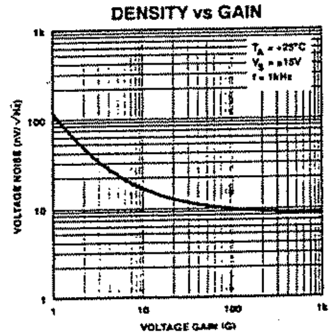
TOTAL HARMONIC DISTORTION vs FREQUENCY



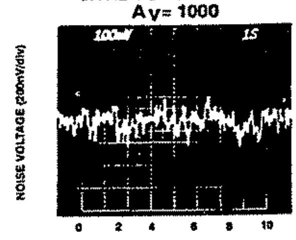
VOLTAGE NOISE DENSITY vs FREQUENCY



RTI VOLTAGE NOISE DENSITY vs GAIN



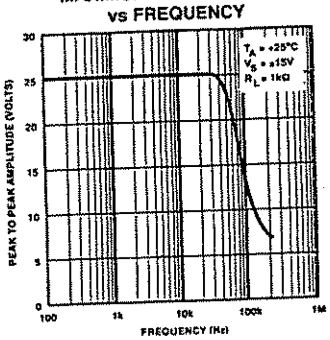
0.1Hz TO 10Hz NOISE A_V= 1000



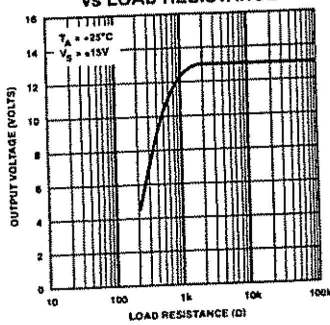
A.2 Instrumentation Amplifier.

TYPICAL PERFORMANCE CHARACTERISTICS *Continued*

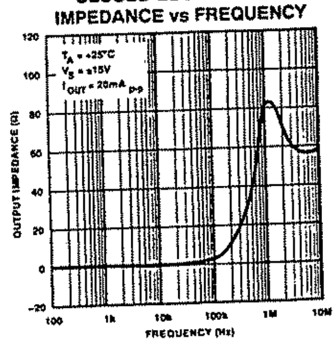
MAXIMUM OUTPUT SWING vs FREQUENCY



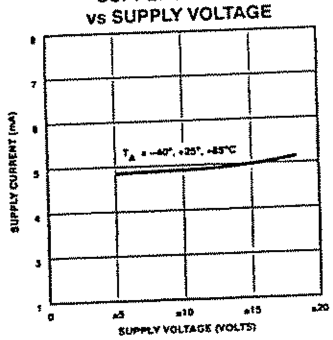
MAXIMUM OUTPUT VOLTAGE vs LOAD RESISTANCE



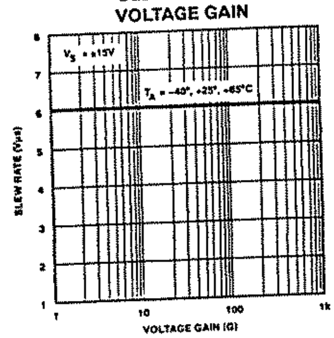
CLOSED LOOP OUTPUT IMPEDANCE vs FREQUENCY



SUPPLY CURRENT vs SUPPLY VOLTAGE



SLEW RATE vs VOLTAGE GAIN



A.2 Instrumentation Amplifier.

APPLICATIONS INFORMATION

INPUT AND OUTPUT OFFSET VOLTAGES

Instrumentation amplifiers have independent offset voltages associated with the input and output stages. The input offset component is directly multiplied by the amplifier gain, whereas output offset is independent of gain. Therefore, at low gain, output-offset-errors dominate, while at high gain, input-offset-errors dominate. Overall offset voltage, V_{OS}, referred to the output (RTO) is calculated as follows:

$$V_{OS}\ (RTO) = (V_{IOS} \times G) + V_{OOS}$$

where V_{IOS} and V_{OOS} are the input and output offset voltage specifications and G is the amplifier gain.

The overall offset voltage drift TCV_{OS}, referred to the output, is a combination of input and output drift specifications. Input offset voltage drift is multiplied by the amplifier gain, G, and summed with the output offset drift:

$$TCV_{OS}\ (RTO) = (TCV_{IOS} \times G) + TCV_{OOS}$$

where TCV_{IOS} is the input offset voltage drift, and TCV_{OOS} is the output offset voltage drift. Frequently, the amplifier drift is referred back to the input (RTI) which is then equivalent to an input signal change:

$$TCV_{OS}\ (RTI) = TCV_{IOS} + \frac{TCV_{OOS}}{G}$$

For example, the maximum input-referred drift of an AMP-02EP set to G = 1000 becomes:

$$TCV_{OS}\ (RTI) = 2\mu V/°C + \frac{100\mu V/°C}{1000} = 2.1\mu V/°C$$

INPUT BIAS AND OFFSET CURRENTS

Input transistor bias currents are additional error sources which can degrade the input signal. Bias currents flowing through the signal source resistance appear as an additional offset voltage. Equal source resistance on both inputs of an IA will minimize offset changes due to bias current variations with signal voltage and temperature. However, the difference between the two bias currents, the input offset current, produces an error. The magnitude of the error is the offset current times the source resistance.

A current path must always be provided between the differential inputs and analog ground to ensure correct amplifier operation. Floating inputs, such as thermocouples, should be grounded close to the signal source for best common-mode rejection.

GAIN

The AMP-02 only requires a single external resistor to set the voltage gain. The voltage gain, G, is:

$$G = \frac{50k\Omega}{R_G} + 1$$

and

$$R_G = \frac{50k\Omega}{G - 1}$$

The voltage gain can range from 1 to 10,000. A gain set resistor is not required for unity-gain applications. Metal-film or wire-wound resistors are recommended for best results.

The total gain accuracy of the AMP-02 is determined by the tolerance of the external gain set resistor, R_G, combined with the gain equation accuracy of the AMP-02. Total gain drift combines the mismatch of the external gain set resistor drift with that of the internal resistors (20ppm/°C typ). Maximum gain drift of the AMP-02 independent of the external gain set resistor is 50 ppm/°C.

All instrumentation amplifiers require attention to layout so thermocouple effects are minimized. Thermocouples formed between copper and dissimilar metals can easily destroy the TCV_{OS} performance of the AMP-02 which is typically 0.5µV/°C. Resistors themselves can generate thermoelectric EMFs when mounted parallel to a thermal gradient.

The AMP-02 uses the triple op amp instrumentation amplifier configuration with the input stage consisting of two transimpedance amplifiers followed by a unity-gain differential amplifier. The input stage and output buffer are laser-trimmed to increase gain accuracy. The AMP-02 maintains wide bandwidth at all gains as shown in Figure 1. For voltage gains greater than 10, the bandwidth is over 200kHz. At unity-gain, the bandwidth of the AMP-02 exceeds 1MHz.

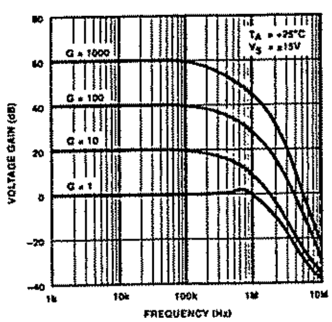


FIGURE 1: *The AMP-02 keeps its bandwidth at high gains.*

COMMON-MODE REJECTION

Ideally, an instrumentation amplifier responds only to the difference between the two input signals and rejects common-mode voltages and noise. In practice, there is a small change in output voltage when both inputs experience the same common-mode voltage change; the ratio of these voltages is called the common-mode gain. Common-mode rejection (CMR) is the logarithm of the ratio of differential-mode gain to common-mode gain, expressed in dB. Laser trimming is used to achieve the high CMR of the AMP-02.

A.2 Instrumentation Amplifier.

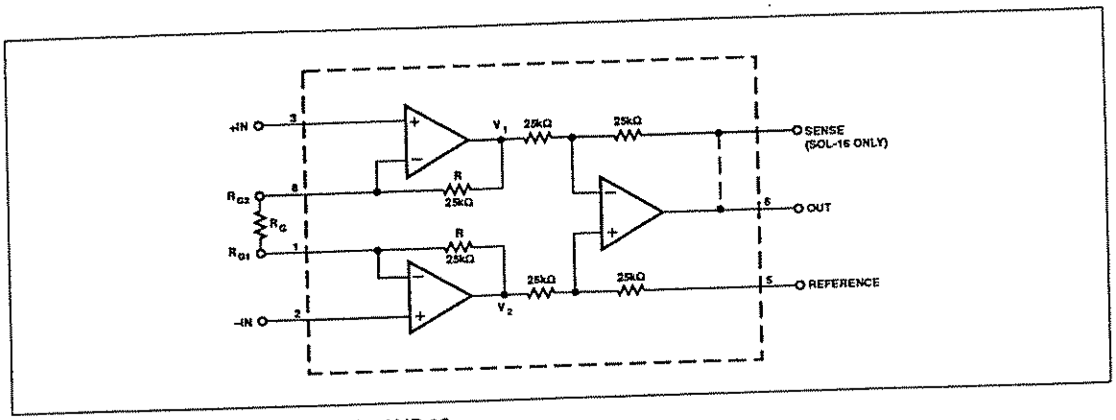


FIGURE 2: *Triple Op Amp Topology of the AMP-02*

Figure 2 shows the triple op amp configuration of the AMP-02. With all instrumentation amplifiers of this type, it is critical not to exceed the dynamic range of the input amplifiers. The amplified differential input signal and the input common-mode voltage must not force the amplifier's output voltage beyond ±12V (V_S = ±15V) or nonlinear operation will result.

The input stage amplifier's output voltages at V_1 and V_2 equals:

$$V_1 = -\left(1 + \frac{2R}{R_G}\right)\frac{V_D}{2} + V_{CM}$$

$$= -G\frac{V_D}{2} + V_{CM}$$

$$V_2 = \left(1 + \frac{2R}{R_G}\right)\frac{V_D}{2} + V_{CM}$$

$$= G\frac{V_D}{2} + V_{CM}$$

where

V_D = Differential input voltage
= (+IN) − (−IN)

V_{CM} = Common-mode input voltage

G = Gain of instrumentation amplifier

If V_1 and V_2 can equal ±12V maximum, then the common-mode input voltage range is:

$$CMVR = \pm\left(12V - \frac{GV_D}{2}\right)$$

GROUNDING

The majority of instruments and data acquisition systems have separate grounds for analog and digital signals. Analog ground may also be divided into two or more grounds which will be tied together at one point, usually the analog power-supply ground. In addition, the digital and analog grounds may be joined, normally at the analog ground pin on the A to D converter. Following this basic practice is essential for good circuit performance.

Mixing grounds causes interactions between digital circuits and the analog signals. Since the ground returns have finite resistance and inductance, hundreds of millivolts can be developed between the system ground and the data acquisition components. Using separate ground returns minimizes the current flow in the sensitive analog return path to the system ground point. Consequently, noisy ground currents from logic gates do not interact with the analog signals.

Inevitably, two or more circuits will be joined together with their grounds at differential potentials. In these situations, the differential input of an instrumentation amplifier, with its high CMR, can accurately transfer analog information from one circuit to another.

SENSE AND REFERENCE TERMINALS

The sense terminal completes the feedback path for the instrumentation amplifier output stage and is internally connected directly to the output. For SOL devices, connect the sense terminal to the output. The output signal is specified with respect to the reference terminal, which is normally connected to analog ground. The reference may also be used for offset correction or level shifting. A reference source resistance will reduce the common-mode rejection by the ratio of 25kΩ/R_{REF}. If the reference source resistance is 1Ω, then the CMR will be reduced to 88dB (25kΩ/1Ω = 88dB).

A.2 Instrumentation Amplifier.

OVERVOLTAGE PROTECTION

Instrumentation amplifiers invariably sit at the front end of instrumentation systems where there is a high probability of exposure to overloads. Voltage transients, failure of a transducer, or removal of the amplifier power supply while the signal source is connected may destroy or degrade the performance of an unprotected device. A common technique used is to place limiting resistors in series with each input, but this adds noise. The AMP-02 includes internal protection circuitry that limits the input current to ±4mA for a 60V differential overload (see Figure 3) with power off, ±2.5mA with power on.

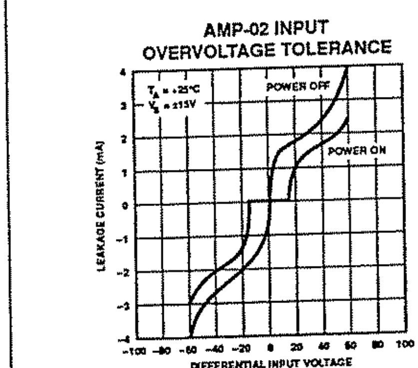


FIGURE 3: *AMP-02's input protection circuitry limits input current during overvoltage conditions.*

POWER SUPPLY CONSIDERATIONS

Achieving the rated performance of precision amplifiers in a practical circuit requires careful attention to external influences. For example, supply noise and changes in the nominal voltage directly affect the input offset voltage. A PSR of 80dB means that a change of 100mV on the supply, not an uncommon value, will produce a 10μV input offset change. Consequently, care should be taken in choosing a power unit that has a low output noise level, good line and load regulation, and good temperature stability. In addition, each power supply should be properly bypassed.

A.3 Connectors to and from SGC racks.

Dimensioning:
Dimensions are in inches and millimeters.
Values in brackets are metric equivalents.

CPC Connectors Series 1

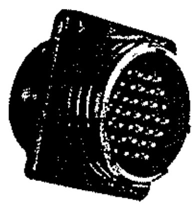
Series 1

Part numbers listed are for connectors only; order contacts separately.

Related Product Data:

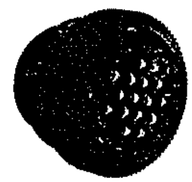
Contacts—pages 11 through 13
Contact Arrangements—page 14
Component Dimensions—page 16
Accessories—pages 30 through 37
Performance Characteristics—page 5
Application Tooling—page 52
Technical Documents—page 53

Standard Sex Connectors



Square Flange Receptacle
(Accepts Multimate Pins)

Free-Hanging Receptacle
(Accepts Multimate Pins)



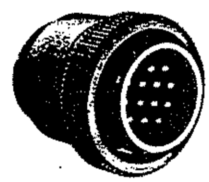
Plug
(Accepts Multimate Sockets)

Arrangement	Square Flange Receptacle	Free-Hanging Receptacle	Plug
11-4	206061-1	206153-1	206060-1
13-9	206705-1	206705-2	206708-1
17-16	206036-1	206036-3	206037-1
23-24	206838-1	206838-2	206837-1
23-37	206151-1	206151-2	206150-1

Reverse Sex Connectors

Square Flange Receptacle
(Accepts Multimate Sockets)

Free-Hanging Receptacle
(Accepts Multimate Sockets)



Plug
(Accepts Multimate Pins)

Arrangement	Square Flange Receptacle	Free-Hanging Receptacle	Plug
11-4	206430-1	206430-2	206429-1
17-14	206043-1	206043-3	206044-1
23-37	206306-1	206306-2	206305-1

Note: Maximum wire insulation dia. is .100 [2.54], except for arrangement 23-24 which will accept insulation dia. of .150 [3.81] max.

Replacement Coupling Rings Available

Shell Size	Part No.
11	206089-1
13	206707-1
17	205958-1
17	213582-1*
23	206251-1

*Impact modified plastic

For drawings, technical data or samples, contact your AMP sales engineer or call the AMP Product Information Center **1-800-522-6752.**

AMP INCORPORATED, HARRISBURG, PA 17105 PHONE 717-564-0100 TWX 510-657-4110 • PRODUCT INFORMATION CENTER PHONE 1-800-522-6752

A.3 Connectors to and from SGC racks.

Multimate Contacts
Series 1

Dimensioning:
Dimensions are in inches and millimeters.
Values in brackets are metric equivalents.
Charts contain dimensions in inches over millimeters

Type III+ (Crimp)

Current Carrying Capabilities Type III+ Contact—

Contact Size—16
Pin Diameter—.062 [1.57]
***Test Current**—13 amperes
(Single contact, free-air test current; not be construed as contact rating current. Use only for testing.)

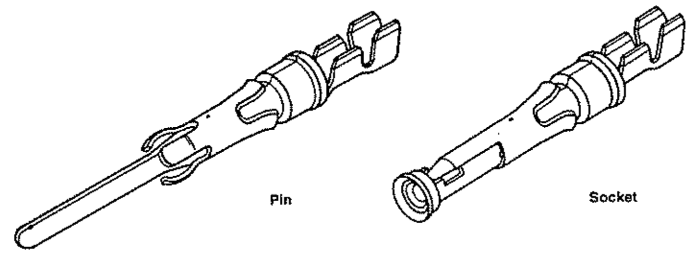
Materials:

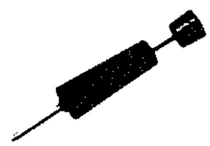
Contact Body—Brass
Spring—Stainless Steel

Contact Finish:

A—.000015 [0.00038] gold on the electrical engagement area over .000050 [0.00127] nickel.
B—.000030 [0.00076] gold on the electrical engagement area over .000050 [0.00127] nickel.
C—Tin

***Note:** Total current capacity of each contact in any given connector is dependent on the heat rise resulting from the combination of electrical loads of all contacts in the connector arrangement and the maximum ambient temperature in which the connector will be operating.





Extraction Tool No. 305183

Wire Size Range AWG	Wire Size Range (mm²)	Ins. Dia. Range	Contact Finish Code	Strip Form Contact No. Pin	Strip Form Contact No. Socket	Loose Piece Contact No. Pin	Loose Piece Contact No. Socket	Tooling No. Applicator	Tooling No. Hand Tool
30-25	0.05-0.15	.040-.060 1.02-1.52	C	66425-6	66424-6	—	—	466598-2[1]	90066-7
			A	66425-7	66424-7	66429-3	66428-3		
			B	66425-8	66424-8	66429-4	66428-4		
		.014-.030 0.36-0.76	A	66393-7	66394-7	—	—	466585-3[1]	90225-2
			B	66393-8	66394-8	66406-4	66405-4		
26-24	0.12-0.2	.035-.055 0.89-1.4	C	66106-6	66108-6	66107-2	66109-2	466321-4[1] or 466908-2[2]	90066-7 or 90277-1[3]
			A	66106-7	66108-7	66107-3	66109-3		
			B	66106-8	66108-8	66107-4	66109-4		
24-20	0.2-0.6	.040-.080 1.02-2.03	C	66102-7	66104-7	66103-2	66105-2 ←	466323-4[1] or 466907-2[2]	90066-7 or 90067-4 90277-1[3]
			A	66102-8	66104-8	66103-3	66105-3		
			B	66102-9	66104-9	66103-4	66105-4		
		.080-.100 2.03-2.54	C	66332-5	66331-5	66400-1	66399-1	466324-2[1] or 466942-1[2]	90067-5 or 90225-2 90277-1[3]
			A	66332-7	66331-7	66400-3	66399-3		
			B	66332-8	66331-8	66400-4	66399-4		
		.060-.135[5] 1.52-3.43	C	66564-6	66563-6	66566-2	66565-2	466383-2[1]	90331-1
			A	—	66563-7	66566-3	66565-3		
			B	66564-8	66563-8	66566-4	66565-4		
18-16	0.8-1.4	.080-.100 2.03-2.54	C	66098-7	66100-7	66099-2	66101-2	466325-2[1] or 466906-1[2]	90067-4 or 90067-5 90277-1[3]
			A	66098-8	66100-8	66099-3	66101-3		
			B	66098-9	66100-9	66099-4	66101-4		
18-14[4]	0.8-2	.110-.150[4] 2.79-3.81	C	66597-1	66598-1	66602-1	66601-1	466752-2[1] or 466958-1[2]	90310-2
			B	66597-2	66598-2	66602-2	66601-2		
18-14	0.8-2	.080-.100 2.03-2.54	C	66359-6	66358-6	66361-2	66360-2	466326-4[1] or 466923-2[2]	90310-3
			A	66359-9	66358-9	66361-3	66360-3		
			B	1-66359-0	1-66358-0	66361-4	66360-4		

[1]These quick-change applicators are used in AMP machines shown on page 52, except the AMP-O-MATIC Stripper/Crimper Machine.
[2]These applicators are used only in the AMP-O-MATIC Stripper Crimper Machine, page 52.
[3]Economy hand tool No. 90277-1 is available for field repair use only.
[4]Contacts can only be used for Series 1 connectors (Arrangement No. 23-24), Series 4 connectors (Arrangement Nos. 23-13M, 23-18M and 23-22M) and VDE connectors
[5]When crimping insulation with diameters greater than .100 [2.54], contacts can only be used for Series 1 connectors (Arrangement No. 23-24), Series 4 connectors (Arrangement Nos. 23-13M, 23-16M and 23-22M) and VDE connectors.
Insertion Tool—Tweezer Style—No. 91002-1
Insertion Tool for High Density Application—No. 211300-1 for insulation dia. greater than .070 [1.78], No. 211300-2 for insulation dia. less than .070 [1.78] Instruction Sheet No. 156736.
Extraction Tool No. 305183

A.3 Connectors to and from SGC racks.

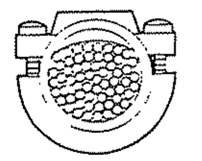
Dimensioning:
Dimensions are in inches and millimeters.
Values in brackets are metric equivalents.
Charts contain dimensions in inches over millimeters.

CPC Connector Accessories
Cable Clamps

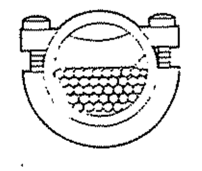
Cable clamps provide strain relief and can be used on all series receptacles and plugs.

Material:

Black thermoplastic heat-stabilized, fire-resistant, self-extinguishing, 94V-1 rated



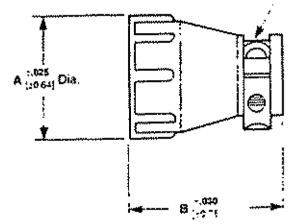
The clamping area can be adjusted by reversing the clamping insert as shown below.

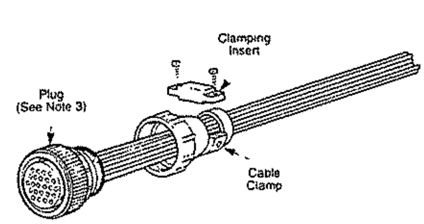


For additional information concerning cable clamps, refer to Instruction Sheet IS 7582.

For drawings, technical data or samples, contact your AMP sales engineer or call the AMP Product Information Center 1-800-522-6752.

Standard Size



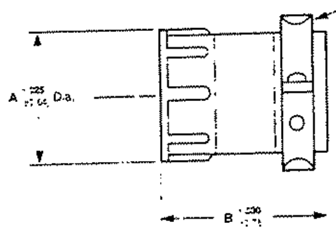


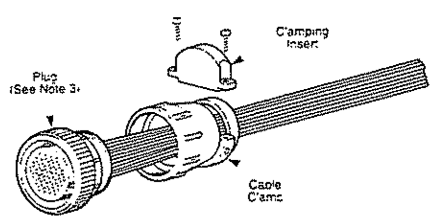
Shell Size	Dimensions A	Dimensions B	Cable O.D. (Max.)	Thread Size	Part No. Individually Packaged	Part No. Bulk Packaged*
11	.825 20.96	1.250 31.75	.329 8.36	5/8-24 UNEF-2B	206062-3	206062-4** (400)
13	.950 24.13	1.400 35.56	.453 11.51	3/4-20 UNEF-2B	206966-1	206966-2** (200)
17	1.125 28.58	1.400 35.56	.453 11.51	15/16-20 UNEF-2B	206070-1	206070-3** (200)
23	1.600 40.64	1.555 39.5	.703 17.86	1-3/8-18 UNEF-2B	206138-1	206138-2** (100)

*Numbers in parentheses specify, in multiples, the minimum quantity of parts that can be ordered.
**Packaging includes two screws: shell sizes 11-17: screw length .500 [12.7]; shell size 23: screw length .625 [15.88].

Notes:
1. Clamping areas adjustable by inverting or changing clamping inserts. The quantity of inserts supplied with each assembly is as follows: for size 11 cable clamps, one insert; for all other cable clamps, two inserts.
2. Components for all cable clamps are packaged unassembled. This includes the cable clamp, two screws and the clamping inserts.
3. Cable clamps can be threaded directly onto plugs or receptacles, or onto back-shell extenders (page 32).
4. Replacement screws are available in the following sizes: 3/8 in. [9.52]—19024-1, 1/2 in. [12.7]—19024-2, 5/8 in. [15.88]—19024-3, 1 in. [25.4]—19024-4.
5. Cable clamp inserts not sold separately.

Large Size





Shell Size	Dimensions A	Dimensions B	Cable O.D. (Max.)	Thread Size	Part No. Individually Packaged	Part No. Bulk Packaged*
11	.850 21.59	1.450 36.83	.453 11.51	5/8-24 UNEF-2B	206358-1	206358-2** (200)
13	9.50 24.13	1.400 35.56	.703 17.86	3/4-20 UNEF-2B	207008-1	207008-2** (100)
17	1.131 28.73	1.655 42.04	.703 17.86	15/16-20 UNEF-2B	206322-1	206322-2** (100)
23	1.600 40.64	1.655 42.04	1.125 28.58	1-3/8-18 UNEF-2B	206512-1	206512-2** (75)

*Numbers in parentheses specify, in multiples, the minimum quantity of parts that can be ordered.
**Packaging includes two screws: shell size 11: screw length .500 [12.7]; shell sizes 13-23: screw length .625 [15.88].

Notes:
1. Clamping areas adjustable by inverting or changing clamping inserts. The quantity of inserts supplied with each assembly is as follows: for size 23 cable clamps, four inserts; for all other cable clamps, two inserts.
2. Components for all cable clamps are packaged unassembled. This includes the cable clamp, two screws and the clamping inserts.
3. Cable clamps can be threaded directly onto plugs or receptacles, or onto back-shell extenders (page 32).
4. Replacement screws are available in the following sizes: 3/8 in. [9.52]—19024-1, 1/2 in. [12.7]—19024-2, 5/8 in. [15.88]—19024-3, 1 in. [25.4]—19024-4.
5. Cable clamp inserts not sold separately.

Accessories

A.4 Connectors for header pins on SGC card.

MTA-100 IDC Connectors—Closed End and Feed-Thru

Material and Finish

Housing —UL94V-2 rated, type 6/6 and 6/12 nylon, see below for color; or UL94V-0 rated, nylon, black

Contacts —Phosphor bronze, post tin plated, or .000030 [0.00076] post gold-plated over nickel

Note: Connectors with contacts .000015 [0.00038] post gold plated over nickel, available upon request. Minimums may apply.

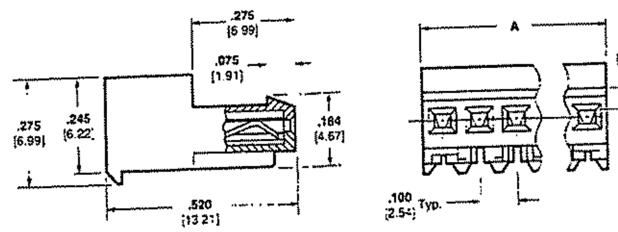
UL94V-2 Color Coding by Wire Size

28 AWG —Green
26 AWG —Blue
24 AWG —Natural
22 AWG —Red

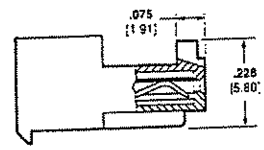
UL94V-0 —Black

For mating half, see pages 10 thru 14.

Closed End Connectors

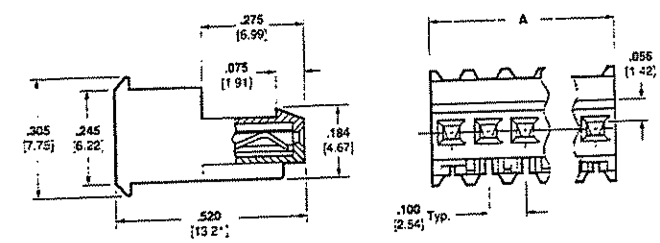


Without Polarizing Tabs

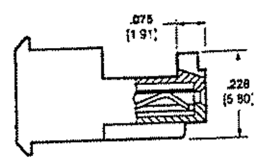


With Polarizing Tabs

Feed-Thru Connectors



Without Polarizing Tabs



With Polarizing Tabs

For drawings, technical data or samples, contact your AMP sales engineer or call the AMP Product Information Center 1-800-522-6752
Dimensions are in inches and millimeters unless otherwise specified. Values in brackets are metric equivalents.
Specifications subject to change. Consult AMP Incorporated for latest specifications.

A.4 Connectors for header pins on SGC card.

MTA-100 IDC Connectors — Closed End and Feed-Thru (Continued)

Connector Ordering Information

The "Base Part Numbers" Chart at right shows the base part number and number of circuits available for the described connectors.

Prefixes and suffixes are determined by the number of circuit positions in the connector. For example the complete part number for a 10-position closed end connector without polarizing tabs for 22 AWG wire would be:

Base number **640440** plus prefix-and-suffix

1- — -0

The correct ordering number is

1-640440-0

Notes:

1. Connector circuits can be molded closed for keying purposes. Minimums may apply
2. Connectors with contacts .000015 [0.00038] post gold plated over nickel available upon request. Minimums may apply
3. Contact AMP Incorporated for available circuit sizes.
4. Other circuit sizes are available upon request. Minimums may apply

UL94V-2 Color Coding by Wire Size

28 AWG — Green
26 AWG — Blue
24 AWG — Natural
22 AWG — Red

UL94V-0 — Black

For mating half, see pages 10 thru 14

Base Part Numbers and Connector Availability

Connector Type & Wire Size	Closed End				Feed-Thru			
	Without Tabs		With Tabs		Without Tabs		With Tabs	
	Connector Part Nos.	No. of Circuits	Connector Part Nos.	No. of Circuits	Connector Part Nos.	No. of Circuits	Connector Part Nos.	No. of Circuits
Standard UL94V-2, Tin Plated								
22 AWG 0.3-0.4 mm²	640440	2–28	643813	2–28	640620	2–28	6445[illegible]	2–15
24 AWG 0.2 mm²	640441	2–28	643814	2–28	640621	2–28	644563	2–15
26 AWG 0.12-0.15 mm²	640442	2–28	643815	2–28	640622[4]	2–14	644564[4]	2–15
28 AWG 0.08-0.09 mm²	640443[4]	2–14	643816[4]	2–14	640623[4]	2–14	644565[4]	2–15
Tape Mounted on Reel UL94V-2, Tin Plated								
22 AWG 0.3-0.4 mm²	640468	2–10	644511	See Note 3	—	—	—	—
24 AWG 0.2 mm²	640469	2–10	644512	See Note 3	—	—	—	—
26 AWG 0.12-0.15 mm²	640470	2–6	644513	See Note 3	—	—	—	—
28 AWG 0.08-0.09 mm²	64047[illegible]	2–5	644514	See Note 3	—	—	—	—
Standard UL94V-2, .000030 [0.00076] Gold Plated								
22 AWG 0.3-0.4 mm²	641237	2–28	644042	2–28	641241[4]	2–14	—	—
24 AWG 0.2 mm²	641238	2–28	644020	2–28	641242[4]	2–14	—	—
26 AWG 0.12-0.15 mm²	641239[4]	2–14	644043[4]	2–14	—	—	—	—
LED*, UL94V-2, Tin Plated (See Note 4)								
22 AWG 0.3-0.4 mm²	641534	2–3	—	—	641653	2–3	—	—
24 AWG 0.2 mm²	641535	2–3	—	—	641654	2–3	—	—
26 AWG 0.12-0.15 mm²	641536	2–3	—	—	641655	2–3	—	—
28 AWG 0.08-0.09 mm²	641537	2–3	—	—	641656	2–3	—	—
Standard UL94V-0, Tin Plated (Gold is available, minimums may apply.)								
22 AWG 0.3-0.4 mm²	643498	2–15	644083	2–15	644575	2–15	644578	2–15
24 AWG 0.2 mm²	644574	2–15	644312	2–15	644576	2–15	644579	2–15
26 AWG 0.12-0.15 mm²	643628	2–15	644313	2–15	644577	2–15	644497	2–15

*LED connectors are designed to mate with .014–.020 [0.36–0.51] diameter posts or square leads.

Connector Length

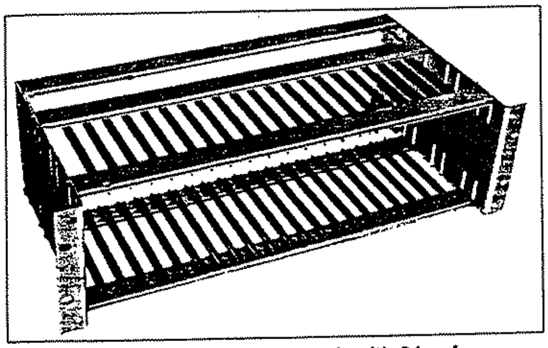
No. of Circuits	Dim. A	Prefix/ Suffix
2	.200 5.08	-2
3	.300 7.62	-3
4	.400 10.16	-4
5	.500 12.7	-5
6	.600 15.24	-6
7	.700 17.78	-7
8	.800 20.32	-8
9	.900 22.86	-9
10	1.00 25.4	1- -0

No. of Circuits	Dim. A	Prefix/ Suffix
11	1.100 27.94	1- -1
12	1.200 30.48	1- -2
13	1.300 33.02	1- -3
14	1.400 35.56	1- -4
15	1.500 38.1	1- -5
16	1.600 40.64	1- -6
17	1.700 43.18	1- -7
18	1.800 45.72	1- -8
19	1.900 48.26	1- -9

No. of Circuits	Dim. A	Prefix/ Suffix
20	2.000 50.8	2- -0
21	2.100 53.34	2- -1
22	2.200 55.88	2- -2
23	2.300 58.42	2- -3
24	2.400 60.96	2- -4
25	2.500 63.5	2- -5
26	2.600 66.04	2- -6
27	2.700 68.58	2- -7
28	2.800 71.12	2- -8

For drawings, technical data or samples, contact your AMP sales engineer or call the AMP Product Information Center 1-800-522-6752.
Dimensions are in inches and millimeters unless otherwise specified. Values in brackets are metric equivalents.
Specifications subject to change. Consult AMP Incorporated for latest specifications.

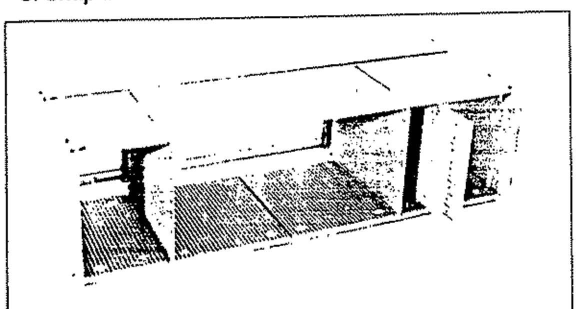
A.5 SGC rack.



CCA13S/90 - Assembled Subrack with 21 pairs of Snap-In Guides

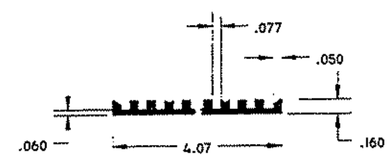
Card-Mount System

- Guide positions at .25" increments
- Adjustable slots
- Construction: .080" thick aluminum, clear anodized finish
- Sidewall slots provide adjustability to 1"
- For 4.5" X 6.5" cards
- Rear struts for mounting connectors

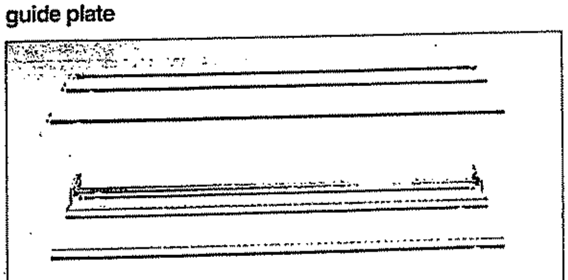


CCA13C/90 - Assembled Subrack with continuous guide plate

Subrack with continuous groove guide plates allows maximum flexibility in card placement.



Guide Plate Detail



CCK13F - Subrack Frame only

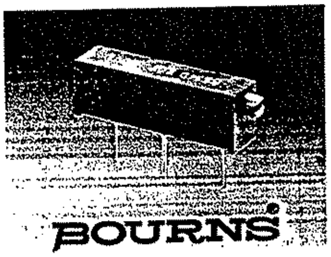
CCK13F is a subrack frame kit. It will accept cardmount modules (see next page) and snap-in (CG2-65S, p. 62) or screw-mount card guides (CG2-65M. CG2-65P, p. 62).

Part No.	Description	Dimensions (H x W x D)	Version
CCK12S/90	Card cage kit	3U (5.25") X 19" X 9"	Kit with 21 pairs of snap-in guides
CCK13F/90	Card cage frame kit	3U (5.25") X 19" X 9"	Frame only
CCA13S/90	Card cage assembly	3U (5.25") X 19" X 9"	Assembled with 21 pairs of snap-in guides
CCA13C/90	Card cage assembly	3U (5.25") X 10" X 9"	Assembled with continuous guide plate (see above)
CCK13S-H/90	Card cage kit	3U (5.25") X 10.25" X 9"	Half-size kit with 11 pairs of snap-in guides
CCK13S-HT/90	Card cage kit	3U (5.25") X 8.24" X 8.12"	Modified. half-size kit with 11 pairs of snap-in guides
CCK14F/90	Card cage frame kit	3U (5.25") X 19" X 12"	Frame only
CCA14S/90	Card cage assembly	3U (5.25") X 19" X 12"	Assembled with 21 pairs of snap-in guides
CCA15S/90	Card cage assembly	4U (7.00") X 9" X 12"	Assembled with 21 pairs of snap-in guides
CCA17S/90	Card cage assembly	5U (8.75") X 19" X 12"	Assembled with 21 pairs of snap-in guides
CCK18F/90	Card cage frame kit	6U (10.50") X 19" X 15.75"	Frame only
CCK 100S	Card cage kit	7U (12.25") X 19" X 9"	Kit with 21 pairs of snap-in guides

VECTOR ELECTRONIC COMPANY

Specifications subject to change without notice.

A.6 SGC card trimpot.



3/4" RECTANGULAR / MULTITURN CERMET / INDUSTRIAL / SEALED

- Low PC board profile - only 1/4" high
- Panel mount option available (see page 67 for details)
- Transparent housing available, setting visually without hook-up and instrumentation ("P" style only)

Model 3006

Trimpot® Trimming Potentiometer

Electrical Characteristics

Standard Resistance Range .... 10 to 5 megohms (see standard resistance table)
Resistance Tolerance .... ±10% std. (tighter tolerance available)
Absolute Minimum Resistance .... 1.0% or 2 ohms max. (whichever is greater)
Contact Resistance Variation .... 1.0% or 1 ohm max. (whichever is greater)
Adjustability
Voltage .... ±0.01%
Resistance .... ±0.05%
Resolution .... Infinite
Insulation Resistance .... 500 vdc. 1,000 megohms min.
Dielectric Strength
Sea Level .... 1,000 vac
80,000 Feet .... 250 vac
Adjustment Angle .... 15 turns nom.

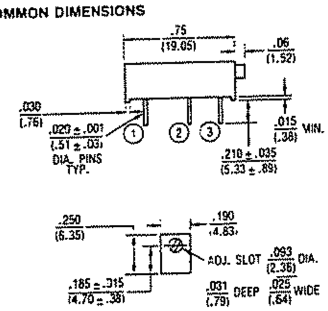
Environmental Characteristics

Power Rating (400 volts max.)
70°C .... 0.75 watt
150°C .... 0 watt
Temperature Range .... -55°C to +125°C
Temperature Coefficient .... ±100ppm/°C
Seal Test .... 85°C Fluorinert*
Humidity ..... MIL-STD-202 Method 103 96 hours (3% ΔTR, 20 Megohms IR)
Vibration .... 20G (2% ΔTR; 2% ΔVR)
Shock .... 50G (2% ΔTR; 2% ΔVR)
Load Life .... 1,000 hours 0.75 watt 70°C (4% ΔTR)
Rotational Life .... 200 cycles (3% ΔTR; 1% or 1 ohm, whichever is greater, CRV)

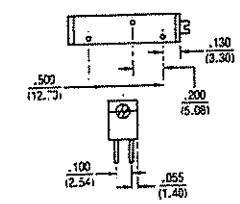
Physical Characteristics

Torque .... 5.0 oz-in. max.
Mechanical Stops .... Wiper idles
Terminals .... Solderable pins
Weight .... 0.04 oz.
Marking .... Manufacturer's trademark, resistance code, terminal numbers, date code, manufacturer's model number and style
Standard Packaging
P&Y Style .... 25 pcs. per tube
W Style .... 50 pcs. per tray

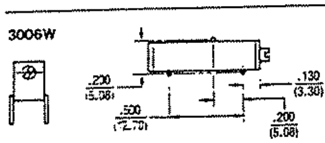
COMMON DIMENSIONS



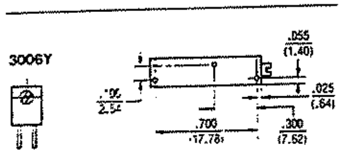
3006P



3006W

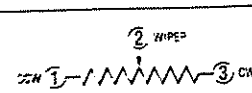


3006Y



TOLERANCES = ±.010 (.25) EXCEPT WHERE NOTED

DIMENSIONS IN. (MM)



STANDARD RESISTANCE TABLE

Resistance (Ohms)	Resistance Code
10	100
20	[illegible]
[illegible]	[illegible]
100	101
200	201
500	501
1,000	102
2,000	202
5,000	502
10,000	103
20,000	203
25,000	253
50,000	503
100,000	104
200,000	[illegible]
250,000	[illegible]
500,000	[illegible]
1,000,000	[illegible]
2,000,000	[illegible]

Popular values listed in boldface. Special resistances available.

HOW TO ORDER

3006 P - 1 - 103 Z

Model
Style
Standard or Modified Product Indicator
-1 = Standard Product
-7 = Transparent Housing
Resistance Code
Optional Suffix Letter
Z = Panel Mount (Factory Installed)

Consult factory for other available options.

Specifications are subject to change without notice.
*"Fluorinert" is a registered trademark of 3M Co.

30

A.7 SGC card filter capacitor

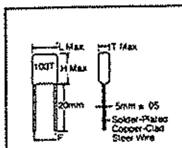
Panasonic. V-Series ± 5% Stacked Metallized Film Capacitors Suitable for Replacement of Monolithic Ceramic Capacitors in Most Cases

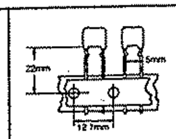
FEATURES:
• High volumetric efficiency • Low dissipation factor • Stacked and non-inductive construction • Operating temperature range: -40°C to +85°C • Temperature coefficient Δc/c: 200 ppm • Dissipation factor (max.): 1.0% • Insulation resistance (25°C): 1000MΩ µF • Self-healing

APPLICATIONS:
• Blocking, by-pass and coupling of DC • Pulse, logic and timing circuits • Light duty pulse forming • Filter and noise suppression

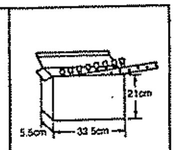
PANASONIC ECQ-V CROSS REFERENCE
Sprague: 453P/454P CSF Thompson: IRD. Siemens: B32509.

(To convert millimeters to inches divide by 25.4.)





* All taped parts have 5mm lead space.



• Panasonic V-Series Stacked Metallized Capacitor Film Kit

P4542-KIT-ND* (50 Volt K) $49.95
P4700-KIT-ND† (100 Volt K) $49.95

Includes 10 each of those parts indicated below (* or †). 180 capacitors. 10 each of the values listed in the chart. Price includes a notebook style storage box with bin guide for easy storage and quick access.

Volts	Cap. µF	L	T	H	F	Digi-Key Part No.	Pricing 10	100	1,000	5,000	10,000	Panasonic Part No.
		Dimensions (mm)					Bulk Package					
	0.01	7.3	3.2	5.0	5.0	P4513-ND*	1.32	11.00	66.00	61.00/M	57.00/M	ECQ-V1H103JL
	0.012	7.3	3.2	5.0	5.0	P4514-ND	1.38	11.50	69.00	64.00/M	60.00/M	ECQ-V1H123JL
	0.015	7.3	3.2	5.0	5.0	P4515-ND*	1.41	11.75	70.00	65.00/M	61.00/M	ECQ-V1H153JL
	0.018	7.3	3.2	5.0	5.0	P4516-ND	1.44	12.00	72.00	67.00/M	62.00/M	ECQ-V1H183JL
	0.022	7.3	3.2	5.0	5.0	P4517-ND*	1.47	12.25	73.00	68.00/M	64.00/M	ECQ-V1H223JL
	0.027	7.3	3.2	5.0	5.0	P4518-ND*	1.50	12.50	75.00	69.00/M	65.00/M	ECQ-V1H273JL
	0.033	7.3	3.2	5.0	5.0	P4519-ND*	1.53	12.75	76.00	71.00/M	66.00/M	ECQ-V1H333JL
	0.039	7.3	3.2	5.0	5.0	P4520-ND	1.55	13.00	78.00	72.00/M	68.00/M	ECQ-V1H393JL
	0.047	7.3	3.2	6.0	5.0	P4521-ND*	1.59	13.25	79.00	74.00/M	69.00/M	ECQ-V1H473JL
	0.056	7.3	3.2	5.0	5.0	P4522-ND	1.68	14.00	84.00	78.00/M	73.00/M	ECQ-V1H563JL
	0.068	7.3	3.2	5.0	5.0	P4523-ND*	1.77	14.75	88.00	82.00/M	77.00/M	ECQ-V1H683JL
	0.082	7.3	3.6	5.0	5.0	P4524-ND*	1.86	15.50	93.00	85.00/M	81.00/M	ECQ-V1H823JL
	0.1	7.3	4.0	5.0	5.0	P4525-ND*	1.83	15.25	91.00	85.00/M	79.00/M	ECQ-V1H104JL
50 WV	0.12	7.3	4.0	5.0	5.0	P4526-ND	2.04	17.00	101.00	94.00/M	88.00/M	ECQ-V1H124JL
	0.15	10.2	3.4	9.0	7.5	P4638-ND	2.02	16.80	100.00	93.00/M	87.00/M	ECQ-V1H154JC
	0.15	7.3	4.4	6.5	5.0	P4665-ND*	2.10	17.50	104.00	97.00/M	91.00/M	ECQ-V1H154JL
	0.18	7.3	4.5	5.5	5.0	P4666-ND*	2.19	18.25	109.00	101.00/M	95.00/M	ECQ-V1H184JL
	0.22	7.3	4.8	5.5	5.0	P4667-ND	2.31	19.25	115.00	107.00/M	100.00/M	ECQ-V1H224JL
	0.27	7.3	4.6	7.0	5.0	P4668-ND*	2.54	22.00	131.00	122.00/M	114.00/M	ECQ-V1H274JL
	0.33	7.3	5.2	7.0	5.0	P4669-ND*	3.00	25.00	149.00	139.00/M	130.00/M	ECQ-V1H334JL
	0.39	7.3	5.7	7.3	5.0	P4670-ND	3.36	28.00	167.00	156.00/M	145.00/M	ECQ-V1H394JL
	0.47	7.3	6.0	7.3	5.0	P4671-ND*	3.69	30.75	184.00	171.00/M	160.00/M	ECQ-V1H474JL
	0.56	7.3	5.8	10.0	5.0	P4672-ND*	4.47	37.25	222.00	207.00/M	194.00/M	ECQ-V1H564JL
	0.68	7.3	6.5	10.0	5.0	P4673-ND*	5.19	43.25	258.00	240.00/M	225.00/M	ECQ-V1H684JL
	0.82	7.3	6.8	10.0	5.0	P4674-ND*	6.21	51.75	309.00	287.00/M	259.00/M	ECQ-V1H824JL
	1.0	7.3	8.0	11.0	5.0	P4675-ND*	7.14	59.50	355.00	331.00/M	309.00/M	ECQ-V1H105JL

E

A.8 Power supply enclosure.

Metal Instrument Cases/Aluminum Boxes (Black Steel Uppers)

CAT NO	DIMENSIONS W x H x L	PRICE EACH 1	10
LA-4	4.4" x 2.7" x 5.2"	$ 5.30	$ 4.54
LA-5	5.5" x 2.6" x 6.7"	13.28	12.40
LA-6	7" x 3.4" x 8.3"	17.38	16.22
LA-7	11.8" x 3.2" x [illegible]	13.28	12.40
E-1	4" x 2.3" x 5.9"	6.75	5.78
E-2	5.1" x 2.6" x 5.9"	7.81	6.70
E-3	5.7" x 2.5" x 6.7"	9.29	8.48
E-4	4.7" x 3.5" x 6.7"	9.65	9.02

A.9 SGC card 1% resistors.

1% METAL FILM FIXED RESISTORS

Available In 1/8, 1/10 & 1/16 Watt Chip, 1/4 Watt Fixed

Standard Resistor Values — See below for complete part numbers when ordering.

10.0	19.1	36.5	69.8	133	255	487	931	1.78K	3.40K	6.49K	12.4K	23.7K	45.3K	84.5K	158K	294K	549K
10.2	19.6	37.4	71.5	137	261	499	953	1.82K	3.48K	6.65K	12.7K	24.3K	46.4K	86.6K	162K	301K	562K
10.5	20.0	38.3	73.2	140	267	511	976	1.87K	3.57K	6.81K	13.0K	24.9K	47.5K	88.7K	165K	309K	576K
10.7	20.5	39.2	75.0	143	274	523	1.00K	1.91K	3.65K	6.98K	13.3K	25.5K	48.7K	90.9K	169K	316K	590K
11.0	21.0	40.2	76.8	147	280	536	1.02K	1.96K	3.74K	7.15K	13.7K	26.1K	49.9K	93.1K	174K	324K	604K
11.3	21.5	41.2	78.7	150	287	549	1.05K	2.00K	3.83K	7.32K	14.0K	26.7K	51.1K	95.3K	178K	332K	619K
11.5	22.1	42.2	80.6	154	294	562	1.07K	2.05K	3.92K	7.50K	14.3K	27.4K	52.3K	97.6K	182K	340K	634K
11.8	22.6	43.2	82.5	158	301	576	1.10K	2.10K	4.02K	7.68K	14.7K	28.0K	53.6K	100K	187K	348K	649K
12.1	23.2	44.2	84.5	162	309	590	1.13K	2.15K	4.12K	7.87K	15.0K	28.7K	54.9K	102K	191K	357K	665K
12.4	23.7	45.3	86.6	165	316	604	1.15K	2.21K	4.22K	8.06K	15.4K	29.4K	56.2K	105K	196K	365K	681K
12.7	24.3	46.4	88.7	169	324	619	1.18K	2.26K	4.32K	8.25K	15.8K	30.1K	57.6K	107K	200K	374K	698K
13.0	24.9	47.5	90.9	174	332	634	1.21K	2.32K	4.42K	8.45K	16.2K	30.9K	59.0K	110K	205K	383K	715K
13.3	25.5	48.7	93.1	178	340	649	1.24K	2.37K	4.53K	8.66K	16.5K	31.6K	60.4K	113K	210K	392K	732K
13.7	26.1	49.9	95.3	182	348	665	1.27K	2.43K	4.64K	8.87K	16.9K	32.4K	61.9K	115K	215K	402K	750K
14.0	26.7	51.1	97.6	187	357	681	1.30K	2.49K	4.75K	9.09K	17.4K	33.2K	63.4K	118K	221K	412K	768K
14.3	27.4	52.3	100	191	365	698	1.33K	2.55K	4.87K	9.31K	17.8K	34.0K	64.9K	121K	226K	422K	787K
14.7	28.0	53.6	102	196	374	715	1.37K	2.61K	4.99K	9.53K	18.2K	34.8K	66.5K	124K	232K	432K	806K
15.0	28.7	54.9	105	200	383	732	1.40K	2.67K	5.11K	9.76K	18.7K	35.7K	68.1K	127K	237K	442K	825K
15.4	29.4	56.2	107	205	392	750	1.43K	2.74K	5.23K	10.0K	19.1K	36.5K	69.8K	130K	243K	453K	845K
15.8	30.1	57.6	110	210	402	768	1.47K	2.80K	5.36K	10.2K	19.6K	37.4K	71.5K	133K	249K	464K	866K
16.2	30.9	59.0	113	215	412	787	1.50K	2.87K	5.49K	10.5K	20.0K	38.3K	73.2K	137K	255K	475K	887K
16.5	31.6	60.4	115	221	422	806	1.54K	2.94K	5.62K	10.7K	20.5K	39.2K	75.0K	140K	261K	487K	909K
16.9	32.4	61.9	118	226	432	825	1.58K	3.01K	5.76K	11.0K	21.0K	40.2K	76.8K	143K	267K	499K	931K
17.4	33.2	63.4	121	232	442	845	1.62K	3.09K	5.90K	11.3K	21.5K	41.2K	78.7K	147K	274K	511K	953K
17.8	34.0	64.9	124	237	453	866	1.65K	3.16K	6.04K	11.5K	22.1K	42.2K	80.6K	150K	280K	523K	976K
18.2	34.8	66.5	127	243	464	887	1.69K	3.24K	6.19K	11.8K	22.6K	43.2K	82.5K	154K	287K	536K	1.00M
18.7	35.7	68.1	130	249	475	909	1.74K	3.32K	6.34K	12.1K	23.2K	44.2K					

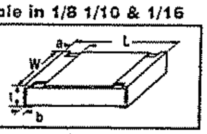
Panasonic.

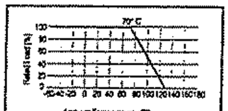
1206 0805 0603 0402

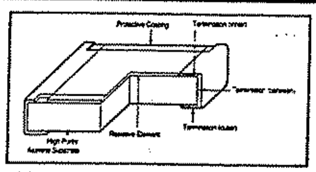
Available in 1/8 1/10 & 1/16

Size	Power Rating at 70°	Maximum RCWV*	Maximum Overload Voltage
0402	1/16 W	50 V	100 V
0603	1/16 W - (1/10 W)**	50 V	100 V
0805	1/10 W - (1/8 W)**	150V	200V
1206	1/8 W - (1/4 W)**	200 V	400V

Resistance to Soldering Heat: ±(1.0% + 0.1Ω) max. with no evidence of mechanical damage. **Dip Time:** 270°C ± 5°C, 10 $^{+1}_{-0}$ seconds. 100 PPM.







* Rated Continuous Working Voltage (RCWV) shall be determined from RCWV = √ Power Rating x Resistance Values, or max. RCWV listed above, whichever is less.

** Available for reduction of load of pulse characteristics (RCWV x 2.5 RCWV x 2.0, R≥1.1kΩ)

Description	L	W	a	b	t	Digi-Key Part No.	200	1,000	5M	10M	50M	100M	Panasonic Part Number
	Dimensions(mm)						Pricing						
1/8 Watt, 1206 1% Chip Metal Film Resistors (Tape & Reel) - (5000 pkg.)	3.20	1.60	0.50	0.50	0.60	P + Value + "FTR-ND"	—	—	22.80/M	20.52M	17.10/M	10.26/M	ERJ-8ENFxxxxV
1/8 Watt, 1206 1% Chip Metal Film Resistors (Bulk) - (200 pkg.)	3.20	1.60	0.50	0.50	0.60	P + Value + "FCT-ND"	9.86	41.75	—	—	—	—	ERJ-8ENFxxxx
1/10 Watt, 0805 1% Chip Metal Film Resistors (Tape & Reel) - (5000 pkg.)	2.00	1.25	0.40	0.40	0.60	P + Value + "CTR-ND"	—	—	22.50/M	20.25/M	16.88/M	10.13/M	ERJ-6ENFxxxxV
1/10 Watt, 0805 1% Chip Metal Film Resistors (Bulk) - (200 pkg.)	2.00	1.25	0.40	0.40	0.60	P + Value + "CCT-ND"	10.93	48.88	—	—	—	—	ERJ-6ENFxxxx
1/16 Watt 0603 1% Chip Metal Film Resistors (Tape & Reel) - (5000 pkg.)	1.60	.80	.30	.30	.45	P + Value + "HTR-ND"	—	—	27.43/M	24.38/M	18.29/M	15.46/M	ERJ-3EKFxxxxV
1/16 Watt 0603 1% Chip Metal Film Resistors (Bulk) - (200 pkg.)	1.60	.80	.30	.30	.45	P + Value + "HCT-ND"	15.38	60.71	—	—	—	—	ERJ-3EKFxxxx
1/16 Watt 0402 1% Chip Metal Film Resistors (Tape & Reel) - (5000 Pkg.)	1.00	.50	.20	.25	.35	P + Value + "LTR-ND"	—	—	—	51.54/M	46.23/M	41.61/M	ERJ-2RKFxxxxX
1/16 Watt 0402 1% Chip Metal Film Resistors (Bulk) - (200 pkg.)	1.00	.50	.20	.25	.35	P + Value + "LCT-ND"	33.08	130.58	95.75/M	—	—	—	ERJ-2RKFxxxx

YAGEO

MF Series

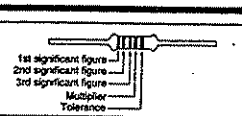
The MF series Metal Film Resistors are manufactured using vacuum sputtering system to deposit multiple layers of mixed metals and passivative materials onto a carefully treated high grade ceramic substrate. the resistors are coated with layers of light-blue lacquer.

General Specifications:

Power Rating: 1/4 Watt. **Max. Working Voltage:** 250V. **Max. Overload Voltage:** 500V. **Rated Ambient Temperature:** 70°C. **Temperature Cycling:** −65°C to +150°C. **Resistance Range:** 10.0Ω to 1.00MΩ. **Resistance Tolerance:** ±1%.

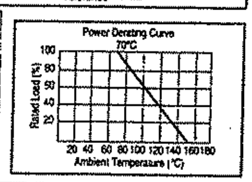
Electrical Specifications:

(See "General Specifications" below). All measurements are taken at +25°C at 1KHz and 65% relative humidity, unless stated otherwise. **Type:** MF-25 **Style:** RN-55 **Power Rating:** 1/4 Watt **Resistance Tolerance:** ±1% **Temperature Coefficient:** ±100PPM/°C



Characteristics

Temperature Cycling, −65° to +150°C	(%) .... ±0.25
Low Temperature Operation, −65°C	(%) .... ±0.25
Short Time Overload	(%) .... ±0.20
Terminal Strength, 5 lb. pull	(%) .... ±0.20
Resistance to Soldering Heat, +350°C	(%) .... ±0.10
Moisture Resistance, Mil Std 202	(%) .... ±0.50
Life 1000 hrs. (Rated Power)	(%) .... ±0.50
Shock, 50G, 11ms	(%) .... ±0.20
Vibration-High Frequency, 10-2000Hz	(%) .... ±0.20
Insulation Resistance	(%) .... $\geq 10^{4}\Omega$
Failure Rate	(%) .... 10^{-4}/h



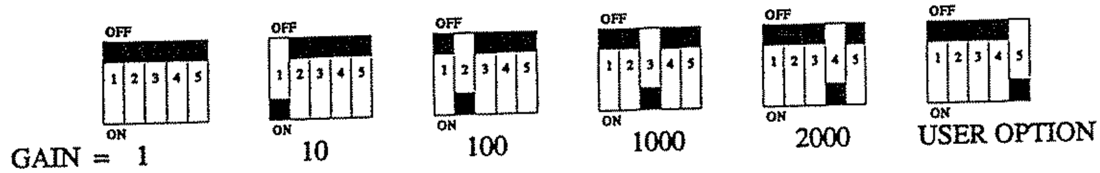
Description	Digi-Key Part No.	5	200	1M	5M	10M	50M	100M	500M	1,000M
		Pricing								
1/4 Watt, 1% Metal Film Resistors Bulk Package	Value + "X" + "BK-ND" (i.e. 12.0XBK-ND)	.54	6.27	21.38	18.24/M	15.67/M	12.54/M	—	—	—
1/4 Watt, 1% Metal Film Resistors Order in multiples of 5,000 (5,000 pcs./reel)	Value + "X" + "TR-ND" (i.e. 10.0XTR-ND)	—	—	—	20.60/M	17.60/M	14.30/M	12.11/M	9.90/M	8.80/M

APPENDIX B

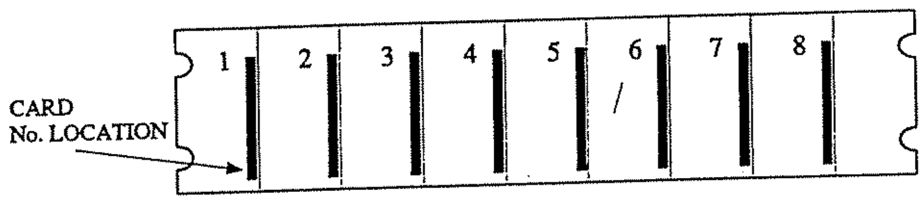
Shunt Calibration Procedure

LCHP-08 STRAIN GAGE CONDITIONER CARD CALIBRATION INSTRUCTIONS

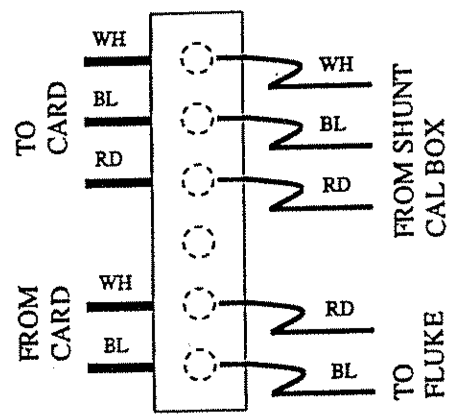
1. Plug the Signal Conditioner Rack into Power Supply
2. Plug the Power Supply into 120V 20A outlet.
3. Turn the Signal Conditioner Power switches to the ON position (to the right). The Yellow Power Light will illuminate.
4. Set the Gain position on each card to the desired gain setting for calibration. Record the Gain position on the Data Sheet.

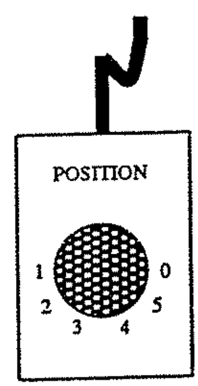


5. Let the Signal Conditioner Rack "warm up" for at least 30 minutes; one hour is preferable.
6. Record the Rack Number and Signal Conditioner Card Numbers on the Data Sheet.



7. Starting with Card 1 and continuing through Card 8 on each Signal Conditioner Rack, perform the following :
   - A. Attach the leads from the Fluke 45 Dual Display Multimeter to the output terminals of the Signal Conditioner Card. The multimeter should be set on DC Voltage (V⎓).
   - B. Attach the 3-wire input from the Shunt Calibration Box to the input terminals of the Signal Conditioner Card.
   - C. Attach the leads from the Fluke 70 Series II Multimeter to the Test Points on the Signal Conditioner Card. (Red to Red, Black to Black). The multimeter should be set on DC Voltage (V⎓).
   - D. Put the Swithch on the Shunt Calibration Box in Position 0.
   - E. Set the BRIDGE VOLTAGE to 4.00 VDC by adjusting the Turn Pot with a Bourns pot turning device. Read the value on the Fluke 70 multimeter and record it on the Data Sheet.
   - F. Balance the quarter bridge by adjusting the BRIDGE BALANCE Turn Pot with a Bourns pot turming device until the display on the Fluke 45 multimeter reads less than +/- 1.00 mVDC. To balance the bridge, turn the pot in the opposite direction from the illuminated Red Balance Light.
   - G. Record on the Data Sheet, the Shunt Calibration Box data for the following Switch positions 0, 1, 2, 3, 4, 5, 0, 1, 2, 3, 4, 5, 0





8. Detach leads and 3-wire input from Card 8, switch the display on the Fluke 45 multimeter to Resistance (Ω), connect the clips to the WH and BL wires and record the value on the Data Sheet. Now connect the clips to the RD and BL wires and record the values for Switch positions 0, 1, 2, 3, 4, 5 on the Data Sheet.

March 9, 1995 Rev. 0

LCHP-08 STRAIN GAGE CONDITIONER CALIBRATION DATA SHEET

PREPARER ________________ DATE ____________
RACK NO. ______ GAIN SETTING ______ BRIDGE VOLTAGE ______ WH-BL WIRE Ω ______

POSITION CARD NO.	1 (mVDC)	2 (mVDC)	3 (mVDC)	4 (mVDC)	5 (mVDC)	6 (mVDC)	7 (mVDC)	8 (mVDC)	SHUNT (Ω)
0									
1									
2									
3									
4									
5									
0									
1									
2									
3									
4									
5									
0									