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# CABIN ATMOSPHERE MONITORING SYSTEM

Honeywell Report  
No. SR-F2107-1

## CABIN ATMOSPHERE MONITORING SYSTEM PRE-PROTOTYPE MODEL DEVELOPMENT CONTINUATION

W.W. Bursack  
W.A. Harris

June, 1975

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A Summary Report  
Contract NAS8-30254

Prepared for:

National Aeronautics and Space Administration  
George C. Marshall Space Flight Center  
Marshall Space Flight Center, Alabama 35812

HONEYWELL INC.  
Systems and Research Center  
Minneapolis, Minnesota 55413



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## FOREWORD

This report is submitted in compliance with Modification S/A 6 to Contract NAS8-30254, and is a summary of work accomplished to date in continuing the development of the pre-prototype model of the Cabin Atmosphere Monitoring System (CAMS). The work was performed under Phase I of Exhibit "B", contract Modification 4, between August, 1974 and June, 1975, and was under the direction of Alex Hafner, S&E-ASTR-IMF.

## ABSTRACT

Work has continued beyond the development of a preprototype model of the Cabin Atmosphere Monitoring System (CAMS). This report summarizes that work which was directed toward improving stability and reliability of the design using flight application guidelines. Considerable effort was devoted to the development of a temperature-stable RF/DC generator used for excitation of the quadrupole mass filter. Minor design changes were made to the preprototype model and are reported. Specific gas measurement examples are included along with a discussion of the measurement rationale employed.

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## SECTION 1

### INTRODUCTION

This report summarizes the work accomplished to date under Exhibit "B" of contract Modification #4 dealing with development of the Cabin Atmosphere Monitoring System (CAMS). The work reported herein followed that done previously in designing and fabricating the preprototype model of CAMS, shown in Figure 1-1, and consisted of design investigations for improving stability and reliability using flight application guidelines.

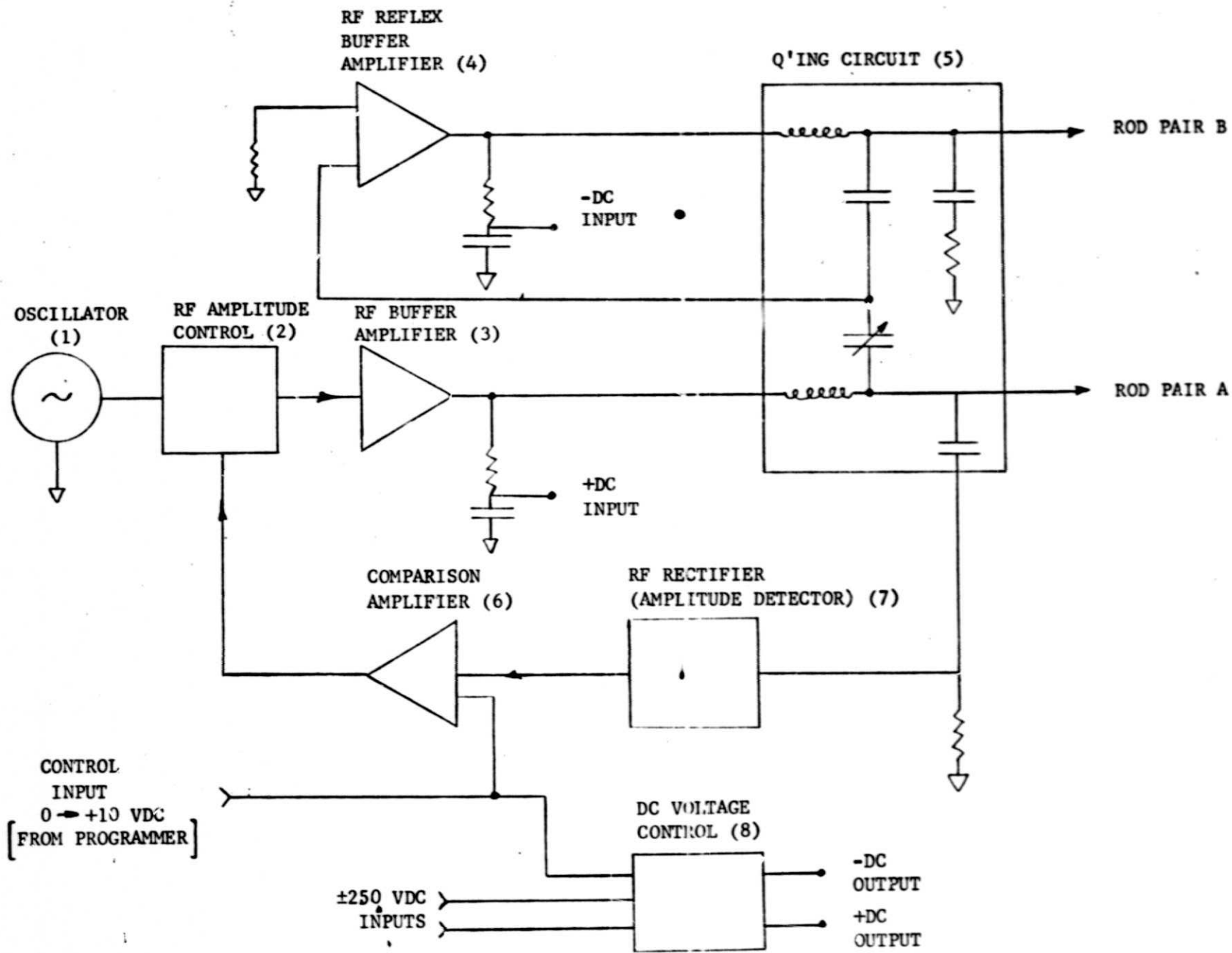
Modifications have been made to the pre-prototype model to improve quadrupole control voltage temperature stability and programming. These modifications are described, and are documented in Appendix A as schematic drawings replacing pages A-30 and A-36 of the CAMS Operations Manual. It had been hoped that the re-designed RF/DC generator would also have been installed in the pre-prototype model. However, operating limitations cannot be eliminated within program time and financial constraints, and the model will function for laboratory use without limitation with the original RF/DC generator. The new RF/DC generator design is described along with recommendations for eliminating the phase-shift problem. In other respects the design objectives for the RF/DC generator have been met, and temperature sensitivity has been virtually eliminated.

Other areas of design investigation included the ion source, ion pump, and pulsed leak. These are described. Commentary on the role of automatic gain control and measurement of specific gases is given.





Figure 1-1. Cabin Atmosphere Monitoring System (Pre-prototype Model)



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Figure 2-1. RF/DC Generator Block Diagram

-Table 2-1-  
Critical Components of the RF/DC Generator

<u>ITEM #</u>	<u>COMPONENT</u>	<u>DESCRIPTION</u>
(Ref. Figure 2-1)		
1	Oscillator	Conner-Winfield TCXO-C12C
2	RF Amplitude Control	Field-Effect Transistor - 2N3821
3	RF Buffer Amplifier	LH0032C & LH0033C - National Semi-Conductor
4	RF Reflex/Buffer Amplifier	LH0032C & LH0033C - National Semi-Conductor
5	Q'ing Circuit	Pot Core (2); #2213C-A40-4C4 Arnold Engrg. Capacitor, low loss - 5004-NPO-200G(AVX)  Capacitor, variable - VC54G
<del>6</del>	<del>Comparison Amplifier</del>	Operational Amplifier, low offset LM108A
7	RF Rectifier (Amplitude Detector)	Diode, switching: HP2810 Amplifier: LH0032C & LH0033C
8	DC Voltage Control	Operational Amplifier: $\mu$ A741(1) and LM108A (2)  Transistor, NPN high voltage (MPSA42) National Semiconductor  Transistor, PNP high voltage (MPSA92) National Semiconductor

$\nabla - 1\mu A$   
 15V - 20f2  
 -15V 3fC

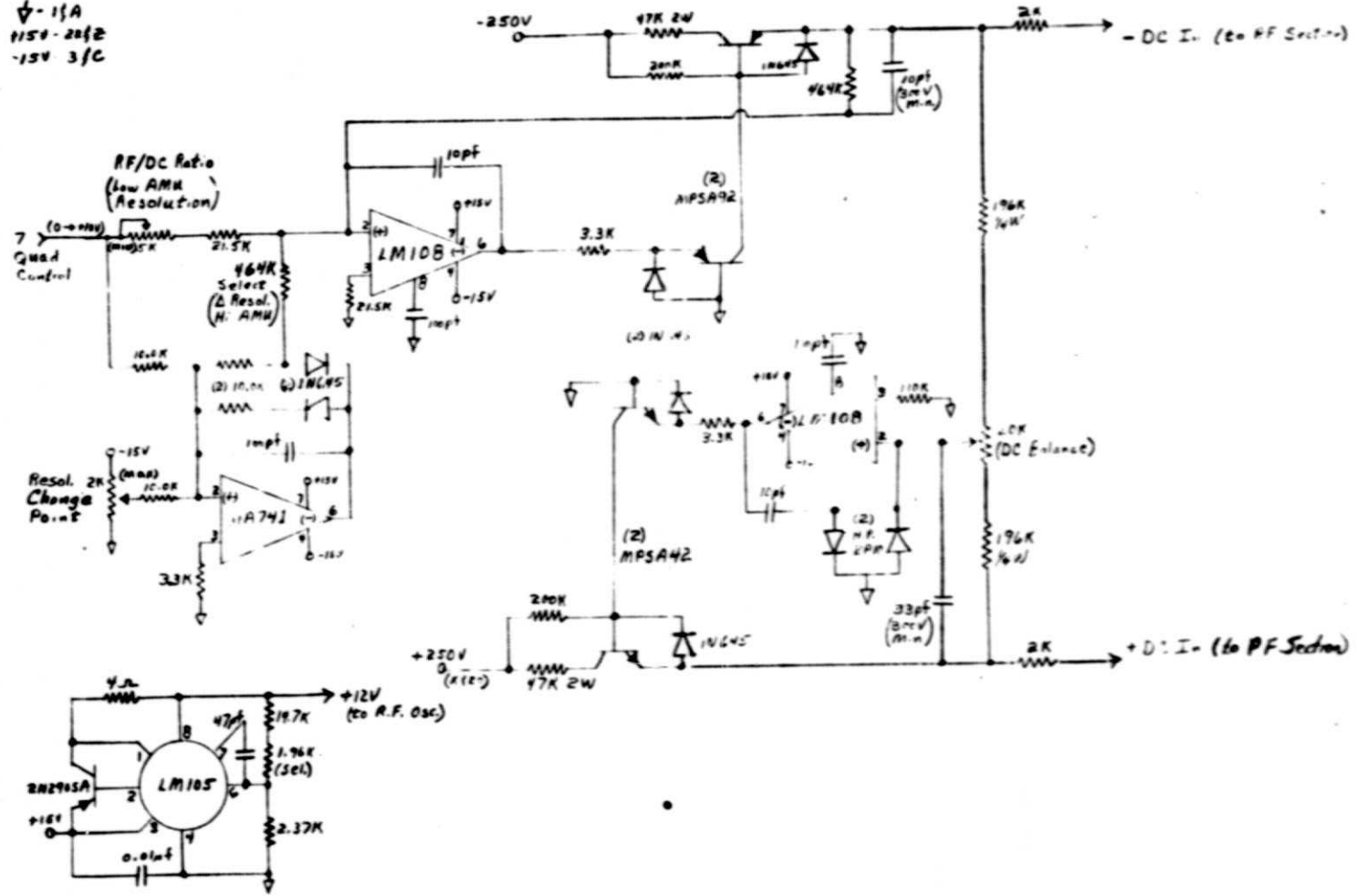


Figure 2-2. DC Voltage Control Section of RF/DC Generator

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- 1) Resistor Values of 3 Digits (eg 10.0K)  
ave 1% Metal Film AN50... (Temp. Coef for low Cap.)
- 2) Capacitors: 0.01 are 0.01µf Disk Ceramic  
all other Cap. are CMO... Mica except  
20pf NPO are AVX # 5004 NPO 2006
- 3) Inductors: 2213C-AV0-4C4 Pot Core  
1997094-9 3 Section Bobbin  
12 Turns (5/44 1.8 wire) per Section.

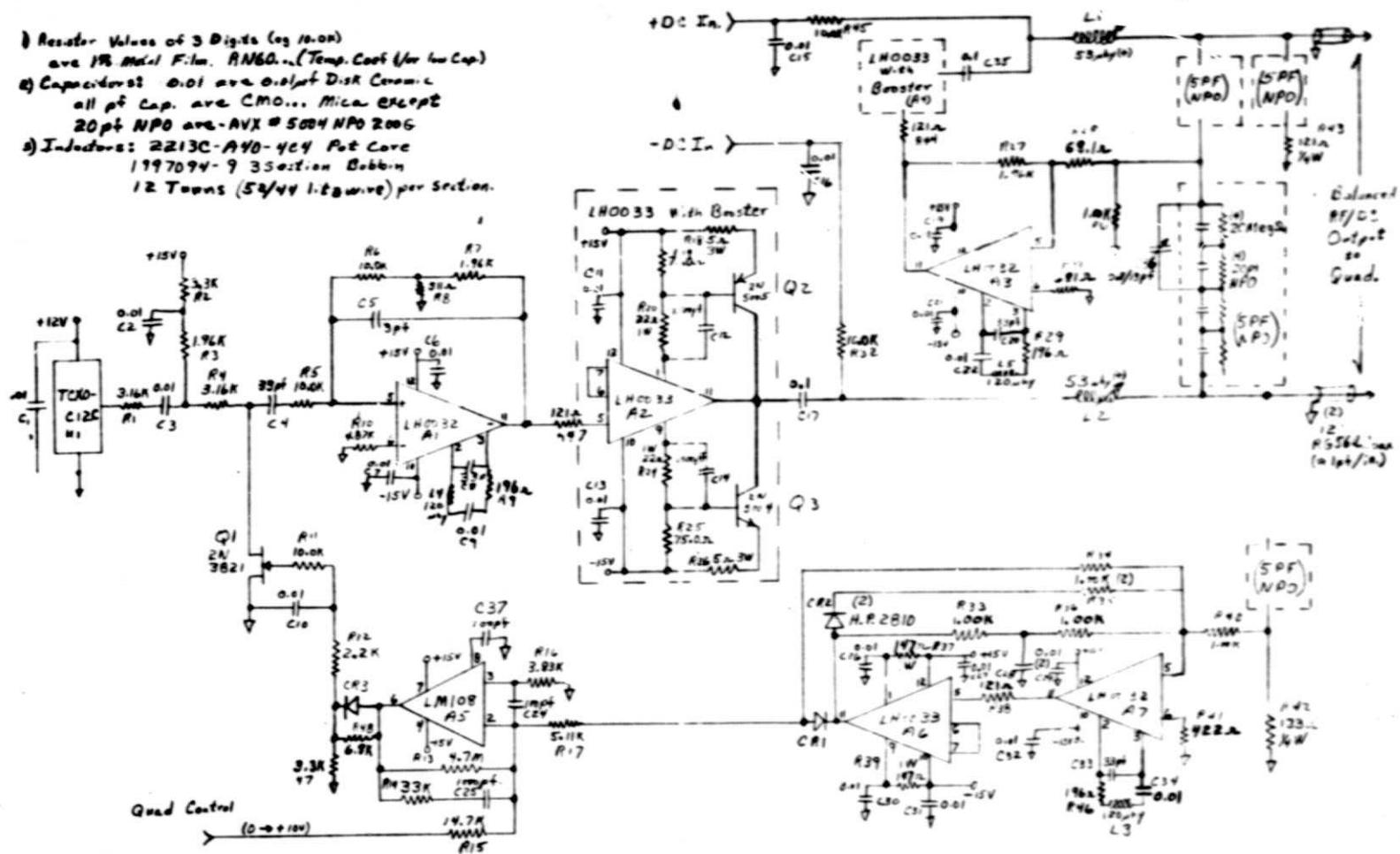


Figure 2-3. R-F Section of RF/DC Generator

The Connor-Winfield Model TCX0-C12C oscillator was chosen on the basis of its inherent frequency stability ( $\pm 0.0002\%$  over the temperature range  $-25^{\circ}\text{C}$  to  $+65^{\circ}\text{C}$ ). The resistor divider network on the output of this oscillator is tailored to the 5VRMS-into-5K-ohm load specification of the oscillator. The oscillator output level is not critical. Oscillator output variations up to  $\pm 25\%$  will be eliminated by the RF amplitude control circuit.

The RF amplitude control is mechanized by using the variable drain-to-source resistance characteristic of a field effect transistor (FET). The comparison amplifier output controls the FET (Q1 of Figure 2-3) resistance. With one milliamp of (forward) gate current the drain-source resistance is about 20 ohms. This resistance increases to about 1K ohm at zero gate voltage (and current). As the FET gate is reverse biased the drain-source resistance continues to increase. A drain-source resistance greater than 100K ohm is achieved at -3 volts. Considering the RF buffer amplifier input resistance of 10K ohm an effective dynamic range of 500 to 1 is thus obtained.

The two RF buffer amplifiers of Figure 2-1 are similarly mechanized as shown on Figure 2-3. The LH0032 is used as a preamplifier with voltage gain. To achieve significant voltage gain at 2.5 MHz and maintain stability above 2.5 MHz, a tuned compensation network is used. Figure 2-4 shows the uncompensated open loop gain characteristics of the LH0032. Open loop gain characteristics for two compensating capacitor values are also shown.

Referring to Figure 2-3 and 2-4, C9 (0.01  $\mu\text{f}$ ) is seen to dominate the gain characteristic below 100 KHz. A very low Q series resonance occurs at about 150 KHz due to L4, C9, R9 and the amplifier's internal impedance. From 150 KHz to 1.5 MHz the inductor L4 dominates the gain characteristic. A parallel resonance with a Q of about 40 occurs at 2.5 MHz due to L4 and C8. This parallel resonance facilitates about 46 dB of open loop gain at the quadrupole rod supply frequency of 2.5 MHz. Above 2.5 MHz C8, 33pf, dominates to assure high frequency stability.

The second part of the RF buffer amplifiers is the LH0033 with a current booster stage as shown on Figure 2-3. Without the booster stage the LH0033 output current is limited to 0.1 amp peak. The LH0033 with the booster can drive 0.9 amp (to 10V) peak current. The booster stage does not affect the other performance characteristics of the LH0033 (such as typical 8-ohm output resistance and 100-MHz full-power bandwidth). It is essential that the LH0033 have 0.01  $\mu\text{f}$  disk ceramic capacitors to bypass the  $\pm 15$  VDC power supplies. These bypass capacitors must be located on or very near the actual power supply pins of the LH0033 to prevent 20 MHz or higher internal oscillations.

The "Q'ing" circuit of Figure 2-1 is mechanized as essentially a balanced pair of series L-C resonant circuits. The inductors of each half are L1 and L2 respectively. The resonant capacitance in each half is the total of the two 5pf NPO, the coax connecting cables, and the quadrupole rod capacitances. The four "pick-off" capacitor strings must be stable since they are used as input, or feedback, circuit elements. Any shift in their values will shift the RF voltage level to the quadrupole rods. The NPO capacitors (AVX #5004-NPO-200G) have a temperature coefficient of  $\pm 30\text{ppm}/^{\circ}\text{C}$  maximum.

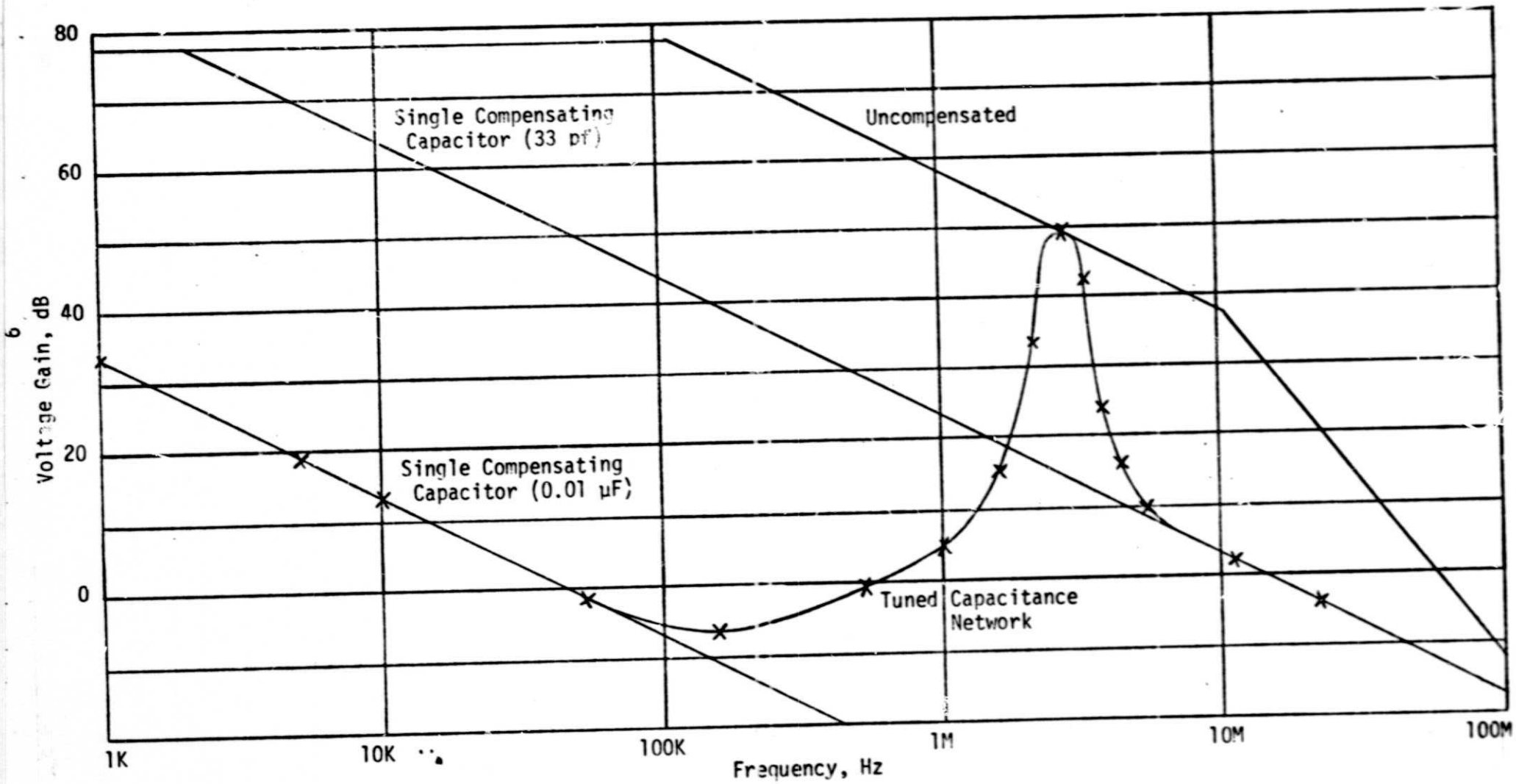


Figure 2-4. LH0032 Compensation (Open-Loop Gain Characteristic)

The RF rectifier circuit consists principally of A6 and A7 on Figure 2-3. The LH0032 is used in the same manner as discussed previously for the RF buffer amplifier. The LH0033 is used without the booster to drive the low impedances required to maintain the H.P. 2810 diode's (CR1 and CR2 of Figure 2-3) rectifying efficiency. The HP2810 has a forward voltage drop of 0.3 volts at 0.1 ma. This forward drop creates a deadband in the RF rectifier voltage response. The output of the RF amplifier (A6 and A7) must swing from zero to about 0.3 volts before any rectified RF output occurs. The net voltage gain of A6 and A7 is 200 at 2.5 MHz. Thus an input voltage to the RF rectifier from the quadrupole rod pair A pickoff of 1.5 millivolts peak will overcome the diode deadband. Temperature variation of the diode forward drop will also be divided by the voltage gain and become insignificant when compared to the 40-milli-volt peak per amu scale factor at this pick off point.

Temperature testing of the RF/DC generator configuration shown in Figures 2-2 and 2-3 was performed at  $75^{\circ}\text{F} \pm 40^{\circ}\text{F}$ . For the purposes of determining stability three values of quadrupole control voltages were used corresponding to:

- atomic nitrogen - amu 14
- argon - amu 40
- carbon tetrachloride - amu 152

At each of the three amu control voltages maximum peak response at the temperature extremes was within 5 millivolts of the room temperature control voltage. (The basic scale factor is 33 millivolts per amu). This 5 millivolts is a maximum shift since without excessive mass resolution the 95% points of a single amu peak are about 10 millivolts apart. Referring to Figure 2-3, the four major contributors to RF drift with respect to the quadrupole control voltage over temperature excursions are:

- NPO capacitors ( $\pm 30$  ppm/ $^{\circ}\text{C}$ )
- RF diode forward voltage (1.5 mv/ $^{\circ}\text{C}$ )
- LH0032-A7-offset (0.025  $\mu\text{V}/^{\circ}\text{C}$ )
- LM108-A5-offset (0.015  $\mu\text{V}/^{\circ}\text{C}$ )

The temperature coefficients shown are the vendor specified maximum limits. In terms of equivalent quadrupole control voltage these components contribute the following maximum temperature drift:

- |  |               |
|--|---------------|
| ● NPO capacitors (amu 40)  | $\pm 0.87$ mv |
| ● RF diode (1.5 mv/ $^{\circ}\text{C} \div$ A7 gain)                           | $\pm 0.17$ mv |
| ● LH0032 offset (0.025 V/ $^{\circ}\text{C} \cdot 14.7\text{K}/5.11\text{K}$ ) | $\pm 1.6$ mv  |
| ● LM108 offset   | $\pm 0.33$ mv |

Thus the temperature drift over the measured temperature range should be less than three millivolts even if these four random variables are additive.



## Limitations of the Breadboard RF/DC Generator

The RF/DC generator mechanization shown on Figure 2-3 has two limitations. The first is a 1 to 200 amu operating range (the CAMS preprototype model operates over a 1 to 300 amu range). The 200 amu upper limit can be increased by changing A2 and A3 (Figure 2-3) to LH0063.\* The LH0063 is similar to the LH0033 except it has twice the output current capacity and a 4-ohm instead of 10-ohm maximum output impedance. Using the booster stage and the larger (more expensive) LH0063 would easily extend the RF/DC generator range to 300 amu.

The second limitation is caused by an inductance change (L1 and L2 of Figure 2-3) with RF current amplitude. The inductance of L1 and L2 increases as the RF current level increases. This increase in inductance is about 1% per decade of RF current amplitude. The closed loop mechanization used in the RF section tends to compensate for this change but the correction is not adequate. For example: if the inductors are tuned for resonance at amu 4, an argon (amu 40) response will be only about one-third that achieved with the circuit tuned at the amu 40 level. Tuning the inductors at midrange (about amu 30) tends to make this effect less apparent. Other core materials were investigated in the hopes of finding a material which does not shift with operating level. All materials identified (except air cores) had other instability factors as bad or worse than the 4C4 pot core material presently used. An air core inductor, although somewhat larger than the present pot core, is one possible solution. A second possibility is to use the 4C4 pot core, but compensate its inductance shift with a varactor diode scheme. The quadrupole control voltage, or either of the  $\pm$ DC rod bias voltages, are available to control a voltage variable compensating capacitor.

## Calibration Procedure: RF/DC Generator Breadboard

Calibration of the re-designed RF/DC generator is relatively simple and straightforward requiring a DC voltmeter and a dual trace oscilloscope. The calibration procedure is the following (Reference Figures 2-2 and 2-3).

- 1.) Set: RF/DC Ratio to minimum.  
Resolution Break Point to Maximum.
- 2.) Apply power to the unit.
- 3.) Set the quadrupole control voltage at about +1VDC.
- 4.) Adjust the DC Balance such that the  $\pm$ DC voltages read on C15 and C16 are equal.
- 5.) Verify oscilloscope calibration by observing the 2.5 MHz sinewave on R42. Both traces should be of equal amplitude and in phase.
- 6.) Simultaneously adjust L1, L2 and C36 such that the output voltage of A2 is in phase with the voltage on R42(L2), the output of A4 is in phase with the voltage on R43(L1) and the voltages on R42 and R43 are equal in amplitude (C36). (The voltages on R42 and R43 will

\*Increasing the CAMS operating range above 200 amu may not be warranted since ions of such high mass would be rare in the mass spectra of gases appearing in the atmosphere.

be 180° out of phase.)

- 7.) While observing a low amu spectra (e.g., 14 through 18 amu - quadrupole control voltage +0.4 to +0.6 V) increase the RF/DC Ratio until the peak height is about twice the between peak (overlap) response. Adjust the DC balance for maximum response. Adjust the RF Balance (C36) for maximum response. Check the two phase measurements of Step 6 above as C36 is changed. After the DC and RF balance have been fine tuned increase the RF/DC ratio until the desired resolution of mass peaks is achieved.
  
- 8.) When all the above adjustments have been made, observe a high amu spectra. The high amu resolution may be decreased without changing the low amu resolution by setting the Resolution Change Point potentiometer. The magnitude of the resolution change may also be adjusted by changing the select resistor.

## ION SOURCE

In order to more effectively implement selective ionization as an analytical process, an indirectly heated dispenser cathode was investigated. This work was carried out in conjunction with a Honeywell-sponsored project directed toward the investigation of low-ppm carbon monoxide measurement and low electron energy analyses involving gas species prone to fragmentation upon ionizing.

An indirectly heated dispenser cathode is of interest since emission occurs with no potential gradient along the emitting surface; that is, the IR drop of the heated-filament cathode can be eliminated. Moreover, the electron yield of the dispenser cathode material is greater than that of tungsten permitting the use of a lower cathode operating temperature. The lower emission temperature decreases the energy spread of the emitted electrons. These two factors contribute toward the attainment of an ideal, though not entirely realizable, condition desired for selective ionization (i.e., the production of monoenergetic electrons). Since the operating temperature of the dispenser cathode is about one-half that of the tungsten-wire cathode a significant narrowing of the electron energy distribution can be expected with its use as well as the elimination of the IR drop of the filament cathode (typically about two volts).

The dispenser cathode chosen uses a barium calcium aluminate formulation as the emitting material; this is fabricated in a disk and installed at one end of a .050-inch diameter molybdenum tube. The heater, an alumina-insulated, double-helically wound, tungsten-alloy wire is installed in the opposite end of the tube. This assembly was mounted co-axially in a .156-inch diameter stainless steel tube by means of three radial wires (.005-inch tantalum) spot-welded to the tubes. (This configuration served to enhance heat retention by the cathode.) The stainless steel tube was fastened at one end by a compression fit within an alumina tube which served as an insulated mount for the entire cathode assembly.

The cathode assembly was installed in a vacuum system employing a miniature bell jar. Observations of the brightness temperature of the cathode were then made using an optical pyrometer. Using an electron emission projection of two amperes per square centimeter at 1100°C brightness temperature, indicated that an emission level somewhat higher than that of the tungsten-wire filament should be achievable at a much reduced cathode temperature and with less than half the driving wattage. Further, it may be possible to improve this performance by use of smaller radial wires supporting the molybdenum tube housing the cathode.

The operating life of the dispenser cathode is strongly dependent upon operating temperature. The cathode manufacturer estimates a 2000-hour life at 1100°C. Each 50°C lowering of temperature would be expected to square the life of the cathode (but halve the emission). However, heater failure occurred in the first-built cathode in about 50 hours in the bell jar environment (pressure in the  $10^{-7}$  Torr range). Failure was attributed to degradation of the alumina heater wire insulation, and subsequent shorting

of heater wire turns (heater wire was 0.0015-inch tungsten alloy). The suggested remedy for this condition is to pot the heater in the molybdenum tube thereby shielding it from the residual gases within the vacuum system, and possibly the use of larger diameter heater wire. Meantime, the negative connections of heater and cathode were connected when the cathode was installed in the multi gas analyzer (MGA) to eliminate possible cataphoretic effect leading to heater failure.

After completing pyrometer observations in the bell jar system, the dispenser cathode was installed in the MGA. The ion source (Reference: Figure B-4, Cabin Atmosphere Monitoring System, Operations Manual) was modified so that the electron beam was at right angles to that occurring with the existing tungsten filaments which were made inoperative. To do this, one end of the Faraday Cage was shortened and its ends closed by electrically-conducting surfaces; however, a gridded aperture 5/32-inch in diameter was installed at the shortened end opposite the dispenser cathode emitting surface to provide access for the electron beam.

The dispenser cathode model was used for obtaining mass spectra of several compounds found in closed, respiratory atmospheres in order to designate "identifier" peaks for these compounds (i.e., peaks which remain relatively strong in the spectra at low electron energies, such as 12 or 15 volts). Heater degradation was evident during these tests, and use of the dispenser cathode was therefore discontinued after about six weeks to avoid undue testing delay.

In addition to limited heater life, the electron emission of the dispenser cathode decreased considerably as the pressure in the multi gas analyzer was increased. Further evaluation of this effect remains to be done. Development of the dispenser cathode for the multi gas analyzer would entail effort as well in heater and cathode mount design and performance testing with gases of analytical interest to determine their effect on emission.

## Ion Pump

The ion pump installed in the preprototype Cabin Atmosphere Monitoring System is a significant weight item - 8½ pounds. Most of the weight is due to the magnet assembly. Contact was made with manufacturers of samarium cobalt magnets to determine the possibilities for weight saving by use of this recently developed material. A modified magnet assembly using thinner pole pieces of this material would weigh about half as much as the present design and yet provide the same flux density. Further weight saving could be achieved by redesigning the flange connection to lighten the ion pump by about 35 percent.

## Pulsed Leak

Design studies of the pulsed leak were carried out as part of another project, and are mentioned briefly here because they bear on the development of the CAMS prototype design.

Consideration was given to a re-design of the poppet suspension and poppet material in order to enhance vacuum sealing capability and life. The poppet is mounted at the center of a spring diaphragm (Reference: Pulsed Leak Description in Monthly Status Report #MSR-F2107-7). This diaphragm is a stainless steel disk secured at its periphery by a clamping ring. In order to reduce spring rate and to minimize undesirable cocking of the poppet on its seat, an alternate design of the spring diaphragm was fabricated. This is a 3-arm design fabricated by chemical etching of a stainless steel disk. The closure force is applied to the poppet by three spring members which are continuous with thicker hub and rim sections. This configuration is intended to provide: preload application which is not affected when clamping the spring in the pulsed leak body, and lower spring rate.

Various elastomers, plastics, and soft metals were studied to determine if there is a good alternate to teflon as the poppet material. Teflon qualifies for this application better than most materials, and considerable experience with it has been gained; it is, however, given to some cold flow with possible loss of closure force. Harder materials (soft metals and some plastics) may not vacuum seal as well because of surface finish and alignment imperfections, while softer materials (elastomers) may not afford as consistent gas delivery upon pulsing because of their greater deformation. In any case the poppet material should be chemically inert to the gases expected in the analytical sample, and provide long-term, vacuum integrity over a temperature range of  $-40^{\circ}\text{F}$  to  $+160^{\circ}\text{F}$ . Two or three of the recently introduced elastomers and plastics appear to have possibilities as poppet materials. Considerable testing would be involved in making a selection among these. Moreover, the gases to be encountered in a given analytical situation should be identified to assure an appropriate selection as to chemical inertness of the poppet material.

Gas delivery configurations (pulsed leak-to-ion source) were studied as to the effect on measurement sensitivity of the MGA. The argon 36 and argon 38 isotopes in air were used primarily as the detected species. The results indicated that on-axis delivery (i.e., gas plume from pulsed leak on the axis of the quadrupole) to the ion source gave better sensitivity than delivery at  $90^{\circ}$  to this axis. Single plume delivery was superior to two-plume delivery with plumes  $15^{\circ}$  off the axis of the quadrupole. Pulsed leak-to-ion source distance and diameter of the gas plume from the pulsed leak were found to be important as well in obtaining maximum sensitivity.

## SECTION 3

### MODIFICATIONS MADE TO THE CAMS PREPROTOTYPE MODEL

Modifications were made to the CAMS Preprototype Model to improve quadrupole control voltage temperature stability and programming. These modifications were made on Card 2 (Voltage Generator - Quad Control) and Card 4 (Program Logic), and are shown by revision of the schematic diagrams SK131065, Sheet 3, and SK131067, Sheet 3, respectively. Revised copies of these schematics are found in Appendix A replacing those found in the CAMS Operations Manual.

The quad control voltage generator was modified to provide better temperature stability. The basic reference element is now the 1N827 temperature-stabilized zener diode rather than the +15 volt power supply. The maximum temperature-induced voltage change of this zener is +2 millivolts over the +40°F range. The +0.3 millivolt offset shift of the LM108 can be added to the +2 millivolt zener shift to predict a maximum quadrupole control voltage temperature shift over the 40°F to 100°F operating range of +2.3 millivolts, or 0.07 amu.

Card 4 was modified to eliminate a possible start-up malfunction. When power is first applied, or when the operating mode is changed from sweep to program, the state flip-flops (U1 through U3) may all be in the cleared state. This causes the quadrupole control voltage to be over range. This over range voltage now (through the added circuitry) forces U1A to be preset. The program now proceeds from state zero as desired.

## SECTION 4

### SOME APPLICATION CONSIDERATIONS

#### AUTOMATIC GAIN CONTROL & ABSOLUTE PRESSURE REFERENCING

Automatic gain control (AGC) provides a means for periodic updating the calibration of the multi gas analyzer (MGA). In the natural atmosphere AGC relies on the partial pressure constancy of a selected inert gas (such as an argon isotope) as the measurement reference. The ready availability of such a partial pressure source permits essentially continuous calibration updating. Sampling of the selected reference gas is made a part of the MGA analytical regimen, and the system gain is automatically adjusted to null out any difference between the measured output and a fixed voltage generated within the MGA.

In an artificial atmosphere, such as that of the space vehicle cabin, there is no innate balance of sources and sinks to insure a constant partial pressure level of a constituent gas. The options then become: (1) reliance on the calibration of the MGA (without AGC); (2) provision of a pressure reference of some sort. In the first case, reference voltages can be established within the MGA against which output measurements would be compared. The "error" signals so developed could be used to effect partial pressure control of the constituent gases. The difference between measured output and reference voltages would be nulled when the partial pressure of a constituent was at the desired value. In the second case, a pressure reference would be provided as a basis for AGC operation.

Generation of a pressure reference in the space cabin preferably would not require the use of gases not normally present nor add significant hardware. Possibilities for generating an absolute pressure reference for AGC operation include cabin total pressure and oxygen partial pressure from the regulated, low pressure supply stage\*. In using cabin total pressure as the reference, the MGA oxygen and nitrogen outputs would be scaled such that their total was in agreement with the value indicated by the total pressure transducer. Use of regulated, low pressure oxygen as the reference would entail temporary diversion of the oxygen supply line to the MGA inlet and assumes absolute and fixed pressure control of the oxygen supply at the low pressure stage. Gain adjustment of the MGA would then be made to bring its oxygen partial pressure measurement into correspondence with the fixed pressure of the oxygen supply. This gain adjustment would then be applied to other measurement channels of the MGA as well.

\*Some use of oxygen for MGA inlet purging is implicit in this scheme, but is small relative to the delivery requirements for crew respiratory support. Since nitrogen is expected to be delivered to the cabin in much smaller quantity, it is not suggested as a partial pressure reference.



AGC using an absolute pressure transducer assumes the permissibility of some inaccuracy in measuring total pressure and the omission of minor atmospheric constituents in summing the partial pressures. The measurement of cabin total pressure can presumably be made to at least 0.5% of the actual value by available, flight-quality absolute pressure transducers. The assumption that the sum of the oxygen and nitrogen partial pressures is equal to the cabin total pressure may be permissible. Such a summation ignores the partial pressures of trace gases, carbon dioxide and water. Trace gas concentrations due only to the impurity of the oxygen and nitrogen supplies may be 10 ppm using so-called "ultra high purity" grade, of 100 ppm using "high purity" grade. If near-normal carbon dioxide concentration (say less than 0.05%) is maintained, its partial pressure is not significant either. Ignoring of water partial pressure may be questionable if relative humidities higher than 40 or 50% (above 1% concentration) are tolerated.

## Specific Gas Measurement Examples

The NASA requirement is for an instrument to monitor and control partial pressures within the atmospheres of manned space cabins. These gases may be present in concentrations as low as "parts per million" or as high as 80 per cent (nitrogen). Analytical techniques of the multi gas analyzer (MGA) which can be applied in the Cabin Atmospheric Monitoring System (CAMS) include ion mass filtering, controlled ionization, and electronic signal recognition.

The CAMS pre-prototype model provides for the simultaneous measurement of four gases (such as nitrogen, oxygen, carbon dioxide, and water) as well as for the derivation of mass spectra in the range of 1 to 300 amu. The measurement of the four cited gases is made using their parent ion (amu 28, 32, 44, 18, respectively).

Many gases of the space cabin are present in very small concentrations demanding good instrument sensitivity and specificity for their measurement. Pulsed sample introduction to the instrument directly at atmospheric pressure results in momentarily high ion populations by which sensitivity can be enhanced. Where ions of the same mass number are generated in the ion source of the instrument by more than one atmospheric gas, it may be possible to lower the ionization level (i.e., use low electron energies in ionizing) to either selectively ionize the gases, or to virtually eliminate an interference by simplifying the ion fragmentation patterns. Although lowered ionization levels result in reduced output signal, sufficient sensitivity may still be realized through pulsed mode operation. The preferred measurement rationale seeks to identify a gas species by a single unique, mass peak using programmed ionization levels as necessary to eliminate mass number interferences. These analytical possibilities are discussed in the following for some of the trace gases which have been used with the MGA.

Methane is metabolically derived and has been reported in significant concentrations in manned simulator tests. The sensitivity of the pre-prototype model of CAMS for methane is about one part per million using the amu 15 ion as the monitored species. The parent peak at amu 16 is somewhat larger than the amu 15 peak, but is subject to interference by atomic oxygen.

Monomethylhydrazine (MMH) is a fuel used aboard the Shuttle vehicle. The detection threshold for MMH is about 0.2 parts per million. The amu 45 ion is used for detection with readout logic preventing indication unless the accompanying parent ion (amu 46) is present in at least equal concentration. To prevent measurement interference from carbon dioxide containing isotopic carbon ( $C^{13}$ ) at amu 45, advantage is taken of the higher ionization potential of carbon dioxide in reducing the electron energy of the ion source to suppress its ionization. MMH oxidizes rapidly in air forming reaction products which can be detected by the MGA using amu 58 and 72 ion peaks.

Nitrogen dioxide ( $\text{NO}_2$ ), an oxidizer for MMH, is also used aboard the Shuttle vehicle. The parent ion, amu 46, is used for its detection. Unlike MMH there is no accompanying amu 45 peak and electronic logic is used to distinguish between MMH and  $\text{NO}_2$ ; i.e., no MMH reading will occur if twice an amu 45 peak is greater than an accompanying amu 46 peak, and no  $\text{NO}_2$  reading will occur unless the amu 46 peak is greater than twice the amu 45 peak. Detection thresholds of about 0.2 parts per million have been obtained for  $\text{NO}_2$ .

Acetone has been reported in closed atmospheres. The minimum detectable sensitivity for acetone, using its amu 43 (most abundant) ion, is less than one part per million.

Carbon monoxide is found in closed cabin atmospheres, but is not detectable at the desired sensitivity for this application because of nitrogen interference at amu 28. Concentrations in the order of 100 to 200 parts per million have been detected by the MGA at lowered electron energies to preferentially ionize the carbon monoxide (ionization potential of molecular carbon monoxide is 14.0 volts while that of nitrogen is 15.6 volts). Approaches for improving sensitivity include: ionization using an electron beam having more nearly mono-energetic electrons to enhance selective ionization, and chemical conversion and measurement as carbon dioxide.

Mass spectra of several trace compounds which may be present in closed atmospheres have been taken at low ionization levels to ascertain which peak could be used for identification of the given compound. At electron energies in the range of 15 to 20 electron volts, the number of peaks in the spectra decreases significantly. The number of peaks having an amplitude more than 1 percent of recorder scale was reduced to a fifth or less of the number occurring at 70 electron volts, at the same time one or more peaks remain at a high enough amplitude to be useful as an "indicator" peak. Benzene was found to have 43 peaks having an amplitude greater than 1 percent recorder scale at an ionization level of 70 electron volts, while at 15 electron volts only three remained. Of these, one was significant as an "indicator" peak. Methyl chloroform had 64 peaks whose amplitude was greater than 1 percent recorder scale at 70 electron volts, while at 15 electron volts only 7 remained two of which were significant. The simplification of spectra obtained by use of low ionization levels greatly reduces the chance for analytical interference when several compounds are present simultaneously.

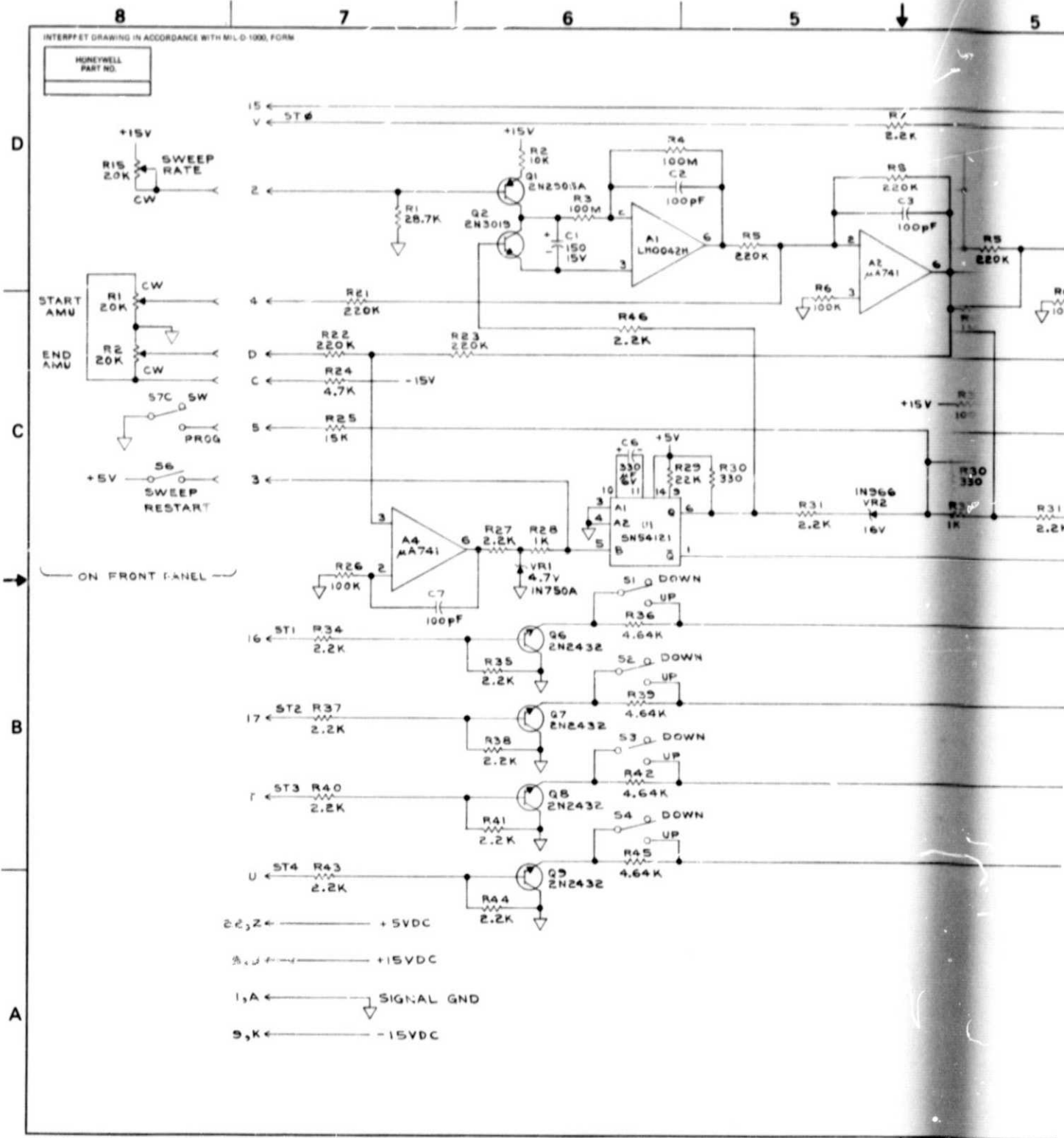
## APPENDIX A

### DRAWING REVISIONS TO CAMS OPERATIONS MANUAL

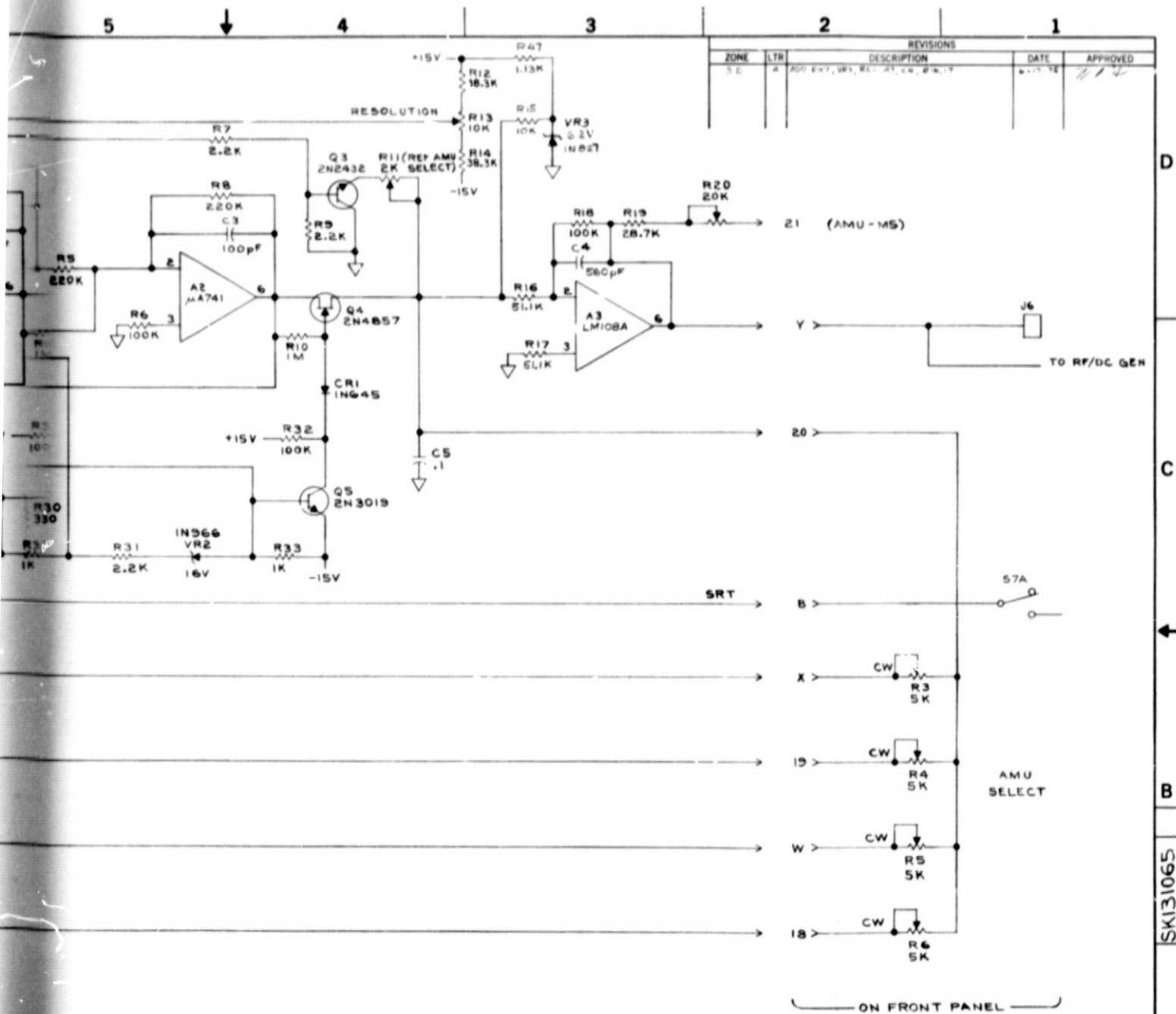
This appendix documents modifications made to the CAMS preprototype model since issuing the Operations Manual. These modifications are indicated in revised copies of pages A-30 and A-36 (SK131065, Sheet 3 and SK131067, Sheet 3, respectively) of the manual in this appendix.

INTERPRET DRAWING IN ACCORDANCE WITH MIL-D-1090, FORM

HONEYWELL  
PART NO.



OUT FRAME 1



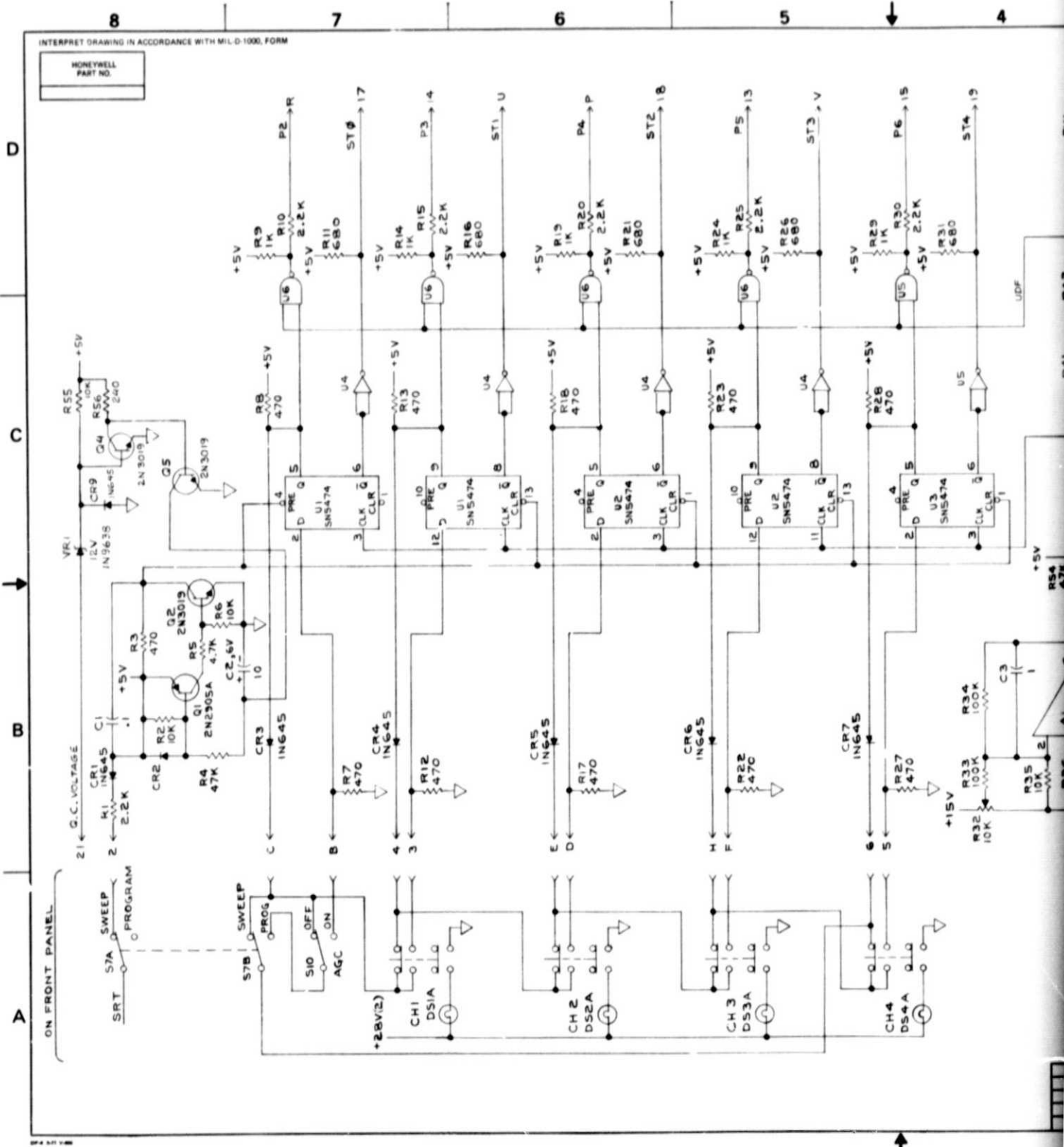
REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED
5, 4	A	ADD ENR, W1, R1, R2, R3, R4, R5, R6, R7	6-17-78	J.J.

TOLERANCES UNLESS NOTED OTHERWISE		DRAFTSMAN	1-17-78	HONEYWELL INC. AEROSPACE AND DEFENSE GROUP	
X	±	CHECK		<input type="checkbox"/> AERO MFGS <input type="checkbox"/> AERO ST PETERSBURG <input type="checkbox"/> GPO SEATTLE <input type="checkbox"/> GPO HOPKINS <input type="checkbox"/> GPO MONTGOMERYVILLE <input type="checkbox"/> S&W CTR Mpls <input type="checkbox"/> INDIANAPOLIS CTR BOSTON	
.XX	±	DEV ENGR		SCHEMATIC DIAGRAM, VOLTAGE GENERATOR - QUAD CONTROL CARD 2	
.XXX	±	PROJ ENGR			
.XXXX	±	RELIABILITY			
FINISH - SEE NOTE		CONTRACT NO.		SIZE	CODE IDENT NO.
MATERIAL				D	27327
LG 15A001				DRAWING NO. SKI31065	
NEXT ASSY				SCALE	WT
APPLICATION				SHEET 3	

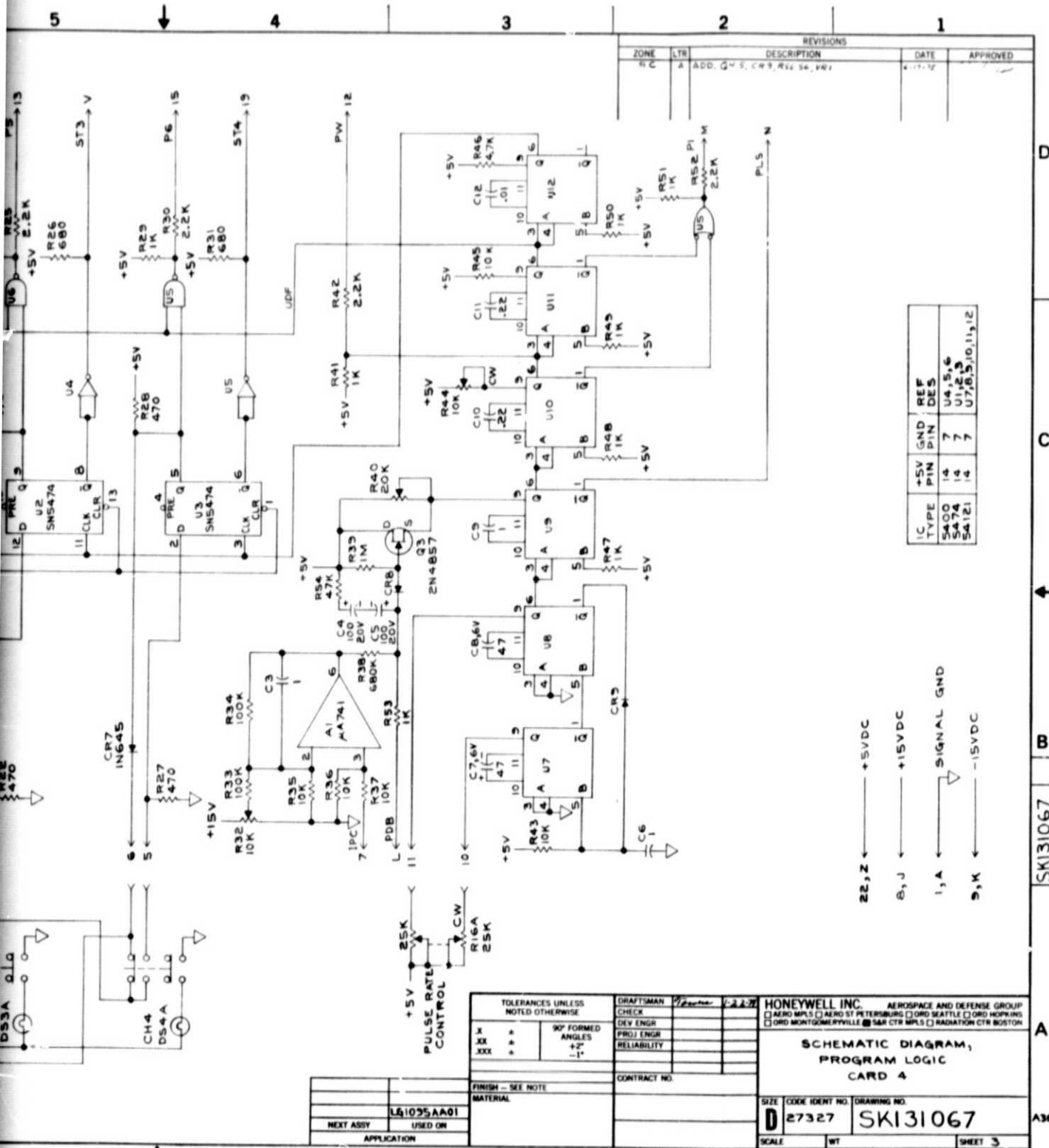
FOLDOUT FRAME

INTERPRET DRAWING IN ACCORDANCE WITH MIL-D-1000, FORM

HONEYWELL  
PART NO.



FOLDOUT FRAME 1



ZONE		LTR		DESCRIPTION	DATE	APPROVED
R	C	A		ADD. Q'S, CR9, R22 5A, 901	4-17-72	

IC TYPE	+5V PIN	GND PIN	REF PIN	DES
5400	14	7	7	U4, 5, 6
5474	14	7	7	U1, 2, 3
54121	14	7	7	U7, 8, 9, 10, 11, 12

TOLERANCES UNLESS NOTED OTHERWISE		DRAFTSMAN	<i>Johnson</i>	DATE	4-22-72
X	+	CHECK			
XX	+	DEV ENGR			
XXX	+	PROJ ENGR			
		RELIABILITY			
FINISH - SEE NOTE		CONTRACT NO.			
MATERIAL					
NEXT ASSY USED ON					
APPLICATION					

HONEYWELL INC. AEROSPACE AND DEFENSE GROUP	
<input type="checkbox"/> AERO MPLS	<input type="checkbox"/> AERO ST PETERSBURG
<input type="checkbox"/> ORD MONTGOMERYVILLE	<input type="checkbox"/> ORD SEATTLE
<input type="checkbox"/> SAR CTR MPLS	<input type="checkbox"/> ORD HOPKINS
<input type="checkbox"/> RADATION CTR BOSTON	
<b>SCHEMATIC DIAGRAM, PROGRAM LOGIC CARD 4</b>	
SIZE	CODE IDENT NO.
<b>D</b>	<b>27327</b>
<b>SKI31067</b>	
SCALE	WT
	SHEET 3

SKI31067 | B | C | D  
 A36

FRONT FRAME 2