110354 - P1
REV A, 7/87

MKS

Instruction Manual

MKS Type 247C 4 Channel Readout

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MKS INSTRUMENTS, INC.

WARRANTY

for Type 247 Equipment

MKS Instruments, Inc. (MKS) warrants that the equipment described in the face of this warranty (the "equipment") manufactured by MKS shall be free from defects in materials and workmanship for a period of one year from date of shipment. For the period commencing with the date of shipment of this equipment and ending one year later, MKS will, at its option, either repair or replace any part which is defective in materials or workmanship without charge to the purchaser. The foregoing shall constitute the exclusive and sole remedy of the purchaser for any breach by MKS of this warranty.

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MKS Type 247C
4 Channel Readout

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SECTION 1

GENERAL INFORMATION

1.1 GENERAL DESCRIPTION

Designed as a power supply/readout and set point source for four Mass Flow Controllers (MFC's)*, the 247C is a versatile instrument that may be used separately or as part of a larger control system.

The 247C consists of a power supply, four signal conditioning channels, four set point circuits and a digital panel meter to display the flow rate of any single channel of MFC.

The 247C may be used to monitor and provide set point levels for MFC's and to provide ratioed set points for multiple gas control. These operations may be done under manual control or under computer control using the MKS Type 232 Interface. These operations will be described in detail in Section 3.

While the 247C is primarily designed to interface with MKS MFC's, most major MFC's may be accommodated with the proper MKS interface cable. These units and the required cables are listed in Section 3, page(3-4).

* The 247C will also power and monitor the flow rate thru Mass Flow Meters.

1.2 SPECIFICATIONS

EACH CHANNEL

INPUT SIGNAL RANGE:	0 to +5VDC (5.5V Maximum)
TRANSDUCER OUTPUT RANGE:	0 to +5VDC
CORRECTED TRANSDUCER OUTPUT RANGE:	0 to +1VDC Nominal. (Scaled with a rear panel scaling control.)
ZERO CORRECTION:	± 3% of Full Scale
SET POINT ADJUST:	0.1% to 100% of Full Scale (Flow). 0.1% to 100% of Input Level (Ratio).

MAIN UNIT

OPERATING VOLTAGE:	(100 to 135/200-270 VAC) 50-60 Hz.
POWER CONSUMPTION:	19 Watts @ 115VAC 60 Hz with NO MFCs attached. Additional 15 watts startup/10 watts operational for each MFC added.
POWER SUPPLY OUTPUT CAPACITY:	± 15 VDC @ 1 Ampere - Ripple < 10mV P-P.
MFC CAPACITY:	4
FLOW DISPLAY:	Digital Display Reading +1.999 MAX.
DISPLAY ACCURACY:	± 0.1% ± 1 Digit.
OPERATING TEMP.:	15 to 40 Deg. C (59 to 104 Deg. F)
PACKAGE:	1/2 Rack (9 1/2"W X 3 1/2"H X 9"D)
WEIGHT:	8 1/2 Lbs. (3.85 Kg.)

*** NOTE: SPECIFICATIONS SUBJECT TO CHANGE WITHOUT NOTICE. ***

SECTION 2

THEORY OF OPERATION

(Ref. Fig. A)

The Type 247 is connected to as many as four MFC's thru connectors J1-J4. Communication to the outside world takes place thru connector P6. Connector P5 is used to connect an additional 247 or a pressure control signal.

A. Flow Signal Path:

The flow signal from the MFC (0 - 5V) enters the 247 at J1-J4 pin 2. Amplifier A buffers the signal and injects a zero correction signal, if necessary, using front panel zero control (G,C page 4-6). This signal now goes to an output pin of P6 and to the Read/Set Point switch (G,D page 4-6). This switch is spring loaded in the up or read position allowing this flow signal to be amplified times 2 (Amplifier B) and scaled by the scaling control (H,D page 4-6). See section 4.4.C for proper scaling setting. This zeroed and scaled signal is now sent to P6 and the Channel Selector switch (G,B page 4-6). This switch now routes the signal to the Front Panel Display (G,G page 4-6) where it is read directly in SCCM or SLM. The Channel Selector switch's second deck gates in the correct decimal point which is set using a Decimal Selector switch (H,E page 4-6).

B. Set Point Signal:

The set point signal that is sent to each MFC thru connectors J1-J4 may be generated in several ways depending upon the application.

1. 247 used to establish up to 4 independent flows of gas.

In this mode of operation, a precise 5.000 VDC signal is generated at section I. This signal flows thru switch (G,F page 4-6) to the set point control attenuator (G,E page 4-6) when the source switch is in the Flow position (the proper position for this application). The signal may then flow to buffer amplifier E. This signal may then be read on the front panel meter by depressing the Read/Set Point switch and if adjustment is necessary, the Set Point Control (G,E page 4-6) will be turned. The set point signal is finally sent to the MFC by placing the front panel Flow Control switch (G,I page 4-6) in the ON position. This switch activates the output switch (E) which allows the set point signal to flow thru it, thru the unity gain buffer amplifier (F), and thence to the MFC. When the Flow Control switch is in the OFF position, the switch places a small negative voltage on the set output line so that the control valve will be closed positively.

When the Flow Control switch is placed in the Remote position a logic signal coming in thru P6 may be used to gate the set point signal to the MFC. A logic low turns the flow ON.

2. 247 used to establish 1 to 3 channels of flow ratioed from channel 1.

In this case, the flow of channel 1 is established by using the set point routing described in 1. above. The remaining channels (2-4) derive the set point signal as follows: The set point source switches of channels 2-4 are placed in the ratio positon; the zeroed flow signal of channel 1 passes thru a switch (J) (Dip switch inside the 247) and into the set point control switch. This signal is then attenuated by the set point control pot (G,E page 4-6) and continues as described in 1, to the MFC. Thus a fraction of the actual flow of channel 1 will be used as the source for the set point of channels 2-4. **Note that the flow in channels 2-4 is ratioed to channel 1 and that the % of Full Scale flow in these channels may not exceed the % of Full Scale flow in channel 1. (ie. with 75% of flow in channel 1 channels 2-4 may not exceed 75% of their rated flow.)**

3. 247 used with an external set point input thru connector P6.

In this case, an external 0 - 5VDC signal may be received at P6 where it is routed by the set point source switch to each MFC. Its application to the MFC is the same as 1. Note that each channel has its own external set point line. Also note that any or all channels may be set pointed or driven from the outside. Those that are not may be adjusted from inside ie. case 1.

4. 247 used to control pressure by manipulating a ratio of flows.

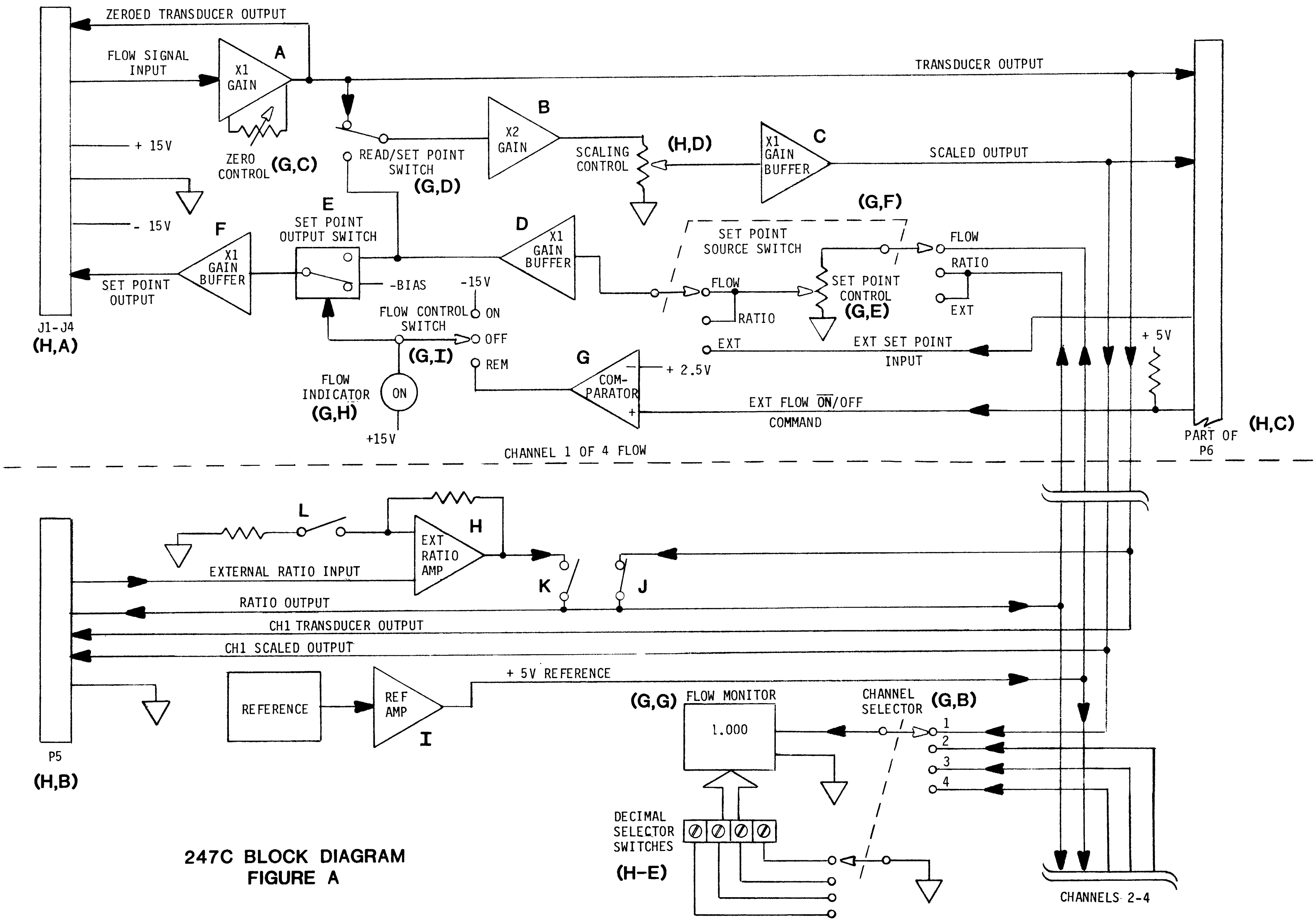
Here a pressure transducer (127/227) and a 250B* controller is added to the system. (See the instruction manuals for these instruments) (See fig. D) The 247 receives a signal from the 250B controller called a pressure control signal (PCS). This signal will go to whatever level (0 - 10VDC) necessary, to drive the pressure signal to equal its set point signal (within the 250B). This PCS voltage enters the 247 at connector P5 where it is buffered (or X5) and by closing switch (K) and opening switch (J), it will be routed to the ratio position of the Set Point Source switch. From this point the paths are the same as 2.

* 250B-1-A or 250B-1-D (No options installed) ONLY.

Note that any or all channels may be used to flow gas to maintain pressure with a preset ratio of flows. Any channel that is not used in this case may be used independently. See section 4.6 for set up of 250B and 127/227.

Note 1: The 250B and 127/227 have been used for example only. Other controllers and pressure transducers may be used provided the signal that enters the 247 goes positive with increasing flow (correct polarity).

Note 2: Controlling a vacuum system in the above fashion is a simple task IF the correct components have been chosen and sized correctly. If not, the system will not work correctly.



247C BLOCK DIAGRAM
FIGURE A

SECTION 3

INSTALLATION

3.1 INSPECTION AFTER SHIPMENT

Reasonable care has been taken to pack the 247C is a manner such that it will reach you in perfect operating condition. However, you should check the instrument throughly for any signs of shipping damage. Should any damage be present, notify your carrier and MKS immediately.

3.2.A MOUNTING (247C)

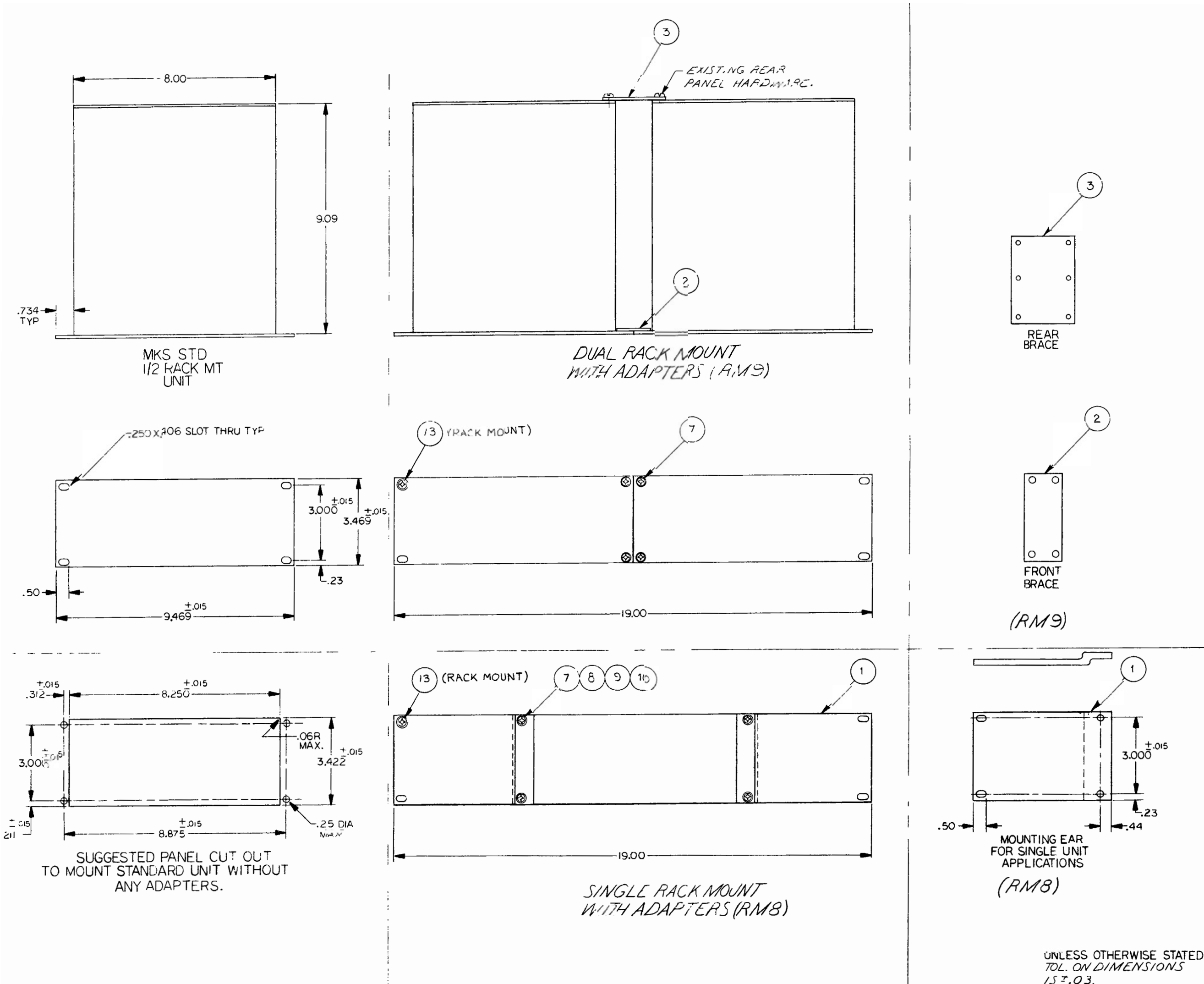
The 247C may be used as a bench top instrument or mounted through a panel or in a standard 19" rack. Figure B indicates the recommended panel cut out required to mount a 247C in a larger panel. Also shown are the available rack mount adapter kits for mounting the unit in a standard 19" rack.

However the unit is mounted, it is necessary to leave adequate space around it for proper ventilation. The 247C with three or more MFC's may become quite warm to the touch, especially when used with higher then nominal, (115 VAC), line voltage.

3.2.B MOUNTING (MFC's) (SEE MFC MANUALS)

Install in the gas stream so that the flow direction corresponds to the flow marking on the base of the equipment.

Allow space for connector clearance, access to zero adjustments and access to the seat adjustment in the control valve. (This adjustment is below the external control valve on 1259B/2259B MFCs and on the top of the case on 1159A/1160A MFCs.)



RM6: RM6 IS A MULTI-PURPOSE RACK MOUNT ADAPTER KIT EQUIVALENT TO AN RM8 PLUS AN RM9.

RM7: RM7 IS A MULTI-PURPOSE RACK MOUNT ADAPTER KIT EQUIVALENT TO AN RM8 PLUS AN RM10.

RM8: RM8 IS A RACK MOUNT ADAPTER KIT USED TO MOUNT A SINGLE HALF RACK UNIT IN A STANDARD 19" RACK.

RM9: RM9 IS A RACK MOUNT ADAPTER KIT USED TO MOUNT 2 HALF RACK UNITS IN A STANDARD 19" RACK.

RM10: RM10 IS A RACK MOUNT ADAPTER KIT USED TO MOUNT A HALF RACK UNIT AND 1 [illegible] MAIN FRAME UNIT IN A STANDARD 19" RACK.

RM11: RM11 IS A RACK MOUNT ADAPTER KIT USED TO MOUNT A 12.00 DF ½ RACK UNIT NEXT TO A 9.50 DF HALF RACK UNIT.

RM12. RM12 IS A RACK MOUNT ADAPTER KIT USED TO MOUNT A 246-MF1 NEXT TO A 12.00 OR 9.[illegible] DF HALF RACK UNIT.

FIGURE B

3.3 INTERCONNECTIONS

When the 247C is purchased as part of a complete system including MFCs it will be supplied with the required interface cables. When purchased separately, cables will not be supplied unless they are made part of the order.

Connection to the measurment and control lines is made through connector P6. The pin assignments for this connector are given below:

CHANNELS 1-4 INTERFACE CONNECTOR (P6)

1. Signal Ground
2. Ch. 1 Transducer Output
3. Ch. 1 Scaled Output
4. Ch. 1 Set Point Input
5. Ch. 2 Set Point Input
6. Ch. 3 Set Point Input
7. Ch. 4 Set Point Input
8. Digital Ground
9. Power Ground
10. Ch. 2 Flow ON/OFF Input
11. Ch. 3 Flow ON/OFF Input
12. Ch. 1 Flow ON/OFF Input
13. Ch. 4 Flow ON/OFF Input
14. Ch. 2 Transducer Output
15. Ch. 2 Scaled Output
16. Ch. 3 Transducer Output
17. Ch. 3 Scaled Output
18. Ch. 4 Transducer Output
19. Ch. 4 Scaled Output
20. N.C.
21. N.C.
22. N.C.
23. N.C.
24. N.C.
25. Chassis Ground

Connector P5 provides connection to the external ratio signal interface. This connector is also used to connect another 247C to increase the number of MFC's being ratioed. The pin assignments are given below:

CHANNEL 1 INTERFACE CONNECTOR (P5)

1. Signal Ground
2. Ch. 1 Scaled Output
3. Digital Ground
4. Power Ground
6. Ch. 1 Transducer Output
7. External Ratio set point Input
8. Ratio Output Voltage
9. Chassis Ground

Connectors J1-J4 provide connection to the MFC's. The pin assignments are given below:

CHANNEL 1-4 INTERFACE CONNECTORS (J1-J4)

1.	N.C.	9.	N.C.
2.	Flow Input Signal	10.	Input Stage Output
3.	N.C.	11.	N.C.
4.	N.C.	12.	Signal Ground
5.	Power Ground	13.	N.C.
6.	-15 Volts	14.	N.C.
7.	+15 Volts	15.	Chassis Ground
8.	Set Point Output Signal		

3.4 MFC INTERFACE CABLES

FROM	TO	MKS CABLE NO.
258B,1158,1258B,2258B	247C J1-J4	CB259-5
259B,1159,1259B,2259B	247C J1-J4	CB259-5
157/1160	247C J1-J4	CB259-10
TYLAN	247C J1-J4	CB259-10
UNIT	247C J1-J4	CB259-10
BROOKS 5850E-EDGEBOARD CONN	247C J1-J4	CB259-10
BROOKS 5850B	247C J1-J4	CB247-6
BROOKS 5850	247C J1-J4	CB247B

3.5 SYSTEM CABLES

Figures C-E indicate the different cables required for the various system configurations of the 247C. This section deals only with cable requirments. The operation of these systems will be covered in detail in Section 4.

MANUAL FLOW CONTROL

Figure C illustrates a simple manual control system which only requires the use of MFC Interface Cables. The flow rate for each gas is individuality controlled with a front panel set point control. Channels 2-4 have the additional option to become a ratioed portion of the flow in Channel 1. Another four channels may be additionally ratioed by adding another 247C and a CB247-4 cable.

PRESSURE CONTROL WITH EXTERNAL CONTROLLER

Figure D illustrates the cabling required to control the gas flow into a chamber to maintain a constant pressure. The CB247-2/1 connects the pressure control signal (PCS) from the 250B to the 247C. The pressure transducer connects to the 250B through the appropriate cable, in this example, a CB254-11. The remaining cables are simply the proper number of MFC Interface Cables. Greater than four gases may be controlled by adding another 247C and using a CB247-2/2 which connects the 250B's PCS to both 247C's.

COMPUTER CONTROL FLOW

Figure E illustrates a system controlled by an external computer through an MKS 232 Interface. A standard RS232-C cable connects the computer to the interface. Input and Output from the interface and the 247C are carried through a CB232-4 or a CB232-5. The former is used to monitor the scaled output from each channel while the latter is used to monitor the direct transducer output from each channel. The remaining cables are the required MFC interface cables.

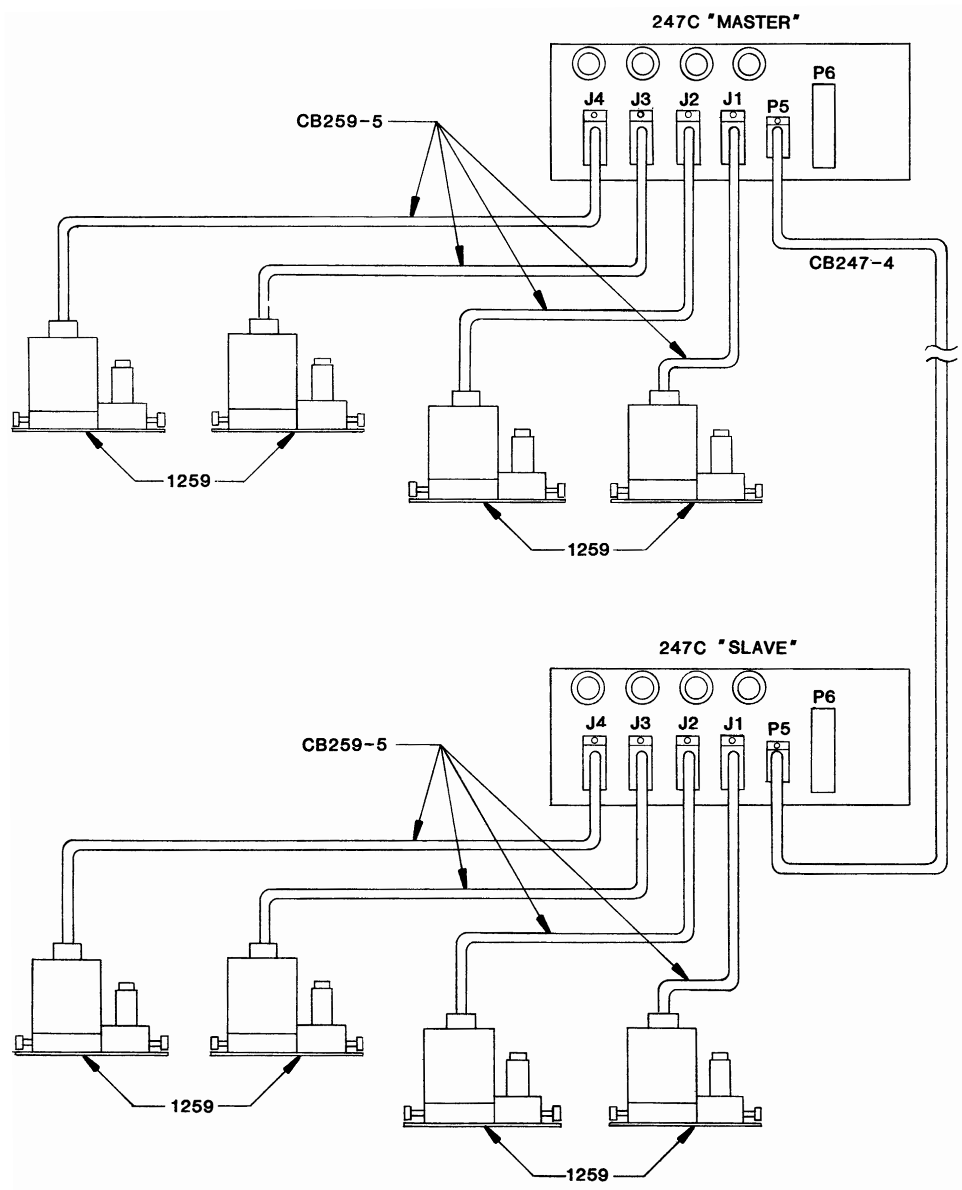


FIGURE C

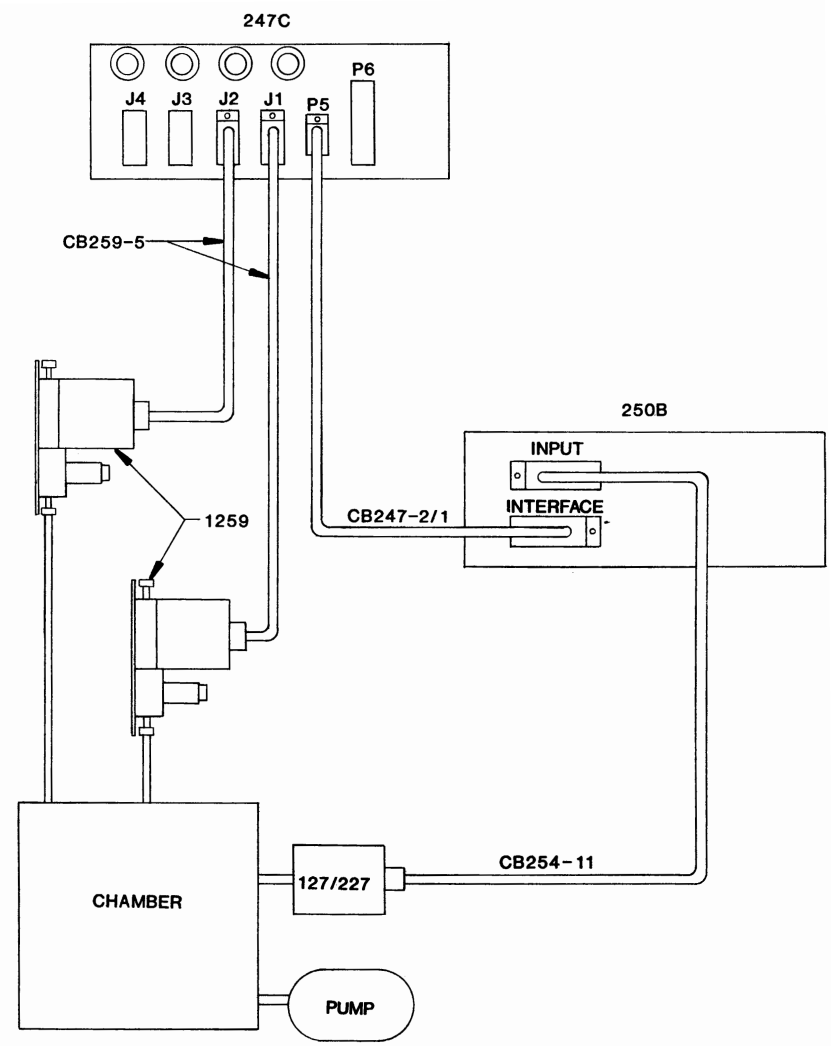


FIGURE D

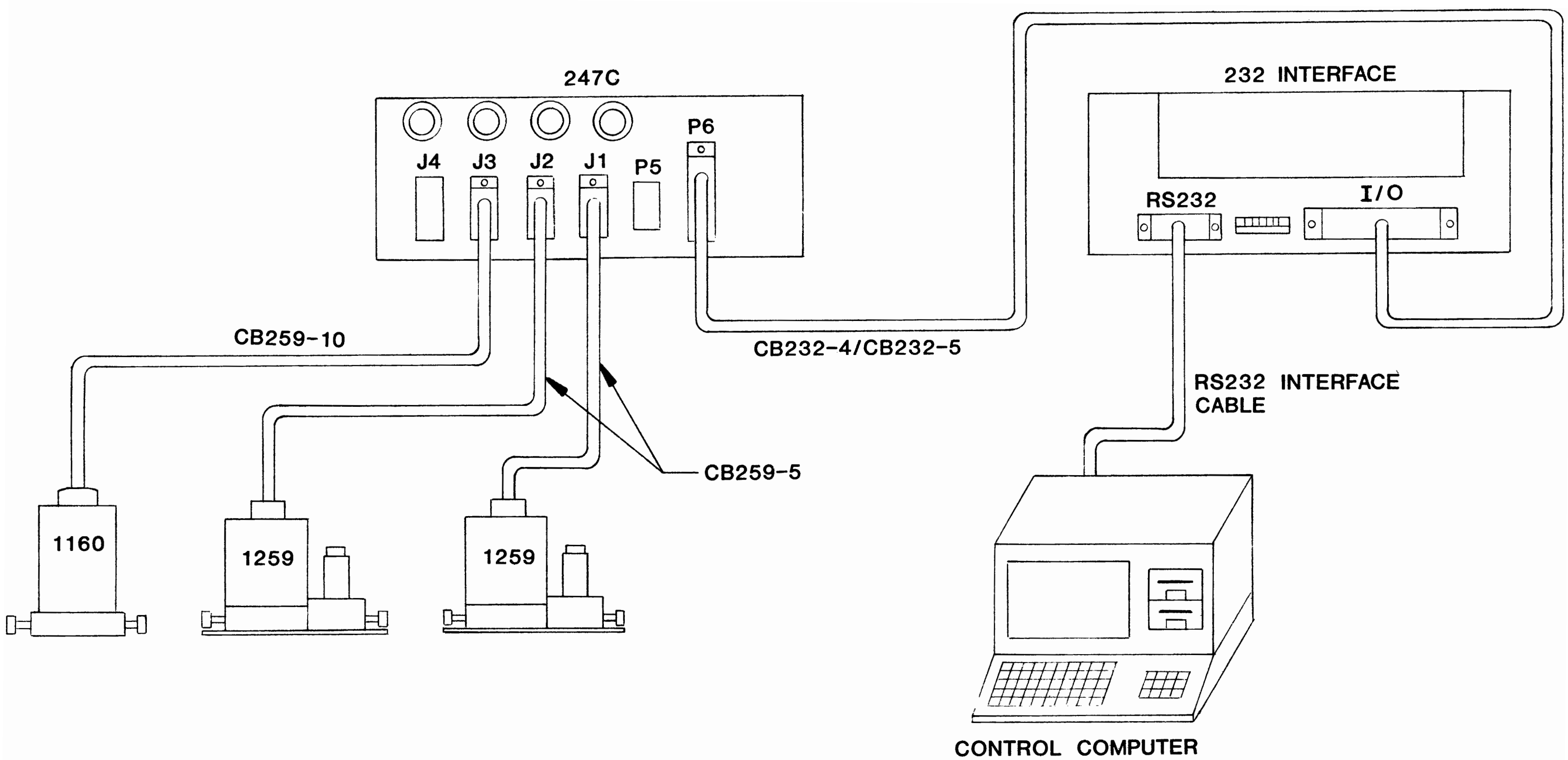

247C
J4
J3
J2
J1
P5
P6
232 INTERFACE
RS232
I/O
CB259-10
CB232-4/CB232-5
RS232 INTERFACE CABLE
CB259-5
1160
1259
1259
CONTROL COMPUTER

FIGURE E

SECTION 4

OPERATION

4.1 247C SYSTEM FUNCTION

To better understand the operation of the 247C, we will briefly discuss it's function within a flow control system. Figure F shows, in a simplified format, the operation of one of the 274C's four channels.

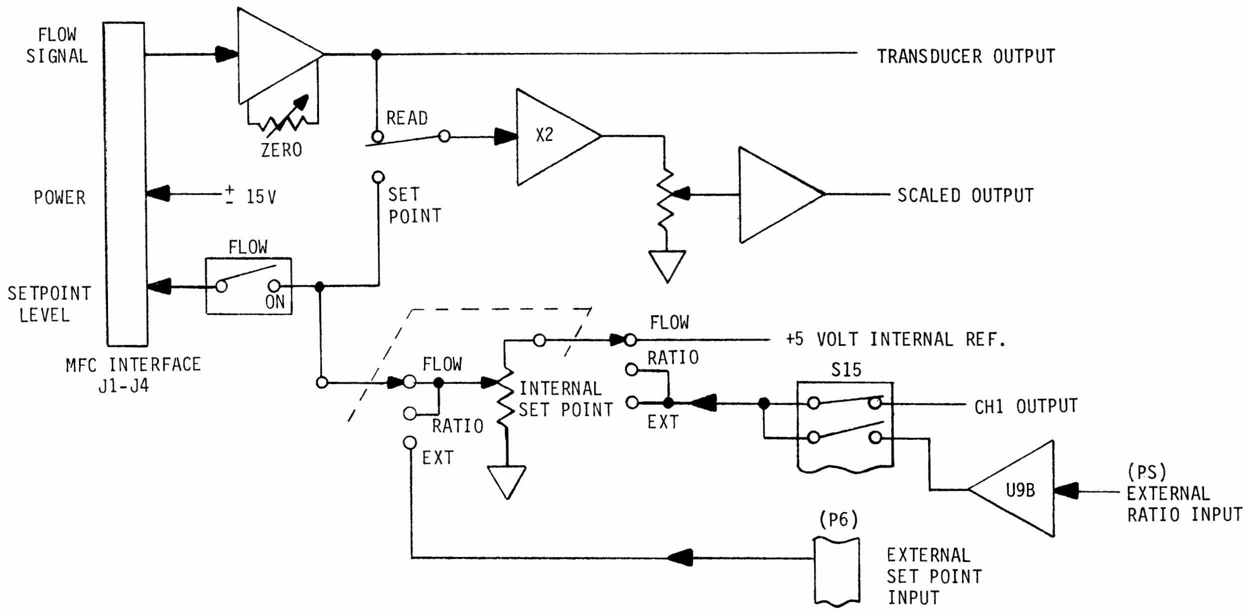


FIGURE F

The main power supply provides ± 15 volts to power the MFC. The voltage corresponding to the flow rate, +5V at full rated flow, is received at the input amplifier where the fine zero correction is made. The output from this amplifier is refered to in this manual as the "transducer output".

This signal is amplified X2 and applied to a scaling control, the output of which is buffered to become the scaled output. This signal is applied to the front panel display and to the "scaled output" on the rear panel connectors P5,P6.

The MFC's set point signal is applied through a switch circuit which is controlled from a front panel switch or a TTL logic level on connector P6. When the circuit is turned ON the set point signal is applied to the MFC and flow begins. Turn the switching circuit OFF and flow will cease.

The flow rate is determined by the magnitude of the set point signal with +5 volts corresponding to full flow.

The source of this signal is selected by a front panel Set Point Source switch as follows:

FLOW POSITION - Selects the set point signal from the front panel set point control; which is driven from the +5V internal reference.

RATIO POSITION - Selects the set point signal from the front panel set point control; which is driven from the Ch 1 transducer output or an External Ratio Set Point Input (P5)

EXT POSITION - Selects the set point signal from a pin on P6. This allows the flow rate to be controlled directly from a external 0 to +5V signal.

4.2 FRONT PANEL CONTROLS (Figure G)

Power Switch (A)

This switch controls power to the 247C and all attached MFC's.

CHANNEL SELECTOR (B)

Input to the front panel Flow Monitor (G) is controlled with this switch.

ZERO CONTROL (C)

This 20 turn potentiometer is used for fine zero adjustment. Since it has a limited range of ± 3% of FS, larger corrections must be made with the MFC's zero control.

READ/SET POINT SWITCH (D)

This spring loaded switch allows the operator to read, using the front panel meter, either the flow rate or the set point value (which may be going to the MFC thru the front panel flow switch). This will allow the operator to check and/or set MFC's zero, check and/or set set point level and check for an agreement between flow and set point when the MFC is so commanded. Note: Both the DPM and the transducer output are scaled to read directly in sccm or slm. Also to read any or all channel info, the front panel selector switch (B) will be used.

SET POINT CONTROL (E)

This 20 turn potentiometer sets the set point level when the Set Point Source Switch (F) is in the Flow or Ratio position. The range is:

Flow Position -- ± 0.1% to 100% of Full Rated Flow.
Ratio Position - ± 0.1% to 100% of Ch.1 Flow/Ext. Ratio Signal.

SET POINT SOURCE SWITCH (F)

This switch selects the source of the Set Point signal to be sent to the MFC. (See Fig. F) The Flow and Ratio positions are driven by the output of the Set Point Control (E) while the EXT position is driven by an externally applied voltage level.

FLOW MONITOR (G)

This 3 1/2 digit panel meter displays the flow rate of the channel selected by the Channel Selector (B). It also displays the MFC's set point signal when the READ/SET POINT switch (D) is held in the SET POINT position. The Scaler Control (D) must be properly set for direct reading in SCCM or SLM (see 4.4.D)

FLOW INDICATOR (H)

A green led indicates that the set point signal has been applied to the MFC. It does not mean that flow is occuring or that its' value is correct.

FLOW CONTROL SWITCH (I)

This switch controls the circuit which applies the set point signal to the MFC. When placed in the REMOTE position, Flow may may be turned ON/OFF by an external TTL signal. (ON=low..OFF=high or open. see 3.3 for pin assignments.)

4.3 REAR PANEL CONTROLS (Figure H)

MFC CONNECTOR (A)

Each connector provides the necessary power, set point voltage and receives the flow output signal.

CHANNEL 1 INTERFACE CONNECTOR (B)

This connector is used to join two 247C's, (Fig. C), or a 250B pressure controller and a 247C (Fig. D). The first connection, (Fig.C), allows additional MFC's to be ratioed to the first channel of #1 247C. The second connection, (Fig.D), allows the 250B controller to provide the pressure control signal that can be applied to all set point controls of the 247C. Individual flow rates are set as a fraction of channel 1 of #1 247C with the front panel set point controls (E) and this ratio is maintained while the total flow is adjusted to maintain the desired pressure.

Note: The MFC that is set to control at the highest % of its rated flow should be connected to channel 1.

CHANNELS 1-4 INTERFACE CONNECTOR (C)

This connector provides the four scaled transducer outputs. Also lines to turn flow ON/OFF, and the external set point input lines which remotely set the flow rate of the MFC's. This connector may be used by the MKS 232.

SCALING CONTROLS (D)

These controls are used to enter the product of the gas correction factor times the gauge factor. This allows the user to read flow rate directly (ie SCCM or SLM.)

DECIMAL POINT SELECTOR SWITCHES (E)

These switches, one for each channel, set the decimal point on the Flow Monitor (G).

LINE VOLTAGE SWITCH (F)

This slide switch sets the power transformer to receive 115 or 230 VAC. The voltage selected is visible in the panel cutout.

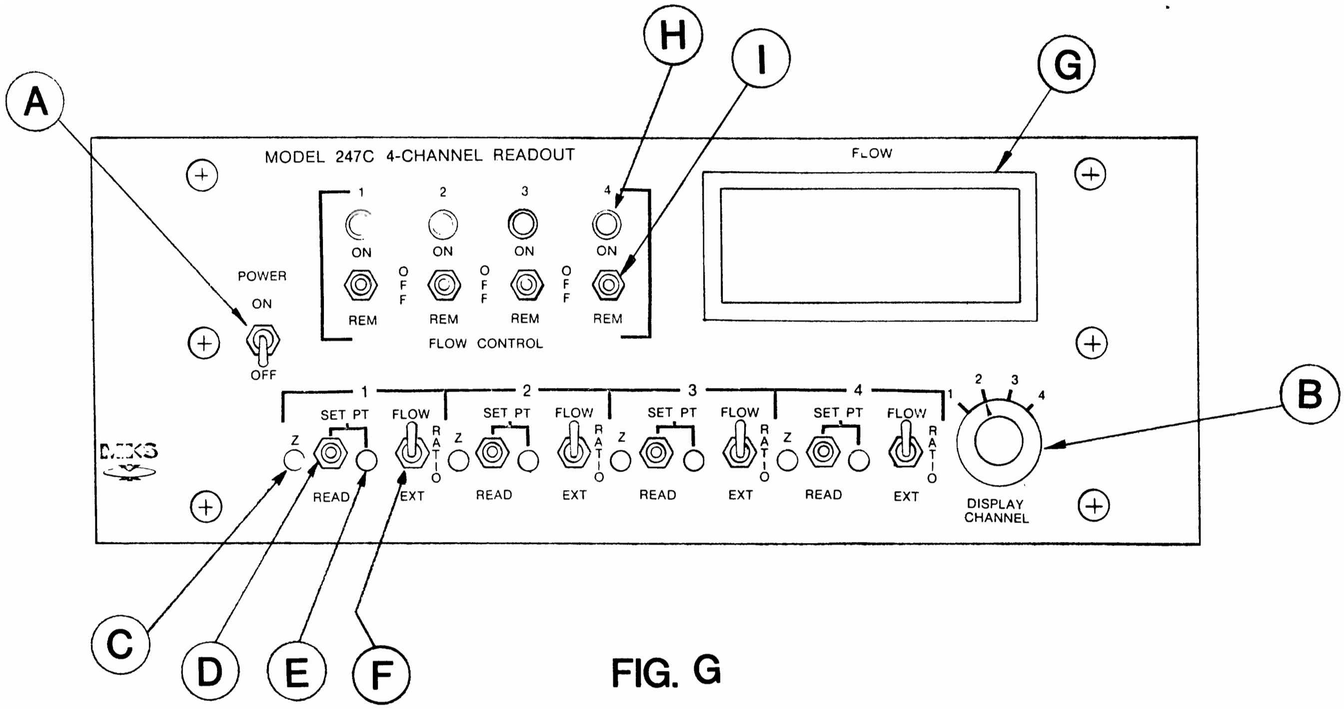
FUSE (G)

This fuse protects the internal circuitry of the 247C. The "High Side" of the line is fused. These fuse values are:

1 ASB @ 115VAC 50-60Hz
1/2 ASB @ 230VAC 50-60Hz

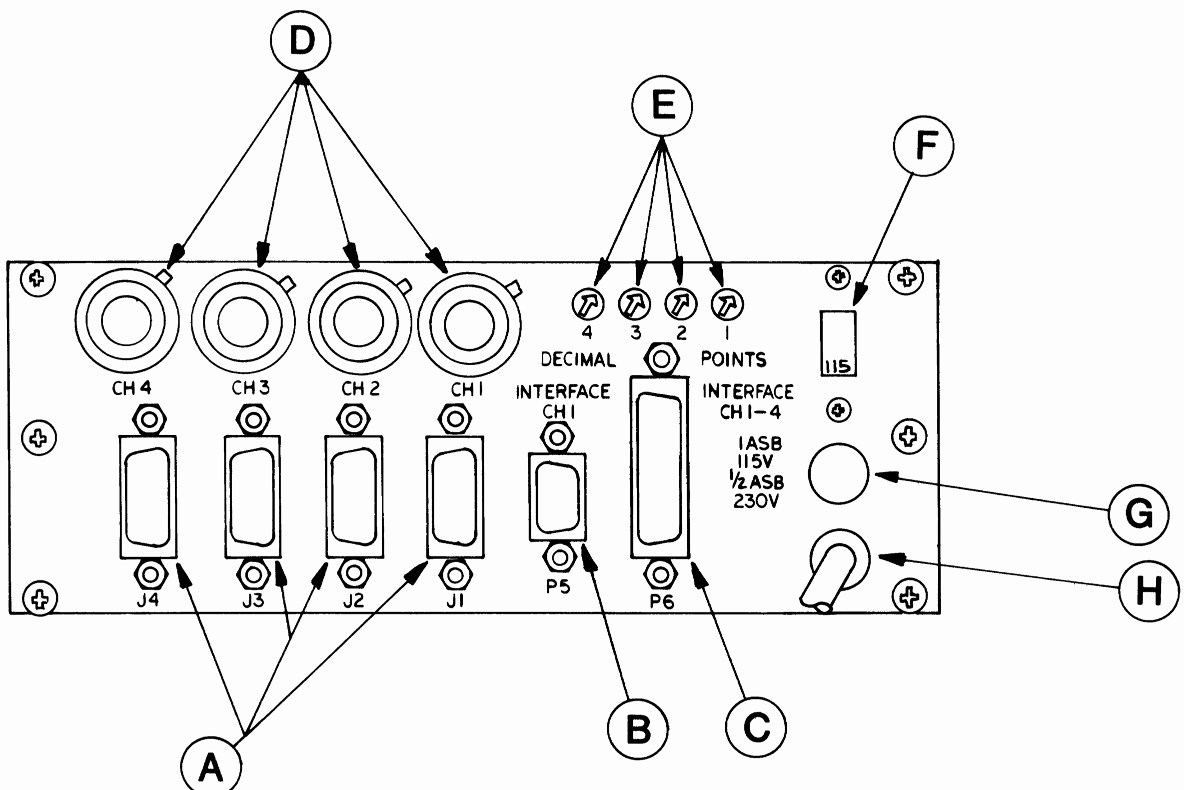
POWER CORD (H)

This cord provides 115 or 230 VAC to the 247C. The slide switch on the rear panel (F) sets the 247C for the proper voltage input.



MODEL 247C 4-CHANNEL READOUT
FLOW
POWER
ON
OFF
1
2
3
4
ON
OFF
REM
FLOW CONTROL
SET PT
FLOW
RATIO
Z
READ
EXT
DISPLAY CHANNEL
A
B
C
D
E
F
G
H
I

FIG. G



CH 4
CH 3
CH 2
CH 1
J4
J3
J2
J1
4
3
2
1
DECIMAL
POINTS
INTERFACE CH 1
P5
INTERFACE CH 1-4
P6
115
1ASB 115V
1/2 ASB 230V
A
B
C
D
E
F
G
H

FIG. H

4.4 DETAILED OPERATION-MANUAL FLOW CONTROL (REF. FIG. C)

Manual control of the flow rate through MFC's in an individual or ratioed mode is accomplished using the system shown in fig. C.

A. Install the MFC's as outlined in 3.2.B. More detailed information reguarding the mechanical installation of the MFC's will be found in the specific manual for the type of MFC being used.

B. Install the 247C, verify that the Line Voltage switch (H,F)* is set to the proper voltage, set the 247C's front panel controls as shown in the table below:

CONTROL	FIG.G, ITEM ...	POSITION
Power Switch	A	OFF
Flow Control Switch (1-4)	I	OFF
Set Point Source Switch (1-4)	F	FLOW
Channel Selector	B	Channel 1

Plug the power cord (H,H)* into the power line.

C. Connect the MFC's to the MFC Input Connectors (H,A)* with the proper interface cable. (See 3.4) Should more than four channels be required, add another 247C.

D. Set the Scaling Control (H,D)* to the product of the GAUGE FACTOR for the MFC in use and the GAS CORRECTION FACTOR of the gas in use. The full scale value of this control is 1000. Gauge Factors are given below:

1,10,100,1000,10K .... SCCM = 100
2,20,200,2000,20K .... SCCM = 200
5,50,500,5000,50K .... SCCM = 50

*** EXAMPLE ***

GAUGE FACTOR X GAS CORRECTION FACTOR = SCALING CONTROL SETTING

(200) X (1.44) Argon Gas = 288

Since the Scaling Control is 1000 at full scale, the above example is 28.8% of full scale. The control is set at shown below:

2

88

<u>THE SCALING CONTROL MUST BE SET PROPERLY FOR EACH MFC IN USE.</u>

*(Figure, Item)

E. Place the power switch in the ON position. This applies power to the 247C and the MFC's. The MFC's should be allowed to warm up for a period of 1 hour prior to any zero adjustments. Best performance is achieved when the MFC is powered continously.

F. The decimal point for channel 1 is set by inserting a screwdriver blade into the slot of the channel 1 decimal selector switch and rotating it CW until the desired decimal point is illuminated on the Flow Monitor (G,G). The decimal selector switches are mounted on the rear panel,(H,E) and the channels that they control are screened below the switch. The position of the decimal point is determined by the full scale range of the MFC in use. A 100 SCCM SCCM MFC requires the decimal point to be positioned as shown:

100.0 (Display at full rated flow)

G. Adjust the MFC's zero by adjusting the Zero Control (G,C)* for a reading of ± 000 on the Flow Monitor (G,G)*. Should this control lack the range for this adjustment, center it and use the zero control on the MFC to bring the reading within the range of the 247C's zero control.

H. The set point for the MFC is adjusted by holding the Read/Set Point Switch (G,D)* in the Set Point position and turning the Set Point Control (G,E)* to the desired level as displayed on the Flow Monitor (G,G)*. Since the Flow Monitor is driven from the Scaled Output, the displayed value has the Gas Correction and Gauge Factor applied. Therefore it represents the actual set point in SCCM for the attached MFC. When the adjustment is completed, release this switch. It is spring loaded and will return to the Read (Flow) position.

I. Switch the Channel Selector (G,B)* to the next position that has an MFC connected and repeat steps 4.4.D through 4.4.H. Continue to the next until all channels with MFC's attached have been properly set. Then return the Channel Selector to the channel that you wish to monitor.

J. The system is now completely adjusted to set the flow of each MFC. All that remains is to turn on the flow by applying the set point signal to the MFC. This is done by placing the Flow Control Switch (G,I)* to the ON position. This will cause the Flow Indicator lamp (G,H)* to be illuminated. When the set point voltage is applied to the MFC, flow will begin after a slight delay. Correct flow will be realized within approx. 1.5 seconds depending on type/brand of MFC used. Flow is turned OFF by placing the switch to the OFF position. The flow through any channel can be displayed on the Flow Monitor (G,G)* by placing the Channel Selector switch (G,B)* to that channel.

*(Figure, Item)

4.5 DETAILED OPERATION-RATIOED FLOW CONTROL (REF. FIG. C)

In the previous example, the Set Point Source switch (G,F)* was set to the Flow position. This connected an internal +5V reference to the top of the Set Point Control (G,E)*. (See Fig.G) Since the +5V corresponds to full rated flow, each Set Point Control could then be adjusted up to a maximum of 100% of the attached MFC's rated flow. When the Set Point Source switch is switched to the Ratio position, the Set Point Control will be connected to either the Transducer Output of Channel 1 or the output of the external ratio amplifier. The source of this signal is controlled by an internal DIP switch which is factory set to the Transducer Output of Channel 1. The following example of ratioed flow will deal with the case where channels 2-4 are ratioed to channel 1.

A. Follow the previous steps 4.4.A through 4.4.G. In the event that more than four MFC's are required, a second 247C may be used and slaved to the first 247C's Channel 1. In this case connect as shown in Fig. C and interconnect with a CB247-4 cable.

B. In this example we will assume a system with four 100 SCCM MFC's and Nitrogen gas. Not a very pratical system, but it makes the math easy. In this case we wish to have channels 2-4 in a ratio of 75,50 and 25% of the flow in channel 1.

C. With channels 1-4 Set Point Source switches (G,F)* in the Flow position, set the Set Point Controls (G,E)* as outlined in 4.4.H to the following levels:

Channel 1 Set Point Control .... (0 to 100 SCCM)
Channel 2 Set Point Control .... 75 SCCM
Channel 3 Set Point Control .... 50 SCCM
Channel 4 Set Point Control ....25 SCCM

D. Leave the Channel 1 Set Point Source switch (G,F)* in the Flow position and place channels 2-4 in the Ratio position. The 247C is now adjusted to control the MFC's connected to channels 2-4 to 75,50 and 25% of the flow rate through channel 1.

E. NOTE: If more than three channels are to be ratioed to CH. 1, a second 247C is required and its' Dip Switch (S15) must be set for External Ratio. (Set S15 as shown in 4.6.A)

*(Figure,Item)

*** EXTERNAL RATIO INPUT ***

As mentioned above, provision has been made to ratio channels 1-4 from an external signal rather than the output from channel 1 as described in the previous example. This is done by disconnecting the Channel 1 Transducer Output from the Ratio positon on the Set Point Source switch (G,F)* and replacing it with the output of the External Ratio Amplifier. These connections are made and broken with an internal DIP switch (S15). This external ratio input is applied through the Channel 1 Interface Connector (H,B)*. The pressure control system illustrated in Fig. D uses this method of control so we will examine it's detailed operation next.

4.6 DETAILED OPERATION-PRESSURE CONTROL WITH RATIOED FLOW (REF.FIG.D)

Pressure control with a ratioed gas flow is accomplished by adding an external controller (250B-1D)** and a pressure transducer (127/227) as shown in figure D. The pressure in the in the chamber is measured by the 127/227 which produces a DC output proportional to the pressure. This output is applied to the controller where it is compared with the pressure set point level. The resulting error signal (PCS) is applied to the 247C as an external ratio signal to produce the gas flow necessary to achieve the required pressure.

SETTING UP THE 247C

A. Remove the 247C's top cover. At the rear of the main PC board there is a four position DIP switch (S15). Set this switch by the following table:

Position 1 .... Open (Off)
Position 2 .... Closed (On)
Position 3 .... Open (Off)
Position 4 .... Open (Off)

This configures the Ratio position on all of the Set Point Source switches (G,F) to be driven by the output of the External Ratio Amplifier rather than the +5V internal reference. Additionally the amplifier is set to unity gain. (Amplifier can be set to a gain of 5 by closing position 4.). **NOW REPLACE THE TOP COVER AND THE RETAINING SCREWS.**

*(Figure, Item)
** 250B-1-A or 250B-1-D (no options installed) ONLY.

B. Connect the pressure transducer to the 250B with the proper cable. This example uses a CB254-11 which connects to the Input Connector on the rear of the 250B. The 247C is connected to the 250B with a CB247-2G1. In the event that more than four MFC's are required, use an additional 247C and use a CB247-2G2 to connect the two 247C's to the 250B. (The G rev. indicates the number of 247C's in use.)

C. Follow the previous steps 4.4.A through 4.4.G to prepare the 247C and the MFC's for flow control.

SETTING UP THE 250B-1D

(For additional information, reference Manual 195-107167B)

D. Verify that the Line Voltage Selector switch is set to the proper voltage and set the front panel controls as shown in the table below:

POWER SWITCH	OFF
INT/EXT	INT
10V/1V/.1V	10V
PHASE LEAD	1.5 SEC
GAIN	20%
BIAS	FULLY CCW
(CAME)**..............................	MANUAL
MANUAL CONTROL	500 OUT OF 1000
SET POINT LEVEL	REQUIRED PRESSURE LEVEL

E. Plug the power cord into the power line and turn on the power switch. Allow the system to warm-up for at least 1 1/2 hours before adjusting the zero.

F. When the chamber is pumped down below the resolution of the transducer, adjust the zero for a reading of $\pm$ 0000 on the 250B's DPM. (On 250B's without the DPM, adjust the Set Point Control to zero and adjust for a zero reading on the Error Meter.)

G. The control settings of step D have configured the 250B to deliver a constant Pressure Control Signal (PCS) of approx. +5V to the 247C's External Ratio Amplifier. This manually produced signal will be used to determine if the required pressure and flow rates can be achieved using a PCS with a nominal value of +5V. (Best control performance is achieved when the PCS is kept high for a good signal to noise ratio.)

*(Figure, Item)
**(Close/Auto/Manual/Ext.Switch)

H. Place the Set Point Source switches (G,F)*, on all channels with a MFC attached, to the Ratio position. Also place those channel's Flow Control switches (G,I)* to the ON positon. This will produce flow through all the MFC's.

I. Adjust the flow rate for each channel to achieve the desired flow rate and ratio between the channels and the desired pressure (within a factor of two) in the chamber. The flow rate is adjusted with the 247C's Set Point Control (G,E)* and the flow rate is displayed on the Flow Monitor (G,G)* which is controlled with the Channel Selector switch (G,B)*. The chamber pressure is displayed on the 250B-1D's panel meter. (To read pressure on a controller without a meter, adjust the controller's set point until the error meter reads zero and multiply the Set Point reading times the full scale of the pressure transducer. 1000 counts = Full Scale)

J. Should the pressure not be adjustable to within the factor of 2, then modification of the system <u>may</u> be necessary. Too high a pressure requires increased pumping capacity or smaller MFC's for less total flow, while too low a pressure requires reduced pumping capacity or larger MFC's for greater total flow.

K. When the pressure is within the desired 2 to 1 range, the system is ready for automatic control. Switch the 250B's (CAME)** switch for AUTO position. The 250B will now vary the PCS to adjust the total flow to achieve the control pressure. While the total flow rate will change, the ratio between the gases will remain constant.

L. The Gain and Phase Lead settings set in the previous step D were only a starting point for control. The 250B should be properly tuned to provide accurate control, free from oscillations. The tune-up section from the 250B manual is included for reference.

CONTROLLER TUNE-UP

Turning the valve switch (CMAE)** to AUTO puts the controller in action. If the Set Point Control is set for the same pressure that the MANUAL control has established, the transition from manual to auto should be smooth and effortless.

*(Figure,Item)
** CLOSE/MANUAL/AUTO/EXT SWITCH

To tune the controller, turn the GAIN up until 0.1% oscillations are apparent. Minimize oscillation amplitude using PHASE LEAD settings. When oscillations cease, turn up GAIN and readjust the PHASE LEAD if necessary. Check settings by changing the Set Point control. Optimum response is for the error to reduce to zero quickly, but with no overshoot. If the flow oscillates (error meter swings from positive to negative) the gain is too high. (The GAIN may be increased later when the PHASE LEAD is properly adjusted.) If the flow overshoots, but settles to the proper value, more PHASE LEAD is required. If the flow is slow rising to the proper value less PHASE LEAD is required. If the flow settles at a steady value which is other than the set point flow, (greater than ±0.25% error) more GAIN is needed

When making final adjustments, move the controls less than 10 deg. to prevent over-controlling. Various pressures will require different setting of GAIN and PHASE LEAD although pressures of up to a decade apart may be controlled using the same settings. Speed will be sacrificed for lower pressures.

NOTE: On controllers with the DVM option (250B-1D), the system error will have to be calculated by subtracting the set point value from the displayed value.

4.7 DETAILED OPERATION-COMPUTER CONTROLLED FLOW (REF. FIG. E)

The Channels 1-4 Interface connector (H,C)* provides a means to remotely turn the flow ON/OFF and to adjust and monitor the flow rate in any channel with an external computer or controller. Fig. E illustrates a system which is controlled by a computer via a MKS 232 Interface.

A. Connect the computer to the MKS 232 Interface with a standard RS-232-C cable.

B. Connect the MKS 232 Interface to the 247C with either a CB232-4 or a CB232-5 cable. The cable type is determined by which flow signal is to be monitored by the computer, the transducer output or the scaled output.

CB232-4 .... Monitors Scaled Output (0 to 1V nominal)
CB232-5 .... Monitors Transducer Output (0 to 5V nominal)

C. Verify that the computer and the MKS 232 Interface are both set to the proper line voltage and plug both instruments into the power line.

*(Figure, Item)

D. Follow the previous steps 4.4.A through 4.4.G to prepare the 247C and the MFC's for flow control.

E. Place the Set Point Source switches (G,F)*, on all channels with a MFC attached, to the EXT position.

F. Place the Flow Control switches (G,I)*, on all channels with a MFC attached to the REM positon.

G. At this point, the 247C is set to be controlled by the computer through the MKS Interface.

*** CONTROL PROGRAM ***

The MKS 232 Interface provides the digital and analog signals necessary to turn on and control the flow in each of the 247C's four channels. To accomplish this, it is necessary to write a program to produce these signals. The construction of this program is beyond the scope of this manual. The manual for the MKS 232 Interface (195-109315-A) contains instruction on writing to and reading from the interface as well as controlling it's digital output lines. Also included are some sample programs for a Hewlett Packard model 85 computer. Pages 3-5 through 3-8 of this manual contain specific programming instructions. In general terms, the computer program must do these tasks:

1. Select the channel to program and send a two byte control word that sets the output DAC to the proper control level and turns ON the flow. The construction of this word is described on page 3-5. The flow is turned ON by setting the MSB of the AUX. digital output to a 0. Conversly, flow is turned OFF by setting the MSB to a 1.

2. The flow rate is monitored by reading in a two byte word from the selected channel and converting the binary data to decimal. The construction of the data word is described on page 3-5.

   The channel selection and the direction of the data transfer is done by sending the proper ASCII character as outlined in table 3 on page. 3-7.

4.8 DETAILED OPERATION-REMOTE CONTROL CUSTOM INTERFACE

Section 4.7 described remote control using a computer and the MKS 232 Interface. This system takes advantage of existing equipment and cables and provides a very powerful control system. However, perhaps all that is required is a TTL level to turn the flow ON or OFF and a simple voltage level to control the flow rate. In this case a custom interface is created by wiring those control signals to the appropriate pins on P6. (See section 3.3)

A. Set up the system as outlined in previous steps 4.7.D through 4.7.G to configure it for remote control.

B. When this is done, simply apply the control signals through the interface. For example: to produce a flow of 50 SCCM through a 100 SCCM MFC connected to channel 1, apply a +2.5 volt signal to P6-4. Reference this voltage to P6-1. Then attach a TTL signal to P6-12. Reference this signal to P6-8. To turn ON the flow, apply a TTL low (0.4 to 0.8V) to P6-12. To turn OFF the flow, apply a TTL high (2.4-5V) or an open circuit.

SECTION 5

MAINTENANCE

GENERAL:

Should any difficulties be encountered in the use of your instrument, it is recommended that you contact any MKS authorized sales office, service center or home office for repair instructions. A list of address may be found in the appendix.

```
****************************************************************
*                                                              *
* Should it be necessary to return the instrument to MKS for   *
* repair, please contact the MKS Service Center for an ERA     *
* NO. (Equipment Return Authorization Number). To expedite     *
* handling and assure the proper servicing of your instrument. *
*                                                              *
****************************************************************
```

5.1 FAULT ISOLATION

The first approach to deal with a problem in the 247C is to isolate the section where the fault lies. Once this is done, the problem is usually easily corrected. The 247C can be broken down into the following sections:

1. Power Supply
2. Channel Amplifier String
3. Flow Reference Voltage Source
4. External Ratio Amplifier
5. Panel Meter (Flow Monitor)
6. Set Point Buffer and Flow Switching Circuit

Since a problem in the power supply will effect the performance of all sections, it is important to begin the fault isolation at this point. Refer to print D110212 for the location of grounds and components.

POWER SUPPLIES

A. Measure the $\pm$ supplies at the power supply jumpers on the PC board. Reference to A ground. The voltages should be within the range of 14.8 to 15.2 volts and the AC ripple should be $<$ 10 mV P-P. If the voltages are ok, proceed to step 5.1.D.

B. If the voltages are incorrect, disconnect the MFC's from the rear panel, one at a time. Should the supplies recover when a MFC is removed, then either the cable or the MFC is defective.

C. The power supplies can be isolated from the circuits in the 247C by disconnecting the power supply jumpers and measuring the supplys on the supply side. **CAUTION! BOTH SUPPLIES** must be disconnected to perform this test. Circuits must not be run with only one supply operative. Schematic D110210-1 shows the typical operating voltages for the supplies when they are operated from a 117 VAC 60Hz power line.

D. If the power supply is found to be normal, the next step is to examine the signal path through the channel amplifiers.

CHANNEL AMPLIFIERS

E. To test a channel, use an external connector with a jumper wire connected between pins 2 and 8. Plug this connector into the appropriate Channel Input connector (H,A). This connects the output of the set point buffer to the input of the channel.

F. Connect a voltmeter to this jumper wire and reference the meter to A ground. Place the channel's Set Point Source switch (G,F) to the Flow position and adjust the Set Point Control (G,E) to produce a +5V reading on the voltmeter. In the event that it is not possible to obtain this voltage, proceed to the Voltage Reference checkout step.

G. Turn the Zero pot (G,C) 25 turns CCW and then 12 turns CW to center it. Also set the Scaling Control (H,D) to 100 (10% of FS).

H. Under these conditions, a normal unit will produce the voltages shown on D110210-2 & 3 and the Flow Monitor (G,G) should display +1000 ± 15 counts.

+5V VOLTAGE REFERENCE

I. In the event that the voltage output from the internal +5V source is not correct, measure the input to the source.

J. Connect the high side of the voltmeter to the junction of R67 and VR1. Reference the meter to A ground. The proper input voltage is +1.23 to +1.25 volts. With this input, the potentiometer R66 can be adjusted to produce a +5V output. (Actually factory set to +5.1 volts)

K. Incorrect input voltage may be caused by a defective reference VR1. Incorrect output may be caused by a defective amplifier U9A.

EXTERNAL RATIO AMPLIFIER

L. Failure of the unit to work properly with an external voltage being used as a ratio signal may be caused by a defective amplifier or by an incorrecting setting on DIP switch S15.

M. The amplifier will accept signals corresponding to a full scale voltage of +1V and +5V. To set the amplifier for a +5V full scale input, S15 must be set by the following table:

S15-1 .... OPEN (OFF)
S15-2 .... CLOSED (ON)
S15-3 .... OPEN (OFF)
S15-4 .... OPEN (OFF)

To set the amplifier for a +1V full scale input, S15 must be set by the following table:

S15-1 .... OPEN (OFF)
S15-2 .... CLOSED (ON)
S15-3 .... OPEN (OFF)
S15-4 .... CLOSED (ON)

N. The input voltage required to produce the output described above, is applied to the 247C through P5-7. Both the input voltage and the meter measuring the output should be referenced to P5-1.

PANEL METER

O. The panel meter (Flow Monitor) is a 3 1/2 digit - 2 V full scale device. The meter is powered by a +5V supply located on the main PC board.

P. Measure the supply voltage to the meter by connecting a voltmeter to the +5V supply jumper on the PC board and referencing the meter to A ground. Voltage should be +4.7 to +5.3 volts.

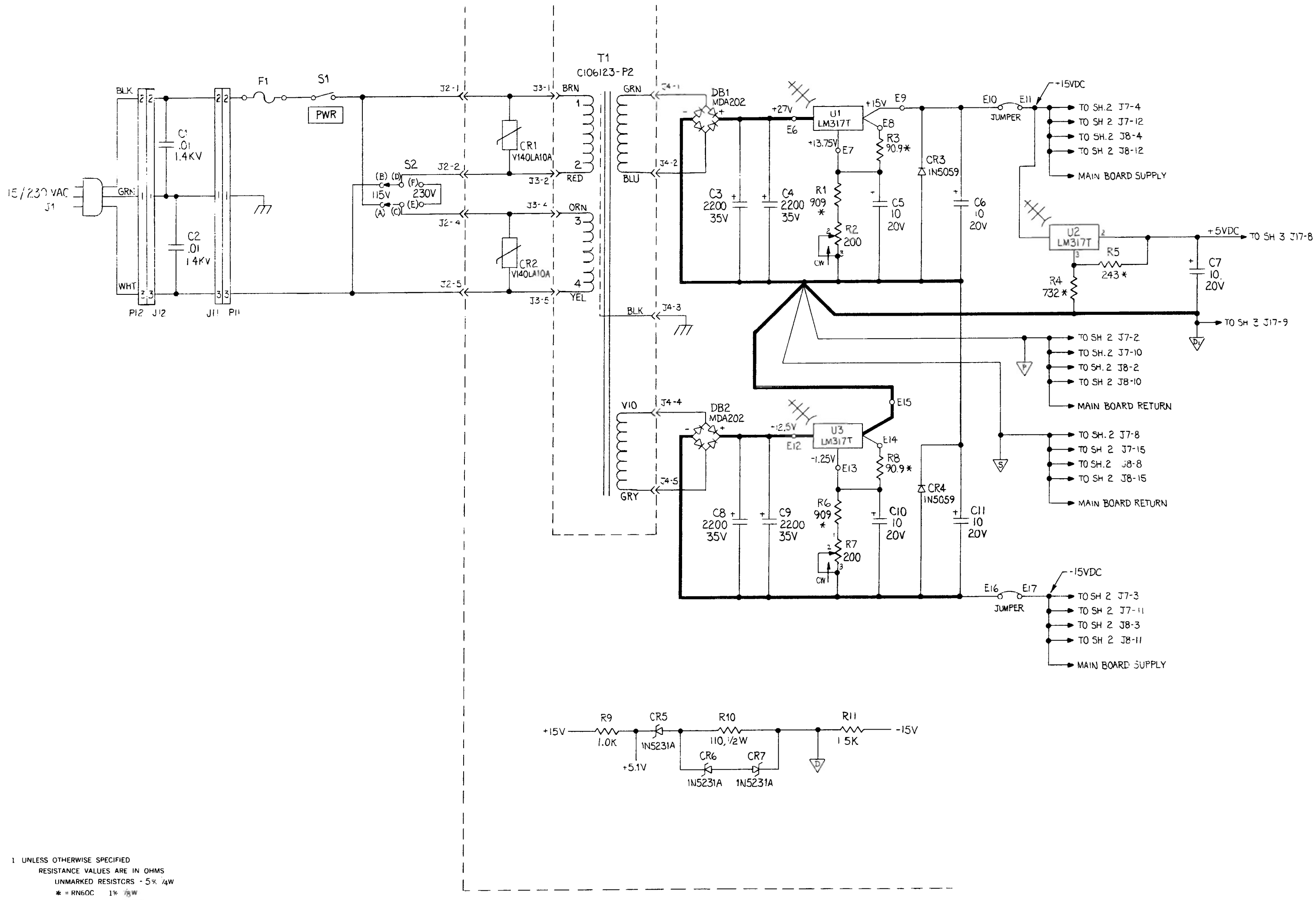
Q. Set up channel 1 for a +1V output as described in 4.5.E thru 4.D.G.

R. Measure the output of the channel on pin 2 of connector P5. The Flow Monitor should track the voltage ± 1 count. There is some adjustment available on the rear of the meter. (The meter must be removed to perform this adjustment.) Should the range of this adjustment be insufficient to bring the meter reading into agreement with the reading on P5-2 then the meter must be replaced.

SET POINT BUFFER AND FLOW SWITCHING CIRCUIT

S. The buffer amplifier prevents the Flow Controller from loading the set point signal. The voltage at the output of the second set point buffer should track the voltage on the arm of the Set Point Control by ± 2mV when the flow is ON. Should this signal be incorrect at the Channel Input Connector, then trace the signal back to the Set Point Control to determine where the fault lies.

T. A negative voltage (approx. −0.1V) at the Channel Input Connector indicates that the FET is ON. If the Flow Lamp (G,H) is on, then the FET is defective or the drive to the gate is incorrect. The drive under these conditions, should be −15V ± 1 volt.



1 UNLESS OTHERWISE SPECIFIED
RESISTANCE VALUES ARE IN OHMS
UNMARKED RESISTORS - 5% 1/4W
* = RN60C 1% 1/8W
⊕ = PRECISION WIREWOUND - 1% W
K = 1,000
M = 1,000,000

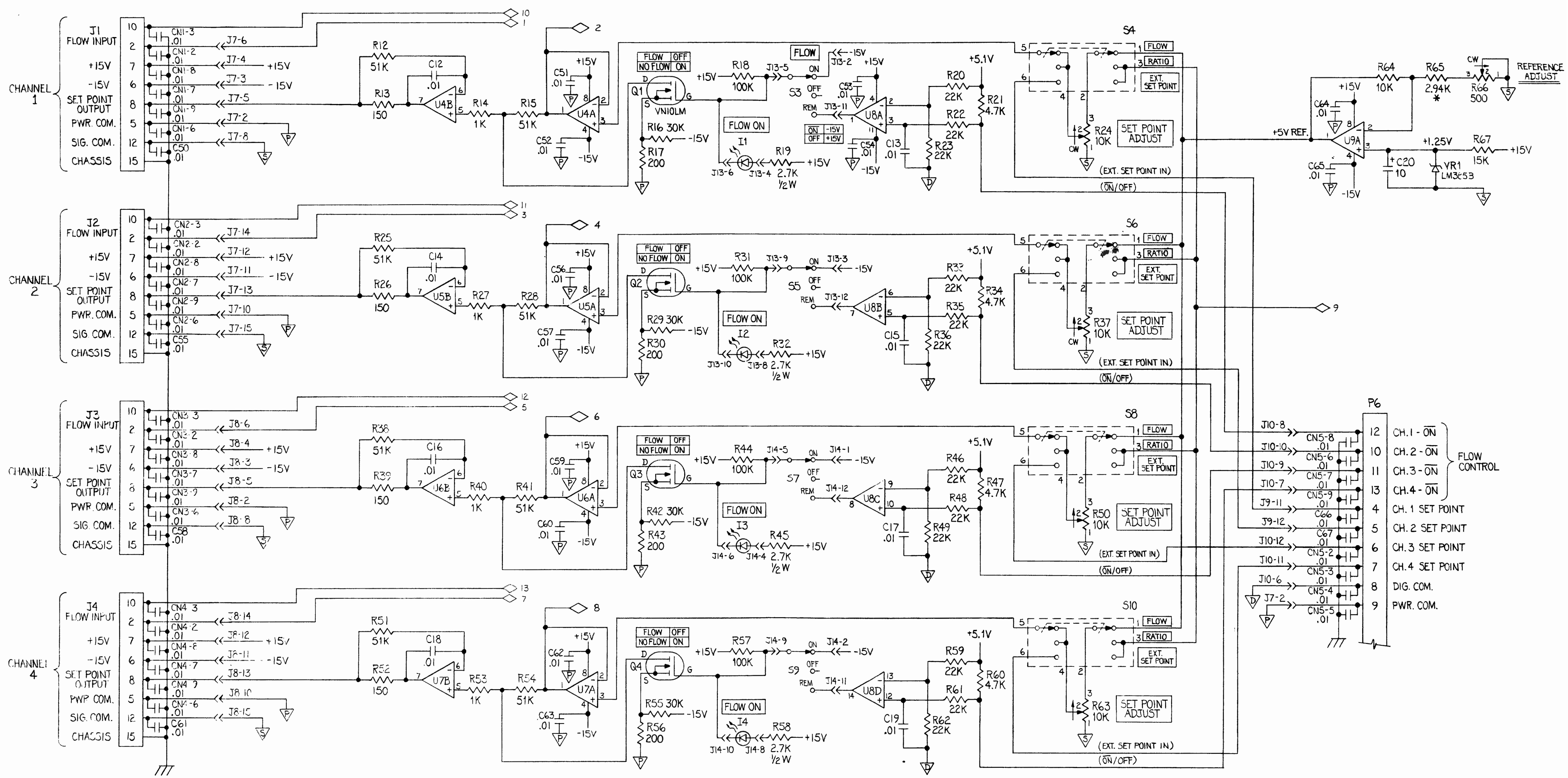
CAPACITANCE VALUES ARE IN MICROFARADS
PF = PICOFARADS
INDUCTANCE VALUES ARE IN MICROHENRIES

NOTES

SCHEMATIC

D110210-A

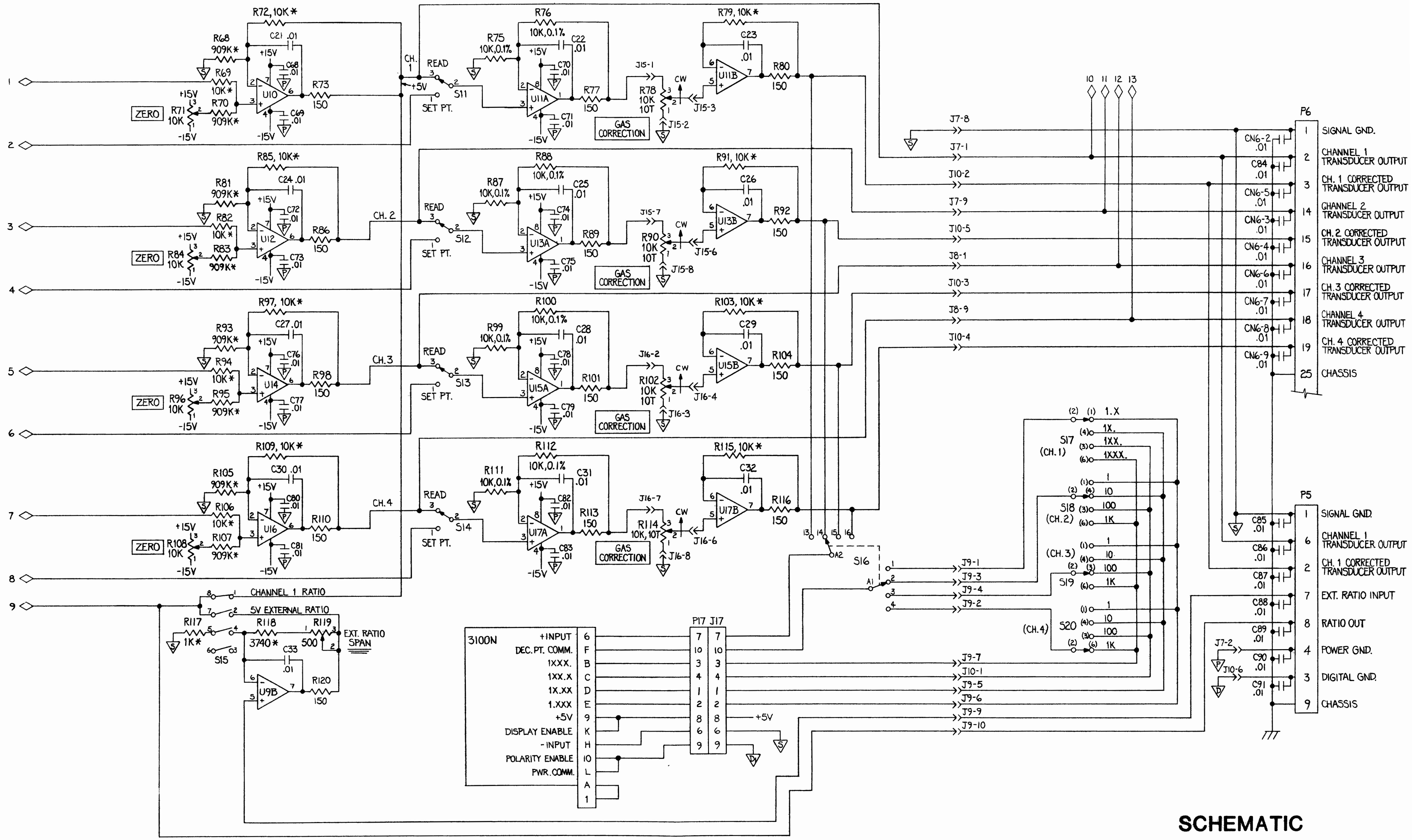
1 OF 3



SCHEMATIC

D110210-A

SHT 2



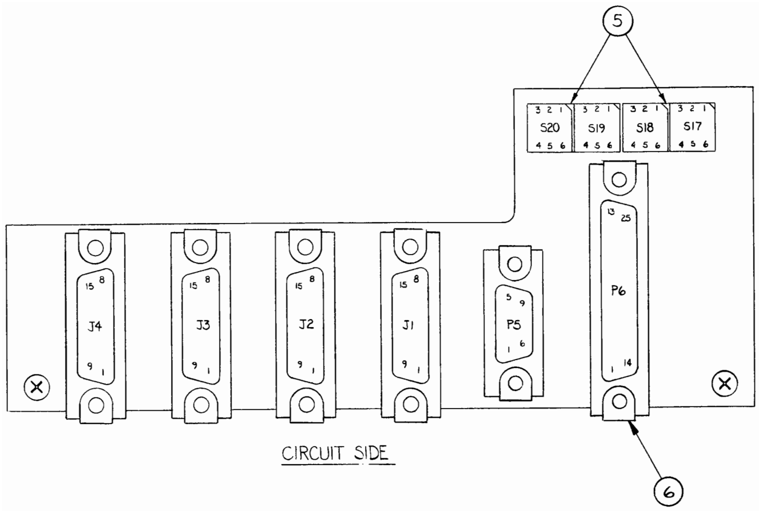
SCHEMATIC

D110210-A

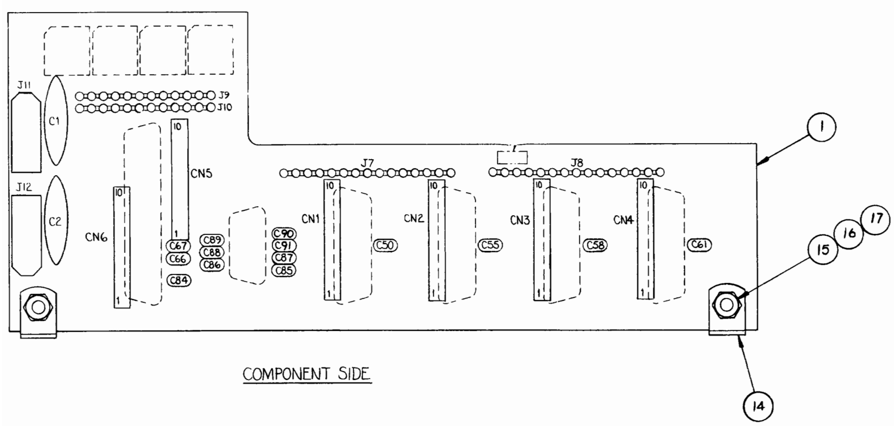
SHT 3

SECTION 6

PARTS LIST



CIRCUIT SIDE



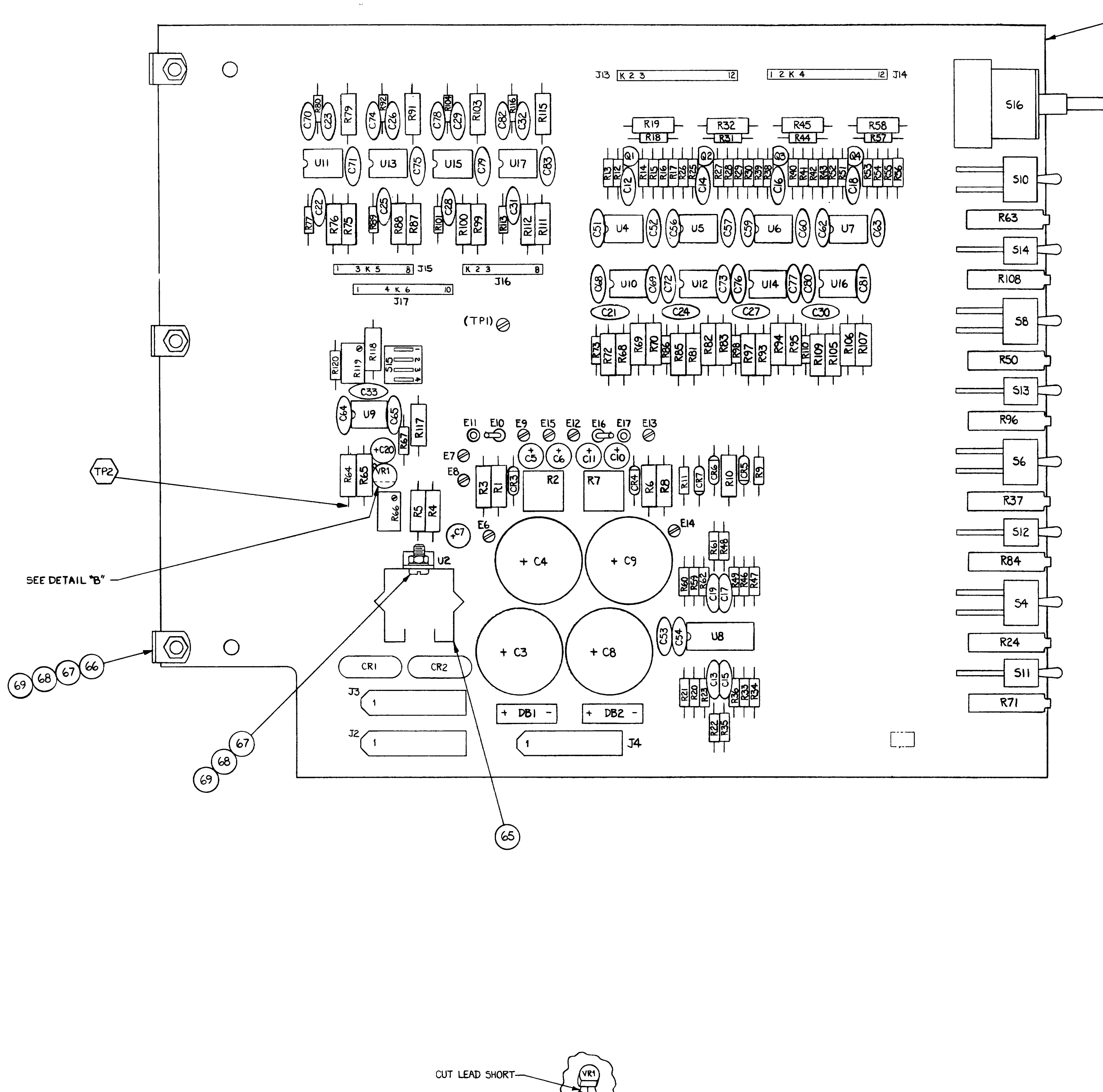
COMPONENT SIDE

QTY G1	ITEM	PART NO.	DESCRIPTION	REMARKS
2	17	146-3754	HEX NUT #6-32	
2	16	185-3745	WASHER, #6 I.T. LOCK	
2	15	160-3709	SCREW, PHIL PAN HD., #6-32 × .25 LG.	
2	14	103-6014	ANGLE BRACKET, #6-32 TAPPED	
6	13	B109626-P1	CAP. NETWORK, 8 CAP., 10 PIN SIP, CN1-6	
2	12	110-6040	CONN., 3PIN NYLON WAFER (FFM), J11, J12	
2	11	096-5601	RIBBON CABLE, 12 COND., 3" LG, J9, J10	
2	10	096-5600	RIBBON CABLE, 15 COND., 3" LG, J7, J8	
1	9	110-6802	CONN., 25 PIN TYPE "D" MALE, P6	
1	8	110-6562	CONN., 9 PIN TYPE "D" MALE, P5	
4	7	110-6491	CONN., 15 PIN TYPE "D" FEMALE, J1-4	
12	6	113-6523	CLIP, RETAINING, 4-40	
2	5	156-2475	I.C. SOCKET, 14 PIN DIP FOR S17-20	
4	4	072-4953	SWITCH, ROTARY 4 POS. REPEATING, S17-20	
2	3	005-4040	CAP., .01µF 1.4KV, C1, C2	
14	2	005-4133	CAP., .01µF 100V CER., C50, 55, 58, 61, 66, 67, 84-91	
1	1	C110213-P1	P.C. BOARD, REAR PANEL	

LIST OF MATERIALS

P.C. ASSEMBLY

D110214-A



DETAIL "B" VR1 - INSTALL 3-LEAD PLASTIC CASE AS SHOWN ABOVE
OR
- INSTALL 2-LEAD METAL CASE AS SHOWN AT LEFT

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QTY -G4	QTY -G3	QTY -G2	QTY -G1	ITEM NO.	PART NUMBER	DESCRIPTION	NOTE
			1	1	D110211-P1	P.C. BD., 247C MAIN ELECTRONICS	
				2			
			1	3	033-4435	I.C., LM317T REGULATOR U2	
			9	4	030-5579	I.C., LT1013CN8 DUAL OP-AMP U4,5,6,7,9,11,13,15,17	
			1	5	030-5007	I.C., LF347N QUAD OP-AMP U8	
			4	6	030-4406	I.C., LF356N OP-AMP U10,12,14,16	
				7			
			49	8	005-3259	CAP., .01 µF C12-19, 21-33, 51-54, 56, 57, 59, 60, 62,	
						63-65, 68-83	
			6	9	007-2962	CAP., 10µF, 20V C5,6,7,10,11,20	
			4	10	007-4356	CAP., 2200µF, 35V C3,4,8,9	
				11			
			2	12	065-4344	RES., 90.9Ω, RN60C R3,8	
			1	13	064-2504	RES., 110Ω, 1/2W R10	
			17	14	064-2582	RES., 150Ω R13,26,39,52,73,77,80,86,89,92,98,101,	
						104,110,113,116,120	
			4	15	064-2443	RES., 200Ω R17,30,43,56	
			1	16	065-4642	RES., 243Ω, RN60C R5	
			1	17	065-4671	RES., 732Ω, RN60C R4	
			2	18	065-4345	RES., 909Ω, RN60C R1,6	

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QTY -G4	QTY -G3	QTY -G2	QTY -G1	ITEM NO.	PART NUMBER	DESCRIPTION	NOTE
			5	19	064-2428	RES., 1K R14,27,40,53,9	
			1	20	065-2712	RES., 1K, RN60C R117	
			4	21	064-2215	RES., 2.7K, 1/2W R19,32,45,58	
			1	22	065-3241	RES., 2.94K, RN60C R65	
				23			
			1	24	065-4706	RES., 3.74K, RN60C R118	
			4	25	064-2470	RES., 4.7K R21,34,47,60	
			1	26	064-2049	RES., 1.5 K R11	
				27			
			13	28	065-2450	RES., 10K, RN60C R69,72,79,82,85,91,94,97,103,106,109,115,	64
			8	29	066-4860	RES., 10K, 0.1%, 25 PPM R75,76,87,88,99,100,111,112	
			1	30	064-2439	RES., 15K R67	
			12	31	064-2445	RES., 22K R20,22,23,33,35,36,46,48,49,59,61,62	
			4	32	064-2436	RES., 30K R16,29,42,55	
			8	33	064-3086	RES., 51K R12,15,25,28,38,41,51,54	
			4	34	064-2469	RES., 100K R18,31,44,57	
			8	35	065-3155	RES., 909K, RN60C R68,70,81,83,93,95,105,107	
				36			
			2	37	053-4346	POT., 200Ω, CERM., TOP ADJ. R2,7	
			2	38	053-4195	POT., 500Ω, CERM., TOP ADJ. R66,119	

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QTY -G4	QTY -G3	QTY -G2	QTY -G1	ITEM NO.	PART NUMBER	DESCRIPTION	NOTE
			8	39	053-2790	POT., 10K, FRONT ADJ. R24,37,50,63,71,84,96,108	
				40			
			2	41	017-5599	VARISTOR, V140LA10A CR1,2	
			2	42	015-2395	DIODE, 1N5059 CR3,4	
			3	43	017-4324	DIODE, 1N5231A CR5,6,7	
			2	44	015-4522	DIODE BRIDGE, MDA202 DB1,2	
			1	45	016-4379	DIODE, LM385B VR1	
				46			
			4	47	086-9061	TRANSISTOR. VN10LM Q1-4	
				48			
				49			
			4	50	072-4296	SWITCH, TOGGLE, 3 POS., DPDT S4,6,8,10	
			4	51	072-4951	SWITCH, TOGGLE, MOMENTARY S11-14	
			1	52	072-4208	SWITCH, 4 POS. DIP S15	
			1	53	072-4880	SWITCH, ROTARY S16	
			1	54	074-4881	MOUNTING WASHER FOR S16	
			2	55	110-6042	CONN., 5 PIN MOLEX (FFMMM) J2,3	
			1	56	110-6560	CONN., 5 PIN MOLEX (MMMMF) J4	
				57			
				58			

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QTY -G4	QTY -G3	QTY -G2	QTY -G1	ITEM NO.	PART NUMBER	DESCRIPTION	NOTE
				59			
			2	60	110-3968	CONN., 12 PIN HEADER J13,14	
			2	61	110-3589	CONN., 8 PIN HEADER J15,16	
			1	62	110-6706	CONN., 10 PIN HEADER J17	
			9	63	173-2857	TERMINAL, SWAGE MT., SLOTTED E6-9, 12-15, TP1	
				64			
			1	65	123-3470	HEAT SINK (USED WITH U2)	
			3	66	103-6014	ANGLE BRACKET, #6-32 TAPPED	
			4	67	160-3687	SCREW, PHIL. PAN HD., #4-40 x .25 LG. (USED ON ITEMS 65 & 66)	
			4	68	185-3744	WASHER, #4 I.T. LOCK (USED ON ITEMS 65 & 66)	
			4	69	146-3753	HEX NUT, #4-40 (USED ON ITEMS 65 & 66)	
			4"	70	093-2100	BUS WIRE, #22 AWG (USED ON E10 & E16)	

MKS INSTRUMENTS, INC. BURLINGTON, MA USA — PL 110212 — REV A — SH 5

MAIN BOARD

D110212-A

APPENDIX

Gas Flow Conversion Chart

GAS	SYMBOL	SPECIFIC HEAT, Cp cal/g°C	DENSITY g/l @ 0°C	CONVERSION FACTOR
Air	------	.240	1.293	1.00
Ammonia	NH_3	.492	.760	.73
Argon	Ar	.1244	1.782	1.44
Arsine	AsH_3	.1167	3.478	.67
Boron Trichloride	BCl_3	.1279	5.227	.41
Bromine	Br_2	.0539	7.130	.81
Carbon Dioxide	CO_2	.2016	1.964	.74
Carbon Monoxide	CO	.2488	1.250	1.00
Carbon Tetrachloride	CCl_4	.1655	6.86	.31
Carbon Tetrafluoride (Freon - 14)	CF_4	.1654	3.926	.42
Chlorine	Cl_2	.1144	3.163	.86
Chlorodifluoromethane (Freon - 22)	$CHClF_2$	.1544	3.858	.46
Chloropentafluoroethane (Freon - 115)	C_2ClF_5	.164	6.892	.24
Chlorotrifluoromethane (Freon - 13)	$CClF_3$	.153	4.660	.38
Cyanogen	C_2N_2	.2613	2.322	.61
Deuterium	D_2	1.722	.1799	1.00
Diborane	B_2H_6	.508	1.235	.44
Dibromodifluoromethane	CBr_2F_2	.15	9.362	.19
Dichlorodifluoromethane (Freon - 12)	CCl_2F_2	.1432	5.395	.35
Dichlorofluoromethane (Freon - 21)	$CHCl_2F$	.140	4.592	.42
Dichloromethylsilane	$(CH_3)_2SiCl_2$	.1882	5.758	.25
Dichlorosilane	SiH_2Cl_2	.150	4.506	.40
1,2 - Dichlorotetrafluoroethane (Freon - 114)	$C_2Cl_2F_4$	.160	7.626	.22
1,1 - Difluoroethylene (Freon - 1132A)	$C_2H_2F_2$	.224	2.857	.43
2,2 - Dimethylpropane	C_5H_{12}	.3914	3.219	.22
Ethane	C_2H_6	.4097	1.342	.50
Fluorine	F_2	.1873	1.695	.98
Fluoroform (Freon - 23)	CHF_3	.176	3.127	.50
Freon - 11	CCl_3F	.1357	6.129	.33
Freon - 12	CCl_2F_2	.1432	5.395	.35
Freon - 13	$CClF_3$	.153	4.660	.38
Freon - 13 B_1	$CBrF_3$	.1113	6.644	.37
Freon - 14	CF_4	.1654	3.926	.42
Freon - 21	$CHCl_2F$	.140	4.592	.42
Freon - 22	$CHClF_2$	.1544	3.858	.46
Freon - 23	CHF_3	.176	3.127	.50
Freon - 113	$C_2Cl_3F_3$	.161	8.360	.20
Freon - 114	$C_2Cl_2F_4$	.160	7.626	.22
Freon - 115	C_2ClF_5	.164	6.892	.24
Freon - 116	C_2F_6	.1843	6.157	.24
Freon - C318	C_4F_8	.185	8.397	.17

Gas Flow Conversion Chart (Cont'd.)

GAS	SYMBOL	SPECIFIC HEAT, Cp cal/g°C	DENSITY g/l @ 0°C	CONVERSION FACTOR
Freon - 1132A	$C_2H_2F_2$	.224	2.857	.43
Helium	He	1.241	.1786	1.454 *
Hexafluoroethane (Freon - 116)	C_2F_6	.1843	6.157	.24
Hydrogen	H_2	3.419	.0899	1.01 *
Hydrogen Bromide	HBr	.0861	3.610	1.00
Hydrogen Chloride	HCl	.1912	1.627	1.00
Hydrogen Fluoride	HF	.3479	.893	1.00
Isobutylene	C_4H_8	.3701	2.503	.29
Krypton	Kr	.0593	3.739	1.543
Methane	CH_4	.5328	.715	.72
Methyl Fluoride	CH_3F	.3221	1.518	.56
Molybdenum Hexafluoride	MoF_6	.1373	9.366	.21
Neon	Ne	.246	.900	1.46
Nitric Oxide	NO	.2328	1.339	.99
Nitrogen	N_2	.2485	1.250	1.00
Nitrogen Dioxide	NO_2	.1933	2.052	.74
Nitrogen Trifluoride	NF_3	.1797	3.168	.48
Nitrous Oxide	N_2O	.2088	1.964	.71
Octafluorocyclobutane (Freon - C318)	C_4F_8	.185	8.937	.17
Oxygen	O_2	.2193	1.427	1.00
Pentane	C_5H_{12}	.398	3.219	.21
Perfluoropropane	C_3F_8	.194	8.388	.17
Phosgene	$COCl_2$	.1394	4.418	.44
Phosphine	PH_3	.2374	1.517	.76
Propane	C_3H_8	.3885	1.967	.36
Propylene	C_3H_6	.3541	1.877	.41
Silane	SiH_4	.3189	1.433	.60
Silicon Tetrachloride	$SiCl_4$	.1270	7.580	.28
Silicon Tetrafluoride	SiF_4	.1691	4.643	.35
Sulfur Dioxide	SO_2	.1488	2.858	.69
Sulfur Hexafluoride	SF_6	.1592	6.516	.26
Trichlorofluoromethane (Freon - 11)	CCl_3F	.1357	6.129	.33
Trichlorosilane	$SiHCl_3$	.1380	6.043	.33
1, 1, 2 - Trichloro - 1, 2, 2 Trifluoroethane (Freon - 113)	CCl_2FCClF_2 $C_2Cl_3F_3$	.161	8.360	.20
Tungsten Hexafluoride	WF_6	.0810	13.28	.25
Xenon	Xe	.0378	5.858	1.32

* CONSULT MKS FOR SPECIAL APPLICATIONS

NOTE: Standard Pressure is defined as 760 mmHg (14.7). Standard Temperature is defined as 0°C.

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