INSTRUCTION OR TEST	AREA OF POSSIBLE PROBLEM
27. In the following steps, you will verify the Module display readings at all of the positions of the A Timebase switch. Touch the alligator clip on the black test lead to Module pin TPD to obtain the PD-GND readings. The "A" Timebase heading indicates the settings of the A Timebase switch. These numbers are approximate.	1. For incorrect logic voltages: a. U1106-U1114 circuitry (see Logic Chart I, III). 2. For incorrect decimal point, V1201-V1205 circuitry. 3. For incorrect indicator lighting: a. U1112. b. V1212-V1216 circuitry.

A Timebase	TPD OPEN	TPD-GND
100 ms	0.950 s	.0950 s
50 ms	0.475 s	.0475 s
20 ms	190.0 ms	19.00 ms
10 ms	095.0 ms	09.50 ms
5 ms	047.5 ms	04.75 ms
2 ms	19.00 ms	1.900 ms
1 ms	09.50 ms	0.950 ms
.5 ms	04.75 ms	0.475 ms
.2 ms	1.900 ms	.1900 ms
.1 ms	0.950 ms	.0950 ms
50 µs	0.475 ms	.0475 ms
20 µs	190.0 µs	19.00 µs
10 µs	095.0 µs	09.50 µs
5 µs	047.5 µs	04.75 µs
2 µs	19.00 µs	1.900 µs
1 µs	09.50 µs	0.950 µs
.5 µs	04.75 µs	0.475 µs
.2 µs	1.900 µs	.1900 µs
.1 µs	.0.9.5.0	.0.9.5.0
X-Y	.0.9.5.0	.0.9.5.0

28. ( ) Set the A Timebase switch to 100 ms.

( ) Set the Δ Delay control for a display reading of "1.050 s". Push the F switch.

29. NOTE: Perform the following steps for the various positions of the A Timebase switch exactly as in the preceeding steps. The numbers are approximate.

A Timebase	TPD OPEN	TPD-GND
100 ms	0.950 Hz	09.50 Hz
10 ms	09.50 Hz	095.0 Hz
1 ms	.0950 kHz	0.950 kHz
.1 ms	0.950 kHz	09.50 kHz
10 µs	09.50 kHz	095.0 kHz
1 µs	.0950 MHz	0.950 MHz
.2 µs	0.475 MHz	04.75 MHz
.1 µs	.0.9.5.0	.0.9.5.0
X-Y	.0.9.5.0	.0.9.5.0

Turn off the Scope power.

Refer to Pictorial 5-13 (Illustration Booklet, Page 16) for the following steps.

INSTRUCTION OR TEST	AREA OF POSSIBLE PROBLEM
30. Install the following ICs: ( ) U1121: **4023** (#443-887). ( ) U1123: **4023** (#443-887).	
31. ( ) Set the A Timebase switch to 2 ms. ( ) On the Module, push the T switch. ( ) On the Module, plug the A/D jumper onto the 2 V pin.	
32. NOTE: The following display sequence must be set precisely, since latching circuitry is activated. If you overshoot the required display, it may be necessary for you to start again at "00.00 ms". ( ) On the Module, set the Δ Delay control for the indicated display. Then measure the indicated voltages on U1123, pins 6 and 10: DISPLAY / PIN 6 / PIN 10 "00.00 ms" −5.0 V +5.0 V "01.10 ms" −5.0 V +5.0 V "19.90 ms" −5.0 V +5.0 V "1 . ms" +5.0 V −5.0 V "19.90 ms" +5.0 V −5.0 V "01.10 ms" +5.0 V −5.0 V "00.90 ms" −5.0 V +5.0 V "00.00 ms" −5.0 V +5.0 V Turn off the Scope power.	1. U1122, U1123 circuitry. 2. Q1102 to Q1105 circuitry.
33. Install the following ICs: ( ) U1105: **4016** (#442-99). ( ) U1122: **4016** (#442-99).	
34. ( ) Set the A Timebase switch to 1 ms. Set the B Timebase switch to 50 μs. ( ) On the Module, connect the A/D jumper wire to the NORM pin.	1. U1015, U1016, U1105, or U1122 circuitry. 2. Q1114 circuitry.

INSTRUCTION OR TEST	AREA OF POSSIBLE PROBLEM
35. NOTE: Be sure to carefully read through each of the next two paragraphs before you perform the indicated operations. ( ) Turn the Δ Delay control slowly CW; the display number should increase from "0.000 ms". When the cursors are approximately 2 cm apart, the display should indicate up to "1.999 ms", briefly show overrange, and then display approximately "02.00 ms". Turn the Δ Delay control CCW. When the cursors are 1 cm apart, the display should decrease to "01.00 ms", briefly flicker, and then show approximately "1.000 ms".	1. U1015, U1016, U1105, or U1122 circuitry. 2. Q1114 circuitry.
36. ( ) Turn the Δ Delay control CW and set it for a display reading of "10.50 ms". Push the F switch; the display should flicker briefly, and then indicate approximately ".0950 kHz". Turn the Δ Delay control CCW. When the cursors are approximately 5 cm apart, the display should increase to ".1999 kHz", briefly show an overrange, then show approximately "0.200 kHz". Turn off the Scope power.	
37. Install the following ICs: ( ) U1119: Volts ROM (#444-195). ( ) U1124: **4023** IC (#443-887).	
38. ( ) On the Module, push the EXT VDC switch in (on). On the main circuit board, set the .2 V Cal and the 2 V Cal controls to the centers of their rotation. ( ) Plug the red test lead into the red Module banana (IN) jack.	

INSTRUCTION OR TEST	AREA OF POSSIBLE PROBLEM
39. ( ) Touch the red test probe to the Hi Cal connector. The display should show approximately "1.200". ( ) Touch the red test probe to the TPE connector; the display should autorange to approximately "05.00".	1. If C (collector) of Q1107 does not measure +4.5 V: a. U1119. b. U1107 circuitry. c. Q1115-Q1117 circuitry. 2. If decimal point(s) improper: a. U1112, U1119 circuitry (see Logic Chart III). 3. If numerals displayed are incorrect: a. RY1101, RY1102 circuitry. b. RP1101 circuitry.
40. NOTE: In the following step, be sure the black test lead does not touch any circuit or ground except as directed. ( ) Unplug the black test lead from the Oscilloscope. Connect the alligator clip across both of the SET HV connector pins on the main circuit board. Touch the red probe to the black lead banana plug; the display should read approximately "−005.0". ( ) Touch the black lead banana plug to the CAL jumper connector. The display should show "−1 ".	
41. ( ) Disconnect the black test lead clip from the SET HV pins. Plug the black test lead into the Module COM jack. Connect the alligator clip to the TPB connector. ( ) Touch the red test probe to U1005 pin 7. The display should momentarily overrange and then autorange to approximately "030.0". When the probe is removed, the display should briefly show "000.0", and then autorange to show "0.000".	WARNING: Do not use any test instrument as you test the A/D circuitry without first removing the alligator clip from test point TPB; otherwise the circuits under test might become severely damaged. 1. If pins 2 of U1123 or U1124 never change from "high" or "low," check U1122 circuitry. 2. If autorange does not occur, or is unstable: a. U1122-U1124 circuitry. b. R1141 to R1144. c. C1112 to C1116. (See Waveform X.)
42. ( ) Disconnect the alligator clip from TPB. Turn off the Scope power.	
43. Install the following ICs. ( ) U1017: **4016** IC (#442-99). ( ) Four **4N26** ICs (#443-808) at U1115-U1118.	
44. On the Module: ( ) Release the EXT VDC to its out position. ( ) Release the Probe and Chan switches to their out positions, if necessary. ( ) Push the front panel VDC switch in. ( ) Connect the voltmeter common lead to the main circuit board CHASSIS GND connector.	

INSTRUCTION OR TEST	AREA OF POSSIBLE PROBLEM
45. NOTE: In the following steps, disregard any decimal point lighting.	1. P401, P501 incorrectly installed. 2. U1017, U1115-U1119 circuitry. 3. SW1004, SW1005 circuitry.
46. NOTE: In the following steps, you will check the Module display in the various positions of the Oscilloscope Channel Y1 Volts/Div switch.	1. U1115-U1119 circuitry. 2. Q1012, Q1013, Q1015 circuitry. 3. SW402, SW502 circuitry. (See Logic Charts IV, V.)

45\.

( ) On the Module, operate the indicated switches to verify the following "truth table" for the indicated lighting:

SWITCH	OUT	IN
CHAN	Y1 on	Y2 on
PROBE	x1 on	x10 on

( ) Release both switches to their **out** positions.

46\.

( ) Rotate the Y1 Volts/Div switch from fully CCW to fully CW and check for the following display readings:

VOLTS/DIV	DISPLAY
10V to 1V	"x1 Y1 00.00"
.5V to .1V	"x1 Y1 0.000"
50 mV to 2 mV	"x1 Y1 .0000"

47\. ( ) Push **In** the Probe switch on the Module, then rotate the Y1 Volts/Div switch and check for the following display readings:

VOLTS/DIV	DISPLAY
10V to 1V	"x10 Y1 000.0"
.5V to .1V	"x10 Y1 00.00"
50 mV to 2 mV	"x10 Y1 0.000"

48\. ( ) Carefully short U1122 pins 3 and 4 together as you rotate the Y1 Volts/Div switch and check for the following display readings:

VOLTS/DIV	DISPLAY
10V to 1V	"x10 Y1 0000"
.5V to .1V	"x10 Y1 000.0"
50 mV to 2 mV	"x10 Y1 00.00"

Turn off the Scope power.

INSTRUCTION OR TEST	AREA OF POSSIBLE PROBLEM
49. Install the following ICs: ( ) U1009: LF**353** (TL072)(#442-707). ( ) U1011: TL**061** (#442-679). ( ) U1012: TL**061** (#442-679).	
50. ( ) On the Oscilloscope, set the Y1 Volts/Div switch to 50 mV. Connect a BNC cable with alligator clips or a x1 probe to the Y1 Input. ( ) On the Module, release the Probe switch to its out position.	
51. ( ) On the Module main circuit board, adjust Y1 Zero control for a display of "x1 Y1 .0000". ( ) On the Scope, set the Y1 input switch to DC. ( ) On the Module, touch the Scope probe to the Lo Cal connector pin; the display should indicate approximately "x1 Y1 .1900". Touch the Hi Cal connector; the display should autorange to approximately "x1 Y1 1.200".	1. U1011, U1009A circuitry. 2. SW1005.
52. ( ) Remove the BNC connector from the Oscilloscope Y1 input jack and connect it to the Y2 Input jack. ( ) On the Module, push the Chan switch to the in position. Adjust the Y2 Zero control to display "x1 Y2 .0000". ( ) On the Oscilloscope, set the Y2 Input switch to DC. ( ) Touch the test cable to the Lo Cal connector pin; the display should now indicate approximately "x1 Y2 .1900". Touch the Hi Cal connector pin; the display should autorange to show approximately "x1 Y2 1.200".	1. U1009B, U1012 circuitry.

( ) Disconnect all test leads from the Module and from the Oscilloscope.

( ) Turn off the Oscilloscope power and disconnect the line cord from the AC outlet.

Refer to Pictorial 5-14 (Illustration Booklet, Page 17) for the following steps.

( ) Temporarily dismount the Module assembly.

Refer to Detail 5-14A for the next four steps.

( ) Identify the foil side of each foil shield. Remove any protective film from the **other side** of each one.

( ) Cut two 3" × 5" pieces from the 5" × 8" paper insulator. Remove the paper backing from one of the 3" × 5" insulators and press it squarely onto the **foil surface** of a foil shield in the manner shown.

( ) In the same manner, press a 3" × 5" insulator on the foil surface of the remaining foil shield.

( ) Cut the "Warning" segment from the calibration label. Remove the paper backing from the "Warning" label and press the label in place on one of the paper insulators as shown.

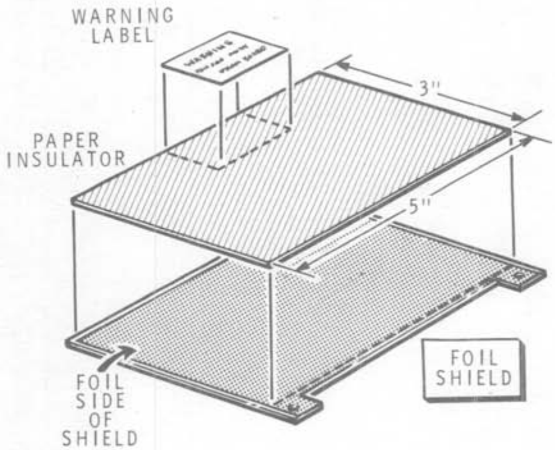
( ) Mount this "labeled" foil shield to the underside of the Module main circuit board using two 4-40 nuts and two #4 flat washers as shown in the Pictorial.

( ) Secure the main circuit board onto the chassis using five 4-40 × 1/2" screws with #4 lockwashers to mount the board. Use four 6-32 × 1/4" screws to secure the front panel brackets. Tighten the bracket screw at A.

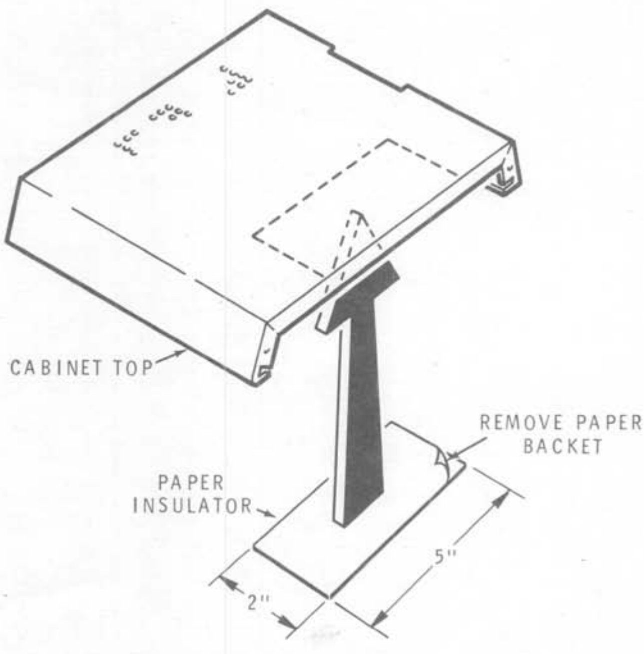
( ) Mount the remaining foil shield, foil-side down, onto the top of the display circuit board brackets using 4-40 × 3/16" screws and #4 flat washers as shown in the Pictorial.

( ) Refer to Pictorial 5-15 and mount the remaining 2" × 5" paper insulator on the inside of the cabinet top along its rear edge as shown. Set the cabinet top aside.

This completes the "Tests and Adjustments." Proceed to the "Calibration" of your Module on the following pages.



Detail 5-14A



PICTORIAL 5-15

CALIBRATION

NOTES:

1. Before you start to calibrate your Time-Voltage Module, you should accurately recalibrate your Oscilloscope to assure the best possible calibration of the Module.

2. The following "Calibration" information is directly applicable to the Heathkit Model IO-4360 Triple-Trace Oscilloscope. If you have a different Heathkit Oscilloscope, refer directly to the Operation Manual for that scope for complete information on the installation, application, operation, and calibration of the Time-Voltage Module for use with that oscilloscope.

IMPORTANT: Be sure to turn off the Oscilloscope power and remove the line cord from the AC outlet before you remove the cabinet top from the Time-Voltage Module.

( ) If necessary, remove the cabinet top from the Module by removing the two screws from the rear panel. Slide the cover from the Module and set it and the screws aside temporarily.

( ) Plug the Oscilloscope line cord into an AC outlet and turn the INTENSITY control on. Then adjust the intensity of the Oscilloscope display for a good viewing level.

IMPORTANT: Allow the Oscilloscope and the Time-Voltage Module to warm up for at least one full hour before you proceed with the following steps.

COARSE ADJUSTMENTS

You may perform the steps of this "Coarse Adjustments" if you are not familiar with the locations of the various calibration controls, or if your Module has recently been serviced. If you have just assembled the Module, you may proceed directly to the section titled "Fine Adjustments."

This section will:

A. Familiarize you with the locations and the nomenclature used to identify various calibration controls and jumpers.

B. Minimize the possibility of erroneous high or low readings which may occure at various points during the calibration, caused by randomly-positioned controls which will be set correctly during the "Fine Adjustments."

C. Improve the effectiveness of voltage and resistance measurements during troubleshooting if a problem should arise during calibration.

NOTE: When you are directed to turn a control in either direction, clockwise or counterclockwise (CW or CCW), this direction refers to the knob-end of panel-mounted controls and to the rotating front of circuit board mounted controls.

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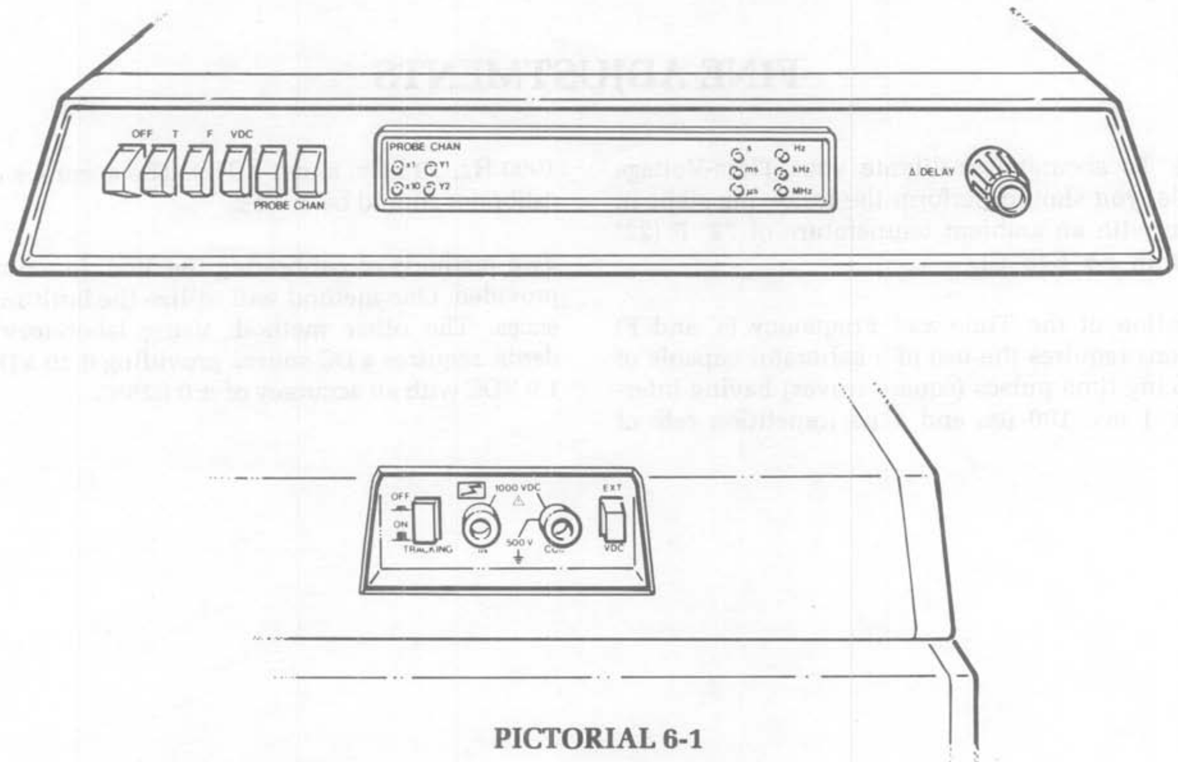


PICTORIAL 6-1

Refer to Pictorials 6-1 and 6-2 (Illustration Booklet, Page 17) and, on the Module, set the switches, controls, and jumpers as follows.

T (Time) switch: In.

TRACKING switch: Out.

EXT VDC switch: Out.

Δ DELAY: CCW.

T CAL: Fully CCW.

CA CAL: Fully CCW.

CB CAL: Fully CCW.

CC CAL: Fully CCW.

F CAL: Center of rotation.

.2V CAL: Fully CCW.

2V CAL: Fully CCW.

Y1 ZERO: Center of rotation.

Y1 CAL: Fully CCW.

Y2 ZERO: Center of rotation.

Y2 CAL: Fully CCW.

CAL jumper: Install to NORM pin.

A/D jumper: Install to NORM pin.

FINE ADJUSTMENTS

NOTE: To accurately calibrate your Time-Voltage Module, you should perform the following steps in a room with an ambient temperature of 72° F (22° C), within ±5° F (3° C).

Calibration of the Time and Frequency (T and F) functions requires the use of a calibrator capable of producing time pulses (square waves) having intervals of 1 ms, 100 μs, and 1 μs (repetition rate of 1000 Hz, 10 kHz, and 1 MHz). The accuracy of this calibrator should be ±0.1%.

Two methods of calibrating the VDC functions are provided. One method will utilize the built-in references. The other method, using laboratory standards, requires a DC source providing 0.19 VDC and 1.9 VDC with an accuracy of ±0.025%.

Refer to Pictorial 6-3 (Illustration Booklet, Page 18) and, on the Oscilloscope, set the controls and switches as follows.

Vertical Preamp (both channels)

INPUT: No probes connected.

COUPLING (AC-GND-DC): GND.

VOLTS/DIV: .2V, VARIABLE at CAL.

POSITION (POS): Center of rotation.

Horizontal

MODE: A (in).

A TIME/DIV: 2 ms.

B TIME/DIV: Pull out, set to .1 ms.

HORIZ POS: COARSE and FINE at centers of rotation; with PULL FOR X10 knob pushed in.

DELAY TIME POSITION: CCW.

VARIABLE TIME: CAL.

Triggering

MODE: AUTO (in).

COUPLING: DC (in).

TRIG SELECT: Y1+; LEVEL at center of rotation.

VARIABLE HOLDOFF: NORM.

Display

MODE: Y1 (in).

ALT/CHOP: Out.

Y2 INVERT: Out.

INTENSITY: As required.

FOCUS: Normal position.

Y3 INPUT: (None).

Y3 POSITION: Center of rotation.

TIME-FREQUENCY CALIBRATION

On the calibration instrument, set the switches and controls as follows:

Output Level: .5 to 1.0 V, P-P.

Pulse Interval: 1 ms (1000 Hz).

NOTES:

1. In the following steps, when you are directed to adjust a switch or a control, the step will include an "(M)" or an "(O)" to indicate that the switch or control is located on the Module (M) or on the Oscilloscope (O).
2. During the following steps, if you fail to obtain the desired results, refer to the "In Case of Difficulty" section of this Manual. Be sure to locate and correct any difficulty before you continue the calibration of your Module.
3. When you are directed to move a cursor to a specific place (on a pulse, for example):
   - Use the leading edge of the left cursor;
   - And the trailing edge of the right cursor (unless you position it to the left graticule, where you'd use the leading edge).

( ) (O): Set the Y1 INPUT switch to DC. Connect the calibrator output to the Y1 input. Adjust the Oscilloscope INTENSITY, FOCUS, and Triggering as required to obtain a stable display on the CRT. Adjust the HORIZ POS control so alternate pulses are aligned with the CRT graticule lines.

( ) (O): Push the A-B switch in. An intensified area, or cursor, should appear on the left side of the CRT.

( ) (M): Rotate the Δ DELAY control clockwise until a second cursor appears. Position this cursor in the right half of the CRT.

RESTART

NOTE: Some of the following steps have two check-off spaces. Complete each of these steps once; then when you are instructed to do so, return to this point and complete each of these steps again as a touch-up.

( ) ( ) (O): Rotate the DELAY TIME POS control to position the left cursor on the third pulse (at the second CRT graticule line).

( ) ( ) (M): Rotate the Δ DELAY control to position the right cursor on the 19th displayed pulse (at the 10th CRT line).

( ) ( ) (O): Push the B (Timebase) switch. Adjust the DELAY TIME POS control to center the waveforms in the CRT viewing area.

( ) ( ) (M): Adjust the Δ DELAY control to precisely superimpose the waveforms.

( ) (M): Adjust the T CAL control to display "15.50 ms" (±.10). NOTE: Perform this step only once.

( ) ( ) (M): Adjust the CA CAL control to display "16.00 ms" (±.01).

( ) ( ) (O): Push **in** the A-B switch.

( ) ( ) Set the calibrator pulse interval to 100 μs (10 kHz).

( ) ( ) (O): Set the A TIME/DIV switch to .2 ms. Set the B TIME/DIV switch to 10 μs. Adjust the HORIZ POS control so alternate pulses are aligned with the CRT graticule lines.

( ) ( ) (O): Adjust the DELAY TIME POS control to position the left cursor on the third pulse (at the second CRT line).

( ) ( ) (M): Adjust the Δ DELAY control to position the right cursor on the 19th pulse (at the 10th CRT line).

( ) ( ) (O): Push the B (timebase) switch. Adjust the DELAY TIME POS control to center the waveforms in the CRT viewing area.

( ) ( ) (M): Adjust the Δ DELAY control to precisely superimpose the waveforms.

( ) ( ) (M): Adjust the CB CAL control to display "1.600 ms" (±.001).

( ) ( ) Set the calibrator pulse interval to 1 μs (1 MHz).

( ) ( ) (O): Push the A-B switch.

( ) ( ) (O): Set the A TIME/DIV switch to 2 μs. Set the B TIME/DIV switch to .1 μs. Adjust the HORIZ POS control so alternate pulses are aligned with the CRT graticule lines.

( ) ( ) (O): Adjust the DELAY TIME POS control to position the left cursor on the third pulse (at the second CRT line).

( ) ( ) (M): Adjust the Δ DELAY control to position the right cursor on the 19th pulse (at the 10th CRT line).

( ) ( ) (O): Push the B (timebase) switch **in**. Adjust the DELAY TIME POS control to center the waveforms in the CRT viewing area.

( ) ( ) (M): Adjust the Δ DELAY control to precisely superimpose the waveforms.

( ) ( ) (M): Adjust the CC CAL control to display "16.00 μs" (±.01).

( ) ( ) (O): Push the A-B switch.

( ) ( ) (O): Set the A TIME/DIV switch to 1 μs. Adjust the HORIZ POS control so a pulse is aligned with each CRT graticule line.

( ) ( ) (O): Adjust the DELAY TIME POS control to position the left cursor on the second pulse (at the second CRT line).

( ) ( ) (M): Adjust the Δ DELAY control to position the right cursor on the third pulse (at the third CRT line).

( ) ( ) (O): Push the B (timebase) switch. Adjust the DELAY TIME POS control to center the waveforms in the CRT viewing area.

( ) ( ) (M): Adjust the Δ DELAY control so the display is down-ranged to show approximately "1.000 μs" and so the waveforms are precisely superimposed. Note only the **numbers** displayed.

( ) ( ) (M): Push the F (Frequency) switch.

( ) ( ) (M): Note only the **numbers** displayed and, compute the difference between this and the previous display. Then carefully adjust the F CAL control to reduce this difference by one-half.

( ) ( ) (O): Set the A (timebase) switch to 2 ms, the B (timebase) switch to .1 ms, and push the A-B switch.

( ) ( ) (M): Push the T (Time) switch.

( ) Set the calibrator to 1 ms (1000 Hz).

( ) Return to "Restart" and again perform each step that has a double checkoff space. When you have completed each of these steps twice, proceed with the followings steps.

( ) Turn off the calibrator and disconnect it from the Oscilloscope.

Proceed to "Voltage Adjustments."

VOLTAGE ADJUSTMENTS

NOTE: Depending on the DC voltage standard you have available, (discussed at the beginning of the "Calibration" section), proceed to the following "Built-In References" or "Laboratory Standards" (Page 95) sections to complete the calibration of your Module.

BUILT-IN REFERENCES

External VDC Calibration

Refer to Pictorial 6-2 (Illustration Booklet, Page 17) for the following steps.

NOTE: In this section, disregard any decimal-points, and note only the **numbers** displayed.

( ) (M): Push the EXT VDC on the side of the Module to the **in** position.

( ) (M): Unplug the gray CAL jumper (at the left side of the main circuit board). Connect the black test lead alligator clip onto the end of the wire (connector). Position the test lead away from any contact with the circuit board components or any ground.

NOTE: In the following step, if auto-ranging should occur, and the display indicates "0190", momentarily touch the black test-lead plug to the nearby display board bracket. This will cause the correct range to be selected.

NOTE: Complete the next two steps once each; then return and complete each one again as a touch-up.

( ) ( ) (M): Touch the black test-lead banana plug to the LO CAL test point. Adjust the .2V CAL control to display "XXXX" (±.0001), where "XXXX" is the number on the calibration label.

( ) ( ) (M): Touch the black test-lead banana plug to the HI CAL test point. Adjust the 2V CAL control to display "YYYY" (±.0001), where "YYYY" is the HI CAL number on the calibration label.

( ) (M): Disconnect the black test-lead alligator clip from the gray CAL jumper. Reconnect the jumper connector to its NORM pin.

( ) (M): On the side of the Module, push the EXT VDC switch to return it to the "out" position.

Internal VDC Calibration

( ) (M): Push the Module VDC switch. Push the PROBE and CHAN switches to illuminate the X1 and Y1 indicators.

( ) (O): Set the Y1 and Y2 VOLTS/DIV switches to their 50 mV positions. Set the Y1 and Y2 input switches to GND.

( ) (O): Connect a BNC (with alligator clips) test lead or a X1 oscilloscope probe to the Y1 INPUT connector. **DO NOT** use a X10 probe.

RESTART

NOTE: Some of the following steps have two check-off spaces. Complete each of these steps once; then return to this point and complete each one again as a touch-up.

( ) ( ) (M): Adjust the Y1 ZERO control to display "X1 Y1 .0000" (±.0001).

( ) ( ) (O): Set the Y1 Input switch to DC.

( ) ( ) (M): Touch the test probe or clip to the HI CAL connector. Adjust the Y1 CAL control to display "X1 Y1 XXXX" (±0001), where XXXX is the HI CAL number on the calibration label.

NOTE: In the following step, if auto-ranging should occur and the display shows "0190", momentarily lift the test probe or clip from the test point to cause the correct range to be selected.

( ) ( ) (M) Touch the test probe or clip to the LO CAL connector. Carefully note the difference between the display and the LO CAL number on the calibration label. Turn the Y1 CAL control to reduce this difference by one-half.

( ) ( ) (O): Move the BNC cable or test probe connector to the Y2 Input connector.

( ) ( ) (M): Push the CHAN switch to light the Y2 indicator.

( ) ( ) (M): Adjust the Y2 ZERO control to display "X1 Y2 .0000" (±.0001).

( ) ( ) (O): Set the Y2 Input switch to DC.

( ) ( ) (M): Touch the test probe or clip to the HI CAL connector. Adjust the Y2 CAL control to display "X1 Y2 XXXX" (±0001) where the XXXX is the HI CAL number on the calibration label.

NOTE: In the following step, if auto-ranging should occur and the display shows "0190," momentarily lift the test cable clip or probe from the test point to cause the correct range to be selected.

( ) ( ) (M): Touch the test probe or clip to the HI CAL connector. Note the difference between the display and the HI CAL number on the calibration label. Then adjust the Y2 CAL control to reduce the difference by one-half.

( ) ( ) (O): Set the Y1 and Y2 switches to GND.

( ) ( ) (M): Push the CHAN switch to the Y1 position.

( ) (O): Move the test probe or clip to the Oscilloscope Y1 Input connector.

Return to "Restart" and again perform each step that has a double checkoff space. When you have completed each one twice, continue with the following steps.

( ) Disconnect the test cable or probe.

( ) Turn the Oscilloscope INTENSITY control to OFF, and unplug the line cord from the AC outlet.

Refer to Pictorial 6-4 (Illustration Booklet, Page 18) for the following steps.

( ) Secure the Module cabinet top onto the Module using two 6-32 × 1/4" screws. NOTE: Be sure the cabinet top edge is **under** the flanges as shown.

( ) Making sure that you don't pinch any wires or cables, secure the cabinet top onto the Oscilloscope using the nine 6-32 × 1/4" screws previously removed.

This completes the "Calibration" of your Time-Voltage Module. Proceed to the "Summary" on Page 97.

LABORATORY STANDARDS

External VDC Calibration

NOTE: In the following steps, disregard any decimal point lighting and note only the **numbers** displayed.

( ) (M): On the side of the Module, push the EXT VDC switch to the "in" position.

( ) Set the DC voltage standard output to 0 volts.

( ) (M): Plug the black test lead banana plug into the COM jack.

( ) Connect the black test lead alligator clip to the low (negative) terminal of the DC voltage standard.

( ) Plug the red test lead into the (positive) output connector on the DC voltage standard.

Refer to Pictorial 6-2 (Illustration Booklet, Page 17) for the following steps.

( ) (M): Unplug the gray CAL jumper wire from the NORM pin and position the wire connector so it does not touch any other components or grounds on the circuit board. NOTE: This jumper is located on the left side of the main circuit board.

186.6 LO

1.210 HI

NOTE: Complete the next four steps once each; then return and complete each one again.

( ) ( ) Set the voltage standard output to +190.0 mV.

NOTE: In the following steps, if auto-ranging should occur and the display shows "0190", hold the probe to the connector and momentarily set the DC voltage standard to 0 to cause the correct range to be selected.

( ) ( ) (M): Touch the probe to the connector on the end of the CAL jumper wire. Adjust the .2V CAL control to display "1900" (±0001).

( ) ( ) Set the DC voltage standard to +1.900V.

( ) ( ) Touch the test probe or clip to the connector on the end of the CAL jumper wire. Adjust the 2 V CAL control to display ".1900" (±0001).

( ) Set the DC voltage standard to 0.

( ) (M): Disconnect the test leads and reconnect the gray CAL jumper wire to the NORM pin.

( ) (M): Push the EXT VDC switch on the side of the Module to the **out** position.

Internal VDC Calibration

( ) (M): Push the VDC switch to the **in** position. Push the CHAN and PROBE switches to turn on the X1 and Y1 indicators.

( ) Set the DC voltage standard to 0.

( ) (O): Set the Y1 and Y2 VOLTS/DIV switches to their 50 mV positions and the Y1 and Y2 Input switches to GND.

( ) (O): Connect a BNC test lead or a X1 oscilloscope probe to the Y1 input connector. Do NOT use a X10 probe. Connect the probe end of the test lead to the DC voltage standard output, with the ground lead to the low (negative) terminal.

RESTART

NOTE: As before, complete each of the following steps once; then return and complete each one again when you are instructed to do so.

( ) ( ) (M): Adjust the Y1 ZERO control to display "X1 Y1 .0000" (±.0001).

( ) ( ) Set the DC voltage standard to +190.0 mV.

NOTE: In the following steps, if auto-ranging should occur and the display shows "0190", momentarily position the Oscilloscope Y1 Input switch to GND to cause the correct range to be selected.

( ) ( ) (O): Set the Y1 Input switch to DC.

( ) ( ) (M): Adjust the Y1 CAL control to display "X1 Y1 1900" (±0001).

( ) ( ) Set the DC voltage standard to +1.900V.

( ) ( ) (M): Note the difference between the display and "X1 Y1 1.900". Adjust the Y1 CAL control to reduce the difference by one-half.

( ) ( ) (O): Move the BNC test lead or probe to the Y2 Input connector.

( ) ( ) (M): Push the CHAN switch to light the Y2 indicator.

( ) ( ) (M): Adjust the Y2 ZERO control to display "X1 Y2 .0000" (±.0001).

( ) ( ) Set the DC voltage standard to +190.0 mV.

NOTE: In the following steps, if auto-ranging should occur and the display shows "0190", momentarily position the Oscilloscope Y2 Input switch to GND to cause the correct range to be selected.

( ) ( ) (O): Set the Y2 input switch to DC.

( ) ( ) (M): Adjust the Y2 CAL control to display "X1 Y2 1900" (±0001).

( ) ( ) Set the DC voltage standard to +1.900V.

( ) ( ) (M): Note the difference between the display and "X1 Y1 1.900". Adjust the Y1 CAL control to reduce the difference by one-half.

( ) ( ) (O): Move the test cable or probe to the Y1 Input connector.

( ) ( ) (M): Push the CHAN switch to light the Y1 indicator.

( ) ( ) (O): Set the Y1 and Y2 Input switches to GND.

Return to "RESTART" and perform each step again. When you have completed each step twice, proceed with the following steps.

( ) Set the DC voltage standard to 0 volts.

( ) Disconnect the BNC test lead or probe from the Oscilloscope.

( ) (O): Turn the INTENSITY control to OFF and unplug the line cord from the AC outlet.

Refer to Pictorial 6-4 (Illustration Booklet, Page 18) for the following steps.

( ) Secure the Module cabinet top onto the Module using two 6-32 × 1/4" screws.. NOTE: Be sure the cabinet top edge is **under** the flanges as shown.

( ) Resecure the Oscilloscope cabinet top (if necessary) using the nine 6-32 × 1/4" screws previously removed. Make sure you don't pinch any wires or cables between these components.

This completes the "Calibration" of your Time-Voltage Module.

SUMMARY

1. All newly-assembled Modules will require time to stabilize any small calibration shifts due to initial aging of components.

2. Modules that are "time-stabilized" may still have small calibration shifts when they are exposed to high or low temperature extremes for the first time. If you are likely to use your Module over a wide temperature range, you should condition it for a period of time at both high and low temperatures and then recalibrate the instrument.

3. Some of the Module circuits may show calibration shifts if the instrument is calibrated at low humidity and used at high humidities, or vice versa. These changes are generally reversible.

4. All precision instruments require regular recalibration to assure maximum accuracy even after time and temperature stabilization. The period between calibrations may vary from a few weeks for newly-assembled instruments to several months for those that have fully stabilized. You should also consider recalibration prior to critical use.

5. When you are in doubt about the accuracy of your Module, verify it **only** against a precision standard. Other forms of verification may be significantly in error.

This completes the "Calibration" of your Module; proceed to "Operation".

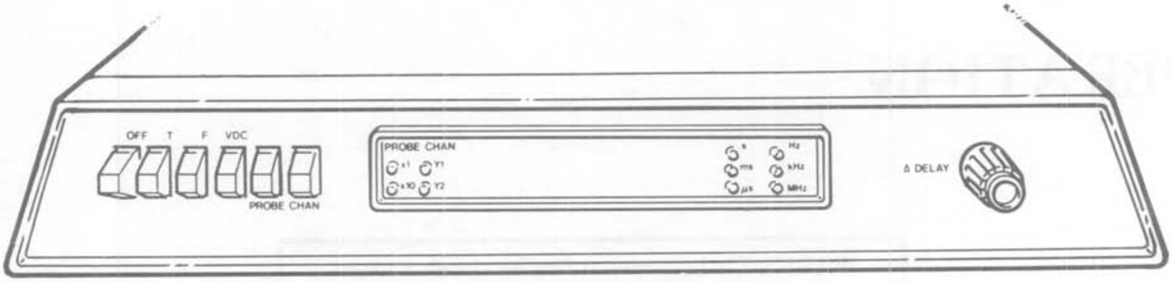
OPERATION

WARNING: To prevent fire or shock hazard, do not expose your Oscilloscope or Module to rain or moisture.

This section of the Manual is divided into two parts. The first part, "General," briefly describes the operation of each switch, control, or connector on the Module. It also provides you with some safety precautions to observe whenever you use the Module. The second part, "Measurements," includes specific operating instructions for each function as well as some guidelines and techniques that will provide optimum measurement accuracy.

NOTE: Be sure to read the information under "General" before you use the Module. Pay particular attention to "Safety Markings" and "Safety Precautions." In addition, be sure to observe all Warnings, Cautions, and Notes provided in the "Measurements" information.

GENERAL



PICTORIAL 7-1

CONTROL FUNCTIONS

Refer to Pictorial 7-1 for the locations of the following front panel switches and controls.

OFF switch — Turns all Module functions off. The Oscilloscope must be turned on for the Module to operate.

T switch — Enables the Module to measure time. One of the time indicators (s, ms, or μs) will light, depending upon the position of the TIME/DIV switch on the Oscilloscope.

F switch — Enables the Module to measure frequency. One of the frequency indicators (Hz, kHz, or MHz) will light, depending upon the position of the TIME/DIV switch on the Oscilloscope.

VDC (internal) switch — Enables the Module to measure the DC voltage present at the Y1 or Y2 INPUT connector on the Oscilloscope. The following conditions apply:

1. The input toggle switch on the Oscilloscope must be at DC.

2. The VOLTS/DIV switch on the Oscilloscope must be set to the correct range. See "VDC (internal) Measurements" on Page 111.

3. Be sure the PROBE and CHAN switches are set correctly.

PROBE switch — When this switch is out, the display indicates the Y1 or Y2 INPUT DC voltage directly and the X1 indicator is lit. When this switch is in, the display indicates ten times the Y1 or Y2 INPUT DC voltage and the X10 indicator is lit. This provides a direct reading display when a X10 probe is used.

CHAN switch — Selects the Y1 INPUT or Y2 INPUT for VDC (internal) measurements. The corresponding Y1 or Y2 indicator will be lit.

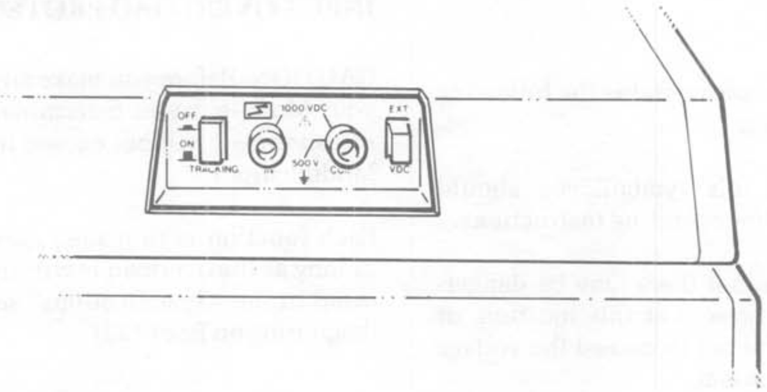
X1 & X10 indicators — Indicates the VDC (internal) range that is selected by the PROBE switch.

Y1 & Y2 indicators — Indicates which Oscilloscope INPUT connector is selected by the CHAN switch for VDC (internal) measurements.

s, ms, & μs indicators — Indicates the time measurement units selected by the TIME/DIV switch on the Oscilloscope.

Hz, kHz, & MHz indicators — Indicates the frequency measurement units selected by the TIME/DIV switch on the Oscilloscope.

Δ DELAY control — Changes the position of the measurement cursor for time or frequency measurements.



PICTORIAL 7-2

Refer to Pictorial 7-2 for the locations of the following side panel switches and connectors.

TRACKING switch — Affects the operation of the cursors during time and frequency measurements. When this switch is out, the DELAY TIME POSITION (DTP) control on the Oscilloscope changes the position of both the measurement and reference cursors. When this switch is pushed, the DTP control moves only the reference cursor and the Δ DELAY control moves the measurement cursor.

IN & COM jacks — Inputs for measuring an external DC voltage.

EXT VDC pushbutton — Causes the Module display to indicate the voltage that is present at the IN and COM jacks. All of the pushbutton switches on the front of the Module (except OFF) are disabled.

Refer to Pictorial 7-3 for the locations of the following controls accessible through holes in the rear panel.

NOTE: You may have to adjust the following controls if you use your Oscilloscope at high or low temperatures, or if you want to make a quick measurement without allowing the Oscilloscope to completely warm up. These controls affect only the VDC (internal) function.

Y1 ZERO ADJ control — Allows you to zero the Module display when no voltage is present at the Y1 INPUT connector (or the input switch is in the GND position).

Y2 ZERO ADJ control — Allows you to zero the Module display when no voltage is present at the Y2 INPUT connector (or the input switch is in the GND position).

PICTORIAL 7-3

SAFETY MARKINGS

The side panel of the Module contains the following standard operator warnings:

⚠ Whenever you see this symbol, you should refer to this Manual for operating instructions.

⚡ This symbol means that there may be dangerously high voltage present at this location, or you should be careful not to exceed the voltage limitation of this terminal.

Refer to "Measurements" for specific limitations of the Module.

SAFETY PRECAUTIONS

Occasionally, you may use your Module to check, maintain, and repair electronic equipment which contains DANGEROUSLY HIGH VOLTAGES. Because of this potential danger, you should always observe the following safety practices:

1. Always handle the test probes by the insulated portions only. Be careful not to touch any exposed metal parts.

2. Whenever you measure high voltages, be sure to turn off the power to the equipment you are testing before you connect the test leads. If this is not possible, be very careful to avoid accidental contact with any object that could provide a ground return (circuit completion).

3. If possible, use only one hand when you make tests on equipment that is turned on. Keep one hand in your pocket or behind your back to help avoid accidental shock.

4. Insulate yourself from ground while you make measurements. Stand on a properly insulated floor or floor covering.

INPUT OVERLOAD PROTECTION

CAUTION: Before you make any measurements with your Module, try to determine, if possible, that the measurement will not exceed the limitations of each Module input.

Each function is protected against input overloads, as long as the overload is within the limitations indicated in the "Specifications" section of this Manual (beginning on Page 133).

OVERLOAD/OVERRANGE INDICATION

Whenever an overload/overrange condition occurs (greater than 1999 counts on the range you have selected), a 1 will light in the left-most digit and the appropriate decimal point will appear. All other display digits are blanked.

±1 COUNT

The right-most display digit will normally alternate one number above or below an indication on successive readings. Under certain conditions, it may vary one or two numbers.

DISPLAY UNITS/POLARITY

During measurements, the display indicates directly and automatically lights the correct decimal point and quantity indicator (s, ms, µs, Hz, kHz, or MHz). The measurement polarity for all functions has an implied "+" and a displayed "−".

WARM-UP

To provide maximum stability and accuracy, you may wish to leave the Oscilloscope and Module turned on continuously during your daily work period. To insure best accuracy, allow a 30-minute warm-up from a cold start before you make measurements. You can, however, use the Module immediately after turn-on. You may wish to slightly readjust the Y1 ZERO or Y2 ZERO controls on the rear panel to zero the display, when you use the VDC (internal) function.

The following "Measurements" section explains how to use each measurement function. In addition, you are provided application information for the VDC functions to assist you in harsh measurement environments. The "Specifications" section of this Manual (beginning on Page 133) provides you with information concerning the accuracy of displayed mesurements.

The following are included in the "Measurements" section:

TIME/FREQ MEASUREMENTS

- Repetitive Pulse Time and/or Rate.
- Time Duration of Pulse Width.
- Time Difference Between Pulses from Different (synchronous) sources.
- Risetime.
- Burst Frequency Measurement

VDC MEASUREMENTS

- Measurement Inputs.
- VDC (internal) Measurements.
- EXT VDC Measurements.
- Additional Considerations for VDC Measurements.
- Minimizing Voltage Measurement Errors.

NOTE: For VDC measurements, it is important that you read "Minimizing Voltage Measurement Errors" to become familiar with the techniques described.

MEASUREMENTS

TIME/FREQ MEASUREMENTS

NOTE: If the EXT VDC switch (on the side of the Module) is pushed in, the T and F functions will be inoperative.

The Time and Frequency functions of the Module improve the accuracy of waveform measurements and make them easier. The following examples show you how to perform some common time/frequency measurements. Keep the following in mind as you read through each of the examples:

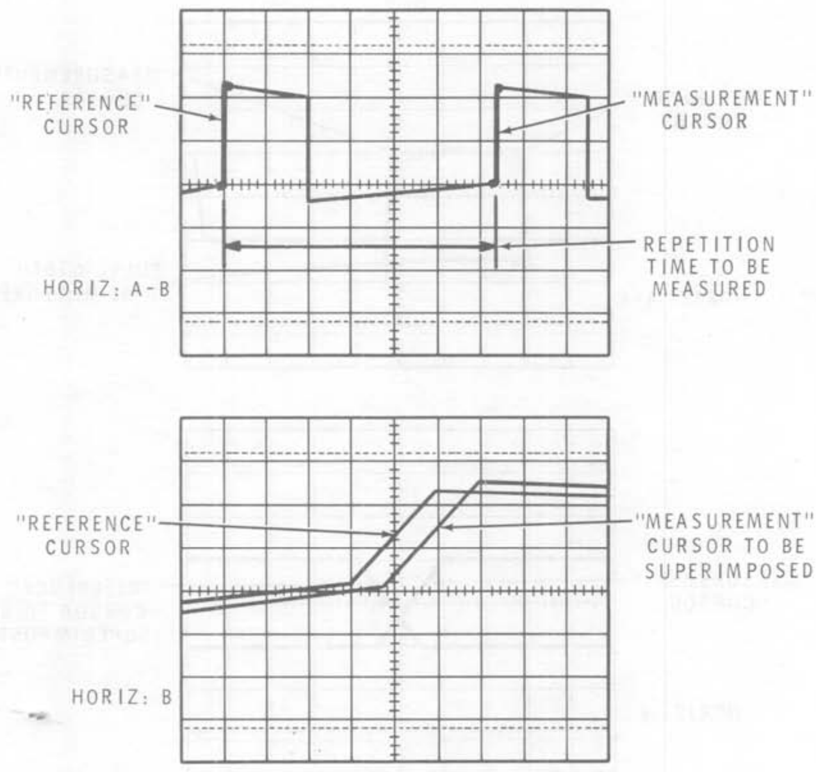
A. Two cursors are used to make time and frequency measurements. When the TRACKING pushbutton on the side panel is in the ON position (out), the DELAY TIME POSITION (DTP) control moves both cursors (reference and measurement cursors) and the Δ DELAY control on the Module moves only one (measurement) cursor. When the TRACKING switch is in the OFF position (in), the DTP control moves only the reference cursor and the Δ DELAY control moves only the measurement cursor. Generally you measure repetitive waveforms when the TRACKING switch is ON (out).

B. When you make frequency measurements, the display will indicate an overrange condition when the cursors are close together as shown below:

A TIMEBASE switch setting	Cursor spacing
"1" decades	.5 division
"2" decades	.25 division
"5" decades	1.0 division

C. The reference cursor will move slightly to the right on the 1.0 μs/div (and lower) ranges, from where it was positioned on a higher range. This does not cause a measurement error, but will require you to use the DTP and/or HORIZ POS control to reposition the cursor. On the .2 μs range, this also reduces the measurement range slightly.

D. Be sure the VARIABLE TIME control on the Oscilloscope is in the detented (CAL) position when you make time and frequency measurements, or the measurement will be in error.



PICTORIAL 7-4

Repetitive Pulse Time and/or Rate

Refer to Pictorial 7-4 as you read the following example.

1. Preset the Oscilloscope and Module controls as follows:

DISPLAY:	Y1 (or Y2).
FUNCTION:	TIME (T).
HORIZ:	A-B.
A TIMEBASE:	To display 2 (or more) pulses.
B TIMEBASE:	3 or 4 positions more clockwise. than the A TIMEBASE.
TRACKING:	ON (out).
Δ DELAY:	Move the measurement cursor to the right of the reference cursor.

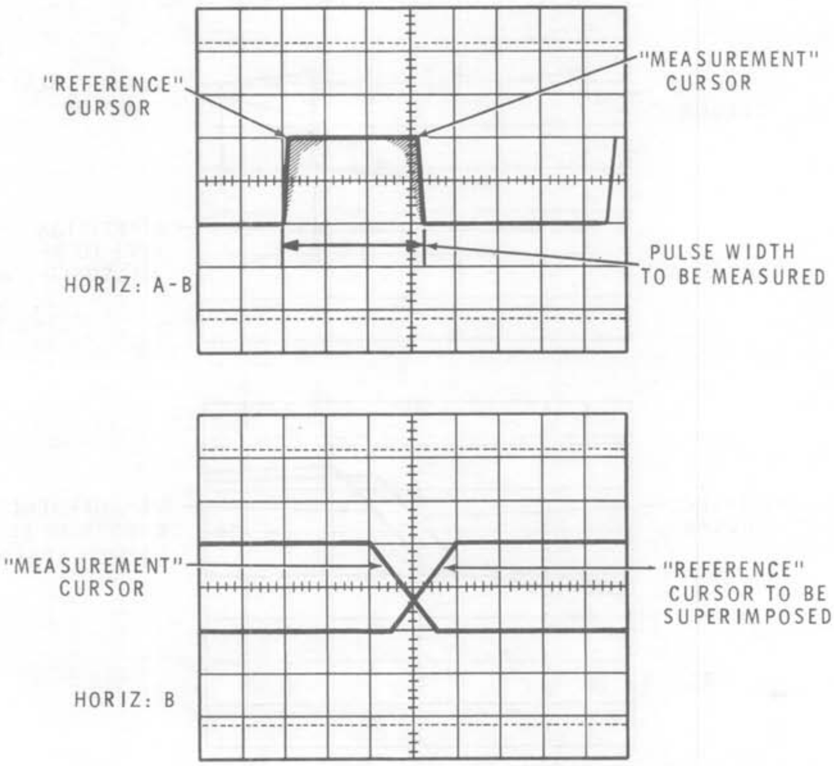
2. Use the DTP control to position the reference cursor to a point on one of the pulses.

3. Use the Δ DELAY control to position the measurement cursor to approximately the same point on the next pulse.

4. Push the B TIMEBASE switch. Then slightly readjust the DTP control to center the waveforms.

5. Adjust the Δ DELAY control to superimpose the waveforms. Then read the display and indicators to determine the pulse repetition time.

6. If you desire to display the pulse frequency (repetition rate), push the FREQ (F) switch on the Module.



PICTORIAL 7-5

Time Duration of Pulse Width

Refer to Pictorial 7-5 as you read the following example.

1. Preset the Oscilloscope and Module controls as follows:

DISPLAY:	Y1 (or Y2).
FUNCTION:	TIME (T).
HORIZ:	A-B.
A TIMEBASE:	To display the start and finish of an event.
B TIMEBASE:	3 or 4 positions more clockwise than the A TIMEBASE.
Δ DELAY:	Move the measurement cursor to the right of the reference cursor.

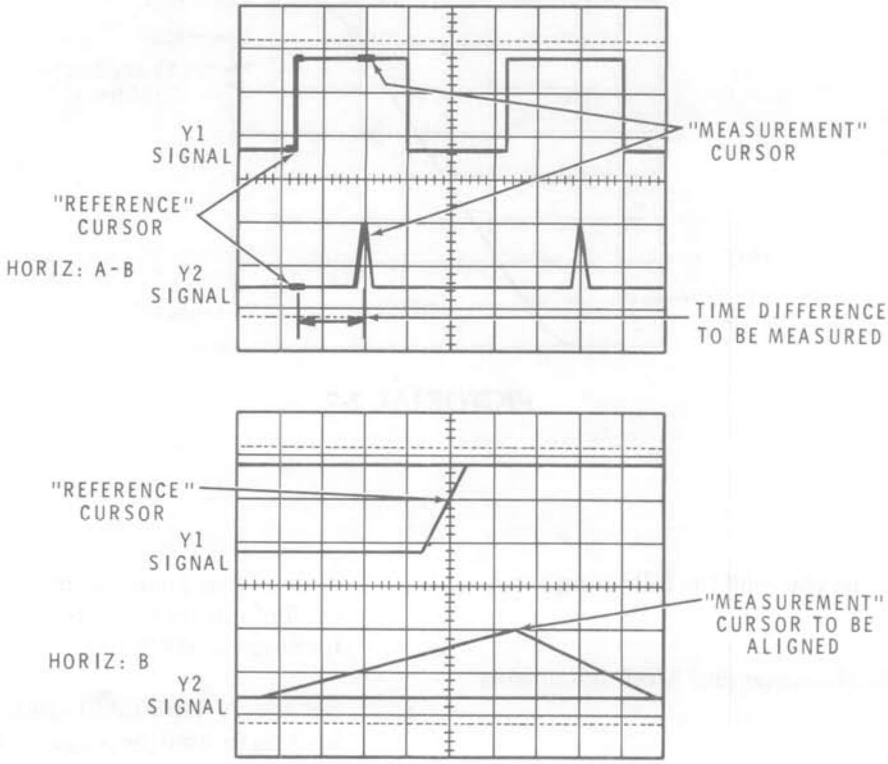
NOTE: You may find it easier to make measurements if you press the TRACKING switch on the Module, which allows you to separately control the position of the cursors.

2. Use the DTP control to position the reference cursor on the leading edge on the waveform.

3. Use the Δ DELAY control to position the measurement cursor to the trailing edge on the pulse to be measured.

4. Push the B TIMEBASE switch. Then slightly readjust the DTP control to center the waveforms.

5. Adjust the Δ DELAY control so the leading and trailing portions cross in the center of the amplitude (50% point). Then read the display and indicators to determine the pulse width.



PICTORIAL 7-6

Time Difference Between Pulses from Different (Synchronous) Sources

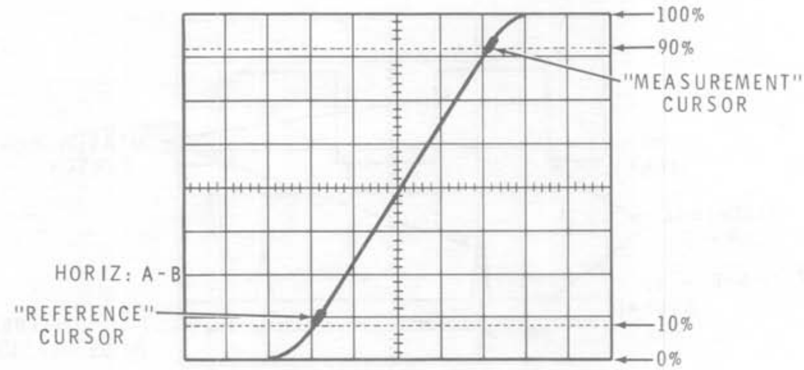
Refer to Pictorial 7-6 as you read the following example.

1. Preset the Oscilloscope and Module controls as follows:

DISPLAY:	DUAL.
FUNCTION:	TIME (T).
HORIZ:	A-B.
A TIMEBASE:	To display the reference waveform on Y1 and the measurement waveform on Y2.
B TIMEBASE:	3 or 4 positions more clockwise than the A TIMEBASE.
Δ DELAY:	Move the measurement cursor to the right of the reference cursor.

NOTE: You may find it easier to make measurements if you push the TRACKING switch on the Module, which allows you to separately control the positions of the cursors.

2. Use the DTP control to position the reference cursor to a point on the reference waveform.
3. Use the Δ DELAY control to position the measurement cursor to a point on the measurement waveform.
4. Push the B TIMEBASE switch. Then slightly readjust the DTP control to center the waveforms.
5. Adjust the Δ DELAY control to align the waveform points. Then read the display and indicators to determine the pulse time difference.



PICTORIAL 7-7

Risetime

Refer to Pictorial 7-7 as you read the following example.

1. Preset the Oscilloscope and Module controls as follows.

DISPLAY:	Y1 (or Y2).
FUNCTION:	TIME (T).
HORIZ:	A-B.
A TIMEBASE:	To display 2 (or more) pulses.
Δ DELAY:	Move the measurement cursor to the right of the reference cursor.

NOTE: You may find it easier to make measurements if you push the TRACKING switch on the Module, which allows you to separately control the positions of the cursors.

2. Set the VOLTS/DIV switch and the VARIABLE control on the Oscilloscope so the amplitude of the display is exactly 8 divisions. Then position the display vertically so the bottom touches the 0% line and the top touches the 100% line.

3. Set the A TIMEBASE switch to display the leading (or trailing) edge of the waveform.

4. Set the B TIMEBASE switch 3 or 4 positions more clockwise than the A TIMEBASE.

5. Adjust the DTP control to position the reference cursor on the 10% dashed graticule line.

6. Adjust the Δ DELAY control to position the measurement cursor on the 90% dashed graticule line. Then read the display and indicators to determine the pulse risetime.

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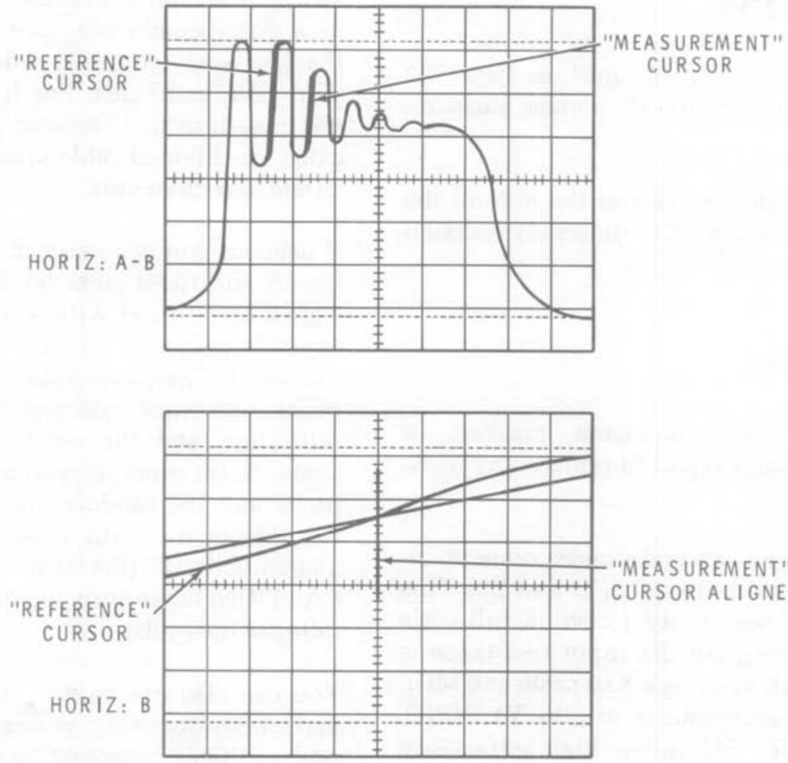


PICTORIAL 7-8

Burst or Ringing Frequency Measurement

Refer to Pictorial 7-8 as you read the following example.

1. Preset the Oscilloscope and Module controls as follows.

DISPLAY:	Y1 (or Y2).
FUNCTION:	TIME (T).
HORIZ:	A-B.
A TIMEBASE:	To display several cycles of the burst or "ringing" frequency.
B TIMEBASE:	3 or 4 positions more clockwise than the A TIMEBASE.
Δ DELAY:	Move the measurement cursor to the right of the reference cursor.

NOTE: You may find it easier to make measurements if you push the TRACKING switch on the Module, which allows you to separately control the positions of the cursors.

2. Use the DTP control to position the reference cursor to a point on the waveform.

3. Use the Δ DELAY control to position the measurement cursor to the same point of the next cycle.

4. Push the B TIMEBASE switch. Then slightly readjust the DTP control to center the waveform. Also readjust the Δ DELAY control to superimpose similar points of the two waveforms.

5. Push the FREQ (F) switch. Then read the display and indicators to determine the frequency.

VDC MEASUREMENTS

Be sure to read "Safety Precautions" on Page 102 before you attempt to make any DC voltage measurements.

NOTE: If the EXT VDC switch (on the side of the Module) is pushed in the VDC (internal) function will be inoperative.

Measurement Inputs

WARNING: Never use uninsulated, cracked, or frayed test leads. Always repair or replace any questionable test leads.

For VDC (internal), you can make measurements directly at the BNC input connectors (Y1 and Y2). This provides maximum sensitivity (.2 volts full-scale with .1 mV resolution), but the input resistance is lower (1 MΩ) than when using a X10 probe (10 MΩ). You may find it advantageous to use the Y1 INPUT with a X10 probe for AC and/or high impedance measurements, and a direct input to the Y2 INPUT for low-level DC voltage measurements. Be sure the PROBE switch is set so the proper probe indicator (X1 or X10) is lit for each input, so the decimal point in the display is in the correct position.

For EXT VDC, connect your test leads to IN and COM (common) jacks on the side panel. These are spaced to accommodate either separate banana plugs or a dual banana plug (3/4" centers). You can use the test leads supplied with the Module or make your own test leads. For low-level measurements, you may find that "twisted pair" test leads, coaxial cable, or shielded cable provide more stable and accurate measurements.

If needed, you can connect a high voltage probe to the IN and COM jacks (as long as the probe is designed to be used with a meter that has a 10 MΩ input impedance). Such a probe is available from the Heath Company. When you use a high voltage probe, you must interpret the auto-ranged display indication and the voltage division ratio of the probe. If, for example, you have a 100:1 high voltage probe and the Module display indicates 140 VDC, the voltage at the tip of the probe is approximately 14,000 volts DC (the display indication times 100). CAUTION: Make sure you do not exceed the voltage rating of the probe.

You can also use an RF probe with the Module to make high-frequency voltage measurements. An RF probe suitable for operation with the EXT VDC function of the Module is available from the Heath Company. Be sure to consult the manufacturer's information and specifications. CAUTION: Do not exceed the input voltage rating of the RF probe.

VDC (internal) Measurements

WARNING: The cabinet and ground circuit of the Oscilloscope is connected through the line cord to earth ground to protect you from a shock hazard. Do not defeat this ground or attempt to connect the Oscilloscope ground to a voltage source that is above earth ground. This can present a safety hazard or damage the Oscilloscope.

CAUTION: ±400 volts (DC plus peak AC) is the maximum voltage allowable at the Y1 or Y2 inputs of the Oscilloscope. Be sure to consult manufacturer's specifications for the input voltage limit when you use a X10 probe.

Use the following procedure to make a VDC (internal) measurement:

1. Turn the Oscilloscope and Module on and allow them to warm up.

2. Push the VDC switch on the front of the Module.

3. Connect a probe or test leads to the Oscilloscope Y1 or Y2 INPUT connector. Then push the CHAN switch on the Module to light the proper (Y1 or Y2) indicator. If you use a X10 probe, push the PROBE switch.

4. Be sure the Y1 or Y2 input switch is at DC.

5. Connect the ground test lead to circuit ground of the circuit under test. CAUTION: This ground is connected to earth ground.

6. Set the VOLTS/DIV switch to the range that corresponds to the DC voltage to be measured. Figure 2 shows the display limits for each range.

7. Touch the test probe to the measurement point in the circuit. The display will autorange to indicate the voltage being measured. If the display shows an overrange condition, turn the VOLTS/DIV switch to a higher range. Be sure the correct CHAN and PROBE indicators are lit.

Direct Input

VOLTS/DIV Range	AUTO-RANGING DISPLAY LIMITS Low	High
2 mV to 50 mV	.0000 to .1999	0.100 to 1.999
100 mV to 500 mV	0.000 to 1.999	01.00 to 19.99
1 V to 10 V	00.00 to 19.99	010.0 to 199.9

With X10 Probe

VOLTS/DIV Range	AUTO-RANGING DISPLAY LIMITS Low	High
2 mV to 50 mV	0.000 to 1.999	01.00 to 19.99
100 mV to 500 mV	00.00 to 19.99	010.0 to 199.9
1 V to 10 V	000.0 to 199.9	0100 to 1999

Figure 2

EXT VDC Measurements

WARNING: When you make any EXT VDC measurement, do not connect the COM jack on the Module (black test lead) to a voltage that exceeds 500 volts (DC plus AC), or 350 volts AC (rms) above earth (power line) ground. This can present a safety hazard or damage the Module.

CAUTION: The maximum voltage allowable between the IN and COM jacks is ±1000 volts (DC plus AC).

Use the following procedure to make EXT VDC measurements:

1. Turn the Oscilloscope and Module on and allow them to warm up.
2. Depress the EXT VDC pushbutton on the Module.
3. Plug your test leads into the IN and COM jacks.
4. Connect the free end of the black test lead to ground in the circuit under test.
5. Touch the red test lead probe to the measurement point in the circuit. Allow the auto-ranging display to stabilize. Figure 3 shows the display limits for each range.

RANGE	AUTO-RANGING DISPLAY LIMITS
2	0.000 to 1.999
20	01.00 to 19.99
200	010.0 to 199.9
2000	0100 to 1999 (1000 max)

Figure 3

Additional Considerations for DC Measurements

Keep the following guidelines in mind when you make VDC measurements:

A. The measurement accuracy specification (Laboratory Standards) for VDC (internal) is ± (0.75% of reading + 2 counts) for voltages at the Y1 and Y2 inputs. For EXT VDC, the accuracy is ± (0.25% of reading + 2 counts). For example, a display indication of 1.000 volt from a low impedance source has an uncertainty of ±0.0095 volts for VDC (internal) and ±0.0035 for EXT VDC. In addition, if you use a X10 probe for VDC (internal) measurements, its possible error (tolerance) must be included in the measurement uncertainty.

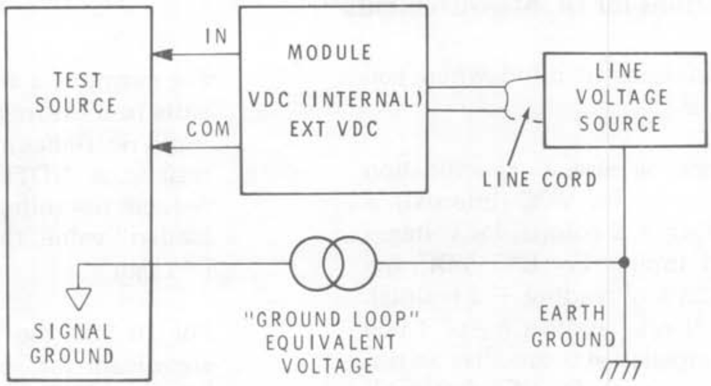
B. For VDC (internal), the input resistance of the Oscilloscope at the Y1 and Y2 inputs is 1 MΩ. If you use a X10 probe, the input resistance is 10 MΩ. For EXT VDC, the input resistance is 10 MΩ. Measurements at relatively high source resistances will cause a significant reading error. You can determine the amount of error, due to loading, from the following equation:

$$\% \text{ Error} = -\left(\frac{\text{R source}}{\text{R source} + \text{R input}}\right) 100$$

For example, a source resistance of 10 kΩ results in a loading error of −1.0% for a 1 MΩ input resistance and −0.1% for a 10 MΩ input resistance. NOTE: Since the loading always reduces the voltage under "load" from its "unloaded" value, the error always has a minus (−) sign.

For 10 MΩ, the loading error becomes very significant for source resistances above 100 kΩ.

C. When the input is open-circuited (for either function), stray AC radiation may cause several counts to be displayed. This is normal and does not produce a significant error when the input is connected to a low resistance source.



PICTORIAL 7-9

Minimizing Voltage Measurement Errors

You can obtain optimum performance from your Module by observing a few precautions when you establish test measurement conditions. The hints included in the following paragraphs are only indicative of a number of measurement environment problems that may influence the performance of the Module.

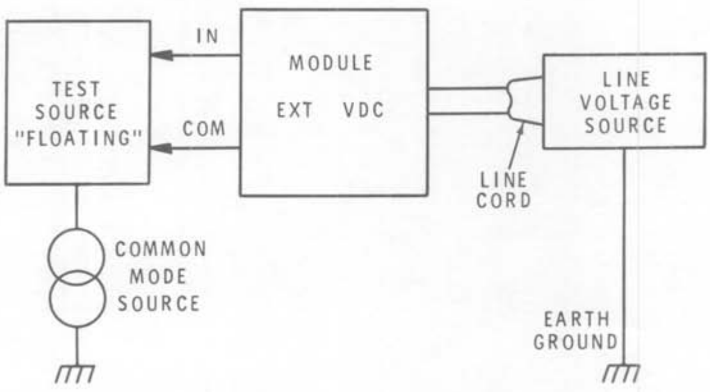
Avoid ground loops. A potential difference may exist between the ground of the power source and the ground of the circuit under test. This difference in ground potential may set up ground-loop currents and affect the measured values. The NMRR (Normal-Mode Rejection Ratio) and CMRR (Common-Mode Rejection Ratio) capability of the Module will greatly reduce this effect. You can also reduce this problem by connecting the test source ground to earth (power line) ground, where possible. Make the connection as close to the Oscilloscope Power ground as you can.

Pictorial 7-9 shows a "typical" ground loop condition.

When you make a "floating" EXT VDC measurement, it is possible to introduce a common-mode voltage by reactive coupling through the Oscilloscope ground circuit. For these measurements, the CMRR capability of the Module should maintain measurement accuracy under most conditions.

Pictorial 7-10 shows a "typical" common-mode voltage condition.

This completes the "Operation" section of your Manual.



PICTORIAL 7-10

IN CASE OF DIFFICULTY

NOTE: It is important that you read the entire "General Troubleshooting Information" and "Troubleshooting Precautions" sections, which follow, before you attempt to service your Module.

This section of the Manual is divided into four parts. The first part, titled "General Troubleshooting Information," describes what to do about the difficulties that may occur right after your Module is assembled.

The second part, titled "Troubleshooting Precautions," points out the care that you should use when you service your Module to prevent damage to components.

The third part, titled "Troubleshooting Procedures," provides specific methods to locate problems that could occur and lists one or more conditions or components ("Possible Cause") that could cause each difficulty.

The fourth part, "Circuit Board Cleaning," should be used only as a last resort to clean a contaminated main circuit board.

GENERAL TROUBLESHOOTING INFORMATION

WARNING: Be sure to turn the power (INTENSITY) switch on the Oscilloscope to OFF before you remove the Module cover.

1. Recheck the wiring. Trace each lead with a colored pencil on the Pictorial as you check it. It is frequenctly helpful to have a friend check your work. Someone who is not familiar with the unit may notice something that you consistently overlook.

2. About 90% of the kits returned for repair do not function properly due to poor soldering. Therefore, you can correct many problems by carefully inspecting the connections to make sure they are soldered as decribed in the "Soldering" information near the front of this Manual. Reheat any doubtful connections.

3. Closely examine each circuit board foil to make sure that there are no solder bridges between adjacent foils. If you are suspect that you have a solder bridge, but are not positive, compare the circuit board foil against the "X-Ray Views" (Illustration Booklet, Page 25). To remove a solder bridge, turn the circuit board foil-side down, and hold a clean soldering iron tip between the two points that are bridged until the excess solder flows **down** onto the tip of the iron. Examine the component side of the main circuit board for solder that may have built up on the top side.

4. Make sure each transistor is in its proper location (correct part number and/or type number). Make sure each transistor lead is in the correct hole and has a good solder connection to the foil. NOTE: All transistors (and integrated circuit U1126) have their flats facing the same direction.

5. Check each integrated circuit (IC) for correct installation. Make sure the dot or marked (pin 1) end of each IC is over the index mark on the circuit board. Check to make sure each lead is in its socket and not bent out or under the IC. NOTE: All ICs (except U1103) have the pin 1 end facing in the same direction.

6. Check each display for the correct installation. Make sure the decimal point end of each display is toward the bottom edge of the display circuit board. Also check each lead to make sure it is in its socket and not bent out or under the display. NOTE: All displays have the pin 1 end facing in the same direction.

7. Check each capacitor value. Make sure the correct value capacitor is installed at each location. Check electrolytic capacitors to make sure the positive (+) or negative (−) marked lead is in its corresponding circuit board hole.

8. Carefully check each resistor value. It would be easy, for example, to install a 22 kΩ (red-red-orange) resistor where a 220 kΩ (red-red-yellow) resistor should be installed. This is especially true for resistors that have five color bands, since the bands can be quite narrow. A resistor that is discolored, cracked, or shows any signs of bulging would indicate that it is damaged and should be replaced. Since damaged resistors are usually the fault of some other difficulty (such as faulty wiring), you should try to find out what caused the damage before you replace the part.

9. Make sure the banded end of each diode is positioned correctly.

10. Check for bits of solder, wire ends, or other foreign matter which may be lodged in the circuit board wiring.

11. Check all component leads connected to the circuit boards. Make sure the leads do not extend through the circuit board and come into contact with other components or parts.

NOTE: In an extreme case where you are unable to resolve a difficulty, refer to the "Customer Service" information inside the rear cover of this Manual. Your Warranty is located inside the front cover.

TROUBLESHOOTING PRECAUTIONS

Observe the following precautions when you troubleshoot your Module:

1. Make sure you do not short any adjacent terminals or foils when you make tests or voltage measurements. If a probe or test lead should slip, for example, and short together two adjacent connections, it is very likely to damage one or more of the transistors, diodes, or integrated circuits.

2. Be especially careful when you test any circuit that contains an integrated circuit or transistor. Although these components have almost unlimited life when used properly, they are much more vulnerable to damage from excess voltage and current than many other parts.

CAUTION: Be particularly careful when you remove or install any CMOS integrated circuit. It is a good idea to treat all ICs as if they are of this type. This eliminates any confusion or question about their type. Refer to the special handling procedures for CMOS ICs on Page 71 of this Manual.

3. Do not remove any components while the Module is turned on. Always turn the power off before you remove any components.

4. When you make repairs to the Module, make sure you eliminate the cause as well as the effect of the trouble. If, for example, you find a damaged resistor, be sure you find out what damaged the resistor. If you do not eliminate the cause, the replacement resistor will most likely become damaged when you place the Module back into operation.

5. In several areas of the circuit boards, the foil patterns are quite narrow. When you unsolder a part to check or replace it, avoid excessive heat while you remove the part. a suction-type desoldering tool makes part removal easier. You may also wish to use the desoldering braid supplied with the kit. Refer to the directions on the package.

6. Do not flex the Oscilloscope to main circuit board wiring repeatedly. When you service the Module, position the circuit board for good access and leave it there throughout the servicing procedure.

COMPONENT REPLACEMENT

To remove faulty resistors and capacitors, first clip them from their leads. Then heat the solder on the foil side and allow each lead to fall out of its hole. Preshape the leads of the replacement part and insert them into their circuit board holes. Solder the leads to the foil and cut off the excess lead lengths.

You can remove transistors in the same manner as resistors and capacitors. Make sure you install the replacement transistor with its leads in the proper holes. Then solder the leads quickly to avoid heat damage. Cut off the excess lead lengths.

FOIL REPAIR

To repair a break in a circuit board foil, bridge solder across the break. Use a length of bare wire to bridge large gaps in the foil. Lay the wire across the gap and solder each end to the foil. Carefully trim off any excess bare wire.

TROUBLESHOOTING PROCEDURES

This part of the "In Case of Difficulty" section is divided into four areas — Basic Meter Tests, Troubleshooting Charts, Waveforms, and Logic Charts.

The Basic Meter Tests portion is intended to identify a general problem area in the Module. A high input impedance (10 MΩ or higher) DC voltmeter is required. Voltage readings may vary ±10% (unless otherwise indicated) from those shown in the charts.

In a newly-assembled Module, the "Initial Tests" section provides a systematic, circuit-by-circuit, check of the Module operation as you install the integrated circuits. If the Module has been in service for some time, you can still use the tests in that section to locate a problem (but in a more general sense). If you do not know the specific area of the problem, you should check the Module for the proper operation by using the procedures listed in this section.

The Troubleshooting Charts identify problems (and possible causes) of a specific nature in each of the measurement functions of the Module. If you have a specific problem in the area identified, you should read through the applicable chart until you find the "Possible Cause" associated with the problem.

The Waveforms and Logic Charts sections provide support information for detailed troubleshooting.

In any of these areas, keep the following in mind:

1. In any area where circuit operation appears to be improper, but is not clearly so, you may find it helpful to review the "Circuit Description" beginning on Page 137.

2. Refer to the "Circuit Board X-Ray Views" and the Schematic to locate the various components or circuit areas listed in the "Possible Cause" column of the charts.

3. Refer to the "Semiconductor Identification Charts" beginning on Page 157 for identification of diode, transistor, and integrated circuit basings. A cross-reference of Heath part numbers and manufacturer's type designations is also included. In several cases, where performance parameters of the part are critical, only the Heath part number is shown.

4. Some circuit areas use integrated circuits or LEDs of the same type. You can often interchange an IC or LED that you think is faulty with one known to be good.

Basic Meter Tests

In these procedures, you are directed to tests and adjustments described in various steps of the "Initial Tests" section of this Manual. A testing setup may also be given prior to an actual test step. If you do not obtain the indicated results in a step, consult the "Possible Cause" column for the step that identifies components or circuit area which may be at fault.

Follow this sequence for each test:

1. Carefully and completely read through the instruction or test information in each step to be sure you are familiar with what is required and what is expected to result from the test.

2. In any instruction where you install or remove an IC or make a solder connection, turn the Oscilloscope Intensity control to OFF before you perform the instruction.

NOTES:

1. Ignore a step that directs you to install an IC where one is already installed. Use the information provided, however, to verify that the correct IC is installed. Also make sure the IC is installed correctly in its socket.

2. The "Initial Tests" section is primarily intended to check unloaded IC outputs and control signals in a newly-assembled Module. You can also use the tests at these points to troubleshoot a Module that has been in use for a period of time. These signals, however, will now have loads connected to them which may affect the results you obtain in a test. If you do not obtain the proper indication at an IC output, for example, it may indicate a failure in that area. It could also be due to a problem in another area. If you are in doubt, consult the Schematic Diagram to see if you can remove other IC loads from the output under test to eliminate these as possible causes of a problem.

TEST PREPARATION

Refer to the "Tests and Adjustments" section of this Manual and Pictorial 8-1 (Illustration Booklet, Page 19) for the locations of the following test points.

( ) Unsolder and clear the "+" and "−" solder pads on the foil side of the main circuit board.

( ) Connect the common lead of a DC voltmeter to the A/D GND connector.

( ) Push the EXT VDC switch.

( ) Move the A/D jumper to the 0.2 position.

POWER SUPPLY AND A/D CIRCUITRY

Perform the steps in the following numbered boxes, starting on Page 76:

( ) Box 16.

( ) Box 17.

( ) Box 18.

( ) Box 19.

( ) Box 20.

( ) Box 21.

( ) Box 22.

EXT VDC CIRCUITRY

( ) Move the A/D jumper to the NORM position.

Perform the steps in the following numbered boxes, starting on Page 81:

( ) Box 38.

( ) Box 39.

( ) Box 40.

( ) Box 41.

( ) Box 42.

CAUTION: BE SURE to disconnect the alligator clip from TPB.

This completes the "Basic Meter Tests." If you obtained the proper results in the previous tests, this shows that the A/D circuitry (and most of the EXT VDC function) is operating properly. Return to the Manual section which directed you to this "In Case of Difficulty" section. If, however, you obtained the proper results in the above procedures, but have some difficulty in any of the functions of the Module, you may proceed with the following:

A. Refer to the Troubleshooting Charts to determine if any of the problems listed there describe the problem you are encountering.

B. Repeat the "Basic Meter Tests." You may want someone else to observe the tests with you, in the event you overlooked something.

C. Contact a Heathkit Electronic Center or the factory for further assistance, or for servicing your Module.

Troubleshooting Charts

EXT VDC OPERATION

NOTE: Make sure the basic meter circuit operates properly, as determined by the previous troubleshooting procedures, before you proceed to the following chart.

The following chart lists the "Problem" and the "Possible Causes" of a number of malfunctions in the EXT VDC circuitry of the Module. If a particular part or area is mentioned (SW1002, Q1003, etc.) as a possible cause, make sure these parts are correctly wired or installed. Also, make sure that the proper part is installed in that location. It is also possible for a part to be faulty.

PROBLEM	POSSIBLE CAUSE
EXT VDC has one of the following problems in the 2V range, at room temperature, after one-hour warmup:	
Does not read 0000 (±0002) with IN and COM inputs shorted, or reads a high count with open-circuit inputs.	1. Open circuit in the IN/COM socket, RP1101, CAL jumper, SW1007, or R1108 circuitry. 2. U1101 to U1105, U1115, U1116, U1124 circuitry. 3. Q1107 to Q1109, Q1116, Q1117, circuitry. 4. RY1101, RY1102. 5. RP1104. 6. C1101 to C1106. 7. High resistance leakage in SW1007 or U1103 circuitry, possibly due to high humidity or contaminants. See "Circuit Board Cleaning" on Page 132.
Reads low (greater than 0 but less than 200 counts).	1. U1105, U1123, U1124 circuitry. 2. Q1108, Q1109 circuitry. 3. RP1104.
Reads more than 200 counts but cannot be calibrated to LO CAL number on calibration label.	1. U1103 to U1105 circuitry. 2. LO CAL voltage in error. 3. R1123 circuitry.
Calibrates properly for LO CAL but is overranged for HI CAL.	1. U1103 to U1105 circuitry. 2. HI CAL voltage in error. 3. R1119 circuitry.
Reads high or low (but not overranged), and cannot be calibrated to HI CAL number on calibration label.	
Is inaccurate (when compared to Laboratory Standards) at full-scale readings only, or ± readings of the same voltage differ by more than 3 counts.	1. Improper adjustment of R1119 or R1123. 2. U1103 circuitry. 3. RP1101. 4. C1101, C1102. 5. Leakage in SW1007, C1102, U1103 circuitry.
Inaccurate at low readings only, or has excessive zero drift.	1. U1102, U1103 circuitry. 2. C1101, C1102.

PROBLEM	POSSIBLE CAUSE
EXT VDC is inoperative on any or all ranges after calibration procedure.	1. Open in IN/COM socket, SW1007, RP1101 circuitry. 2. RY1101, RY1102 circuitry. 3. EXT VDC switch not pushed in. 4. CAL jumper not on NORM pin.
Auto-ranging is unstable or improper for input voltages less than 20 volts.	1. U1121 to U1123 circuitry. 2. Q1102 to Q1105 circuitry. 3. C1112 to C1115. 4. A/D jumper not on NORM pin.
Auto-ranging is unstable only for input voltages greater than 20 volts.	1. U1123, U1124 circuitry. 2. Q1108, Q1109, Q1114 circuitry. 3. RY1101, RY1102.
Decimal point is improper or not lighted on one or more ranges. VDC (Internal), TIME, or FREQ indicators are lighted.	1. U1106 to U1114, U1119 circuitry. 2. RP1004 RP1006, RP1105 to RP1107 circuitry. 3. V1202 to V1205. 4. Q1115 circuitry. 5. D1104.
Readings on any range are unstable or erratic.	1. High normal-mode or common-mode voltage. 2. C1107 to C1109, C1111, C1117. 3. Shields not properly installed at display circuit board brackets.

VDC (internal) OPERATION

NOTE: Make sure the basic meter and the EXT VDC circuitry operates properly as determined by the previous troubleshooting procedures before you proceed with the following chart.

The following chart lists the "Problem" and the "Possible Causes" of a number of malfunctions in the VDC (internal) circuitry of the Module. If a particular part or area is mentioned (SW1002, Q1003, etc.) as a possible cause, make sure these parts are correctly wired or installed. Also, make sure that the proper part is installed at that location. It is also possible for a part to be faulty.

PROBLEM	POSSIBLE CAUSE
VDC (Internal) is inoperative (or reads 0000) with Y1 input connected to "1VCAL (P-P)" connector on 50 mV/div range with Y1 Input switch to DC and CHAN switch out.	1. Open in P401, S111, U1011, SW1003, SW1005 circuitry. 2. U1011 circuitry. 3. EXT VDC switch pushed in. 4. Improper +15, −15, or +5 power supply voltages.
Y1 input operates (as above), but Y2 does not.	1. Open in P501 circuitry. 2. U1012 circuitry. 3. SW1005.
Indicators are not lighted or are improper for CHAN and PROBE switch positions.	1. Open in P401, P501, SW1004, SW1005 circuitry. 2. U1017, U1112 to U1119 circuitry. 3. Q1012, Q1013 circuitry. 4. RP1005, RP1006, RP1106, RP1109 circuitry. 5. V1206 to V1209.
Readings for Y1 or Y2 inputs are inaccurate at low readings or display does not read 0000 with Input switch to GND.	1. Improper adjustment of R1047 or R1054. 2. U401, U501, U1011, U1012 circuitry.
Readings for Y1 or Y2 input have excessive drift at warm-up or at high or low temperatures.	NOTE: It is normal for there to be a few counts of zero shift (less than 10) when the Oscilloscope is turned on and not warmed up.
VDC readings for Y1 or Y2 inputs are inaccurate (when compared to Laboratory Standards) at full-scale readings only, or cannot be calibrated to HI CAL number on calibration label.	1. Improper adjustment of R1048 or R1055. 2. U1011, U1012 circuitry. 3. Q401 to Q403, Q501 to Q503 circuitry.
VDC (Internal) readings are unstable or erratic.	1. High normal-mode voltage. 2. U1009 circuitry. 3. C1018 to C1025.

TIME/FREQ OPERATION

NOTE: Make sure the basic meter and the VDC (internal) circuitry operates properly as determined by the previous troubleshooting procedures before you proceed with the following chart.

The following chart lists the "Problem" and the "Possible Causes" of a number of malfunctions in the Time and Frequency circuitry of the Module. If a particular part or area is mentioned (SW1002, Q1003, etc.) as a possible cause, make sure that these parts are correctly wired or installed. Also, make sure that the proper part is installed in that location. It is also possible for a part to be faulty.

PROBLEM	POSSIBLE CAUSE
TIME (or FREQ) shows no cursor, one cursor, or two cursors, but none can be controlled by the DTP control.	1. Open at S704, SW1001 circuitry. 2. U1002, U1003, U1007, U1008 circuitry. 3. Q1007, Q1008 circuitry. 4. D1001, D1002. 5. Short in TPA connector circuitry.
TIME shows one or two cursors and neither is controlled by Δ DELAY control with TRACKING switch pushed in.	1. U1005, U1007 circuitry. 2. R1028 wiring. 3. D1003 to D1005. 4. SW1006.
TIME shows proper cursor operation with TRACKING switch pushed in but not when it is released.	1. U1004A/Q1009 or U1004B/Q1011 circuitry.
TIME cursor operation is proper, but display reads:	
0000 for any setting of Δ DELAY control.	1. U1001, U1006 circuitry. 2. SW1001, SW1002 circuitry. 3. Q1001 to Q1006 circuitry. 4. EXT VDC switch pushed in.
Overrange for any setting of Δ DELAY control.	1. U1013 to U1016 circuitry. 2. SW1001, SW1002 circuitry.
Overrange for "negative" cursor positioning.	1. U1101, U1102 circuitry. 2. C1101. 3. U1103.
TIME display shows overrange for any A TIMEBASE position with less than 4 divisions of cursor separation, or less than 200 counts with 10 divisions of cursor separation.	1. U1005, U1006, U1015, U1016 circuitry. 2. R1035 to R1039.
TIME display NUMBERS do not show approximately 2000 counts in "2" ranges, 1000 counts in "1" ranges, or 500 counts in "5" ranges of A TIMEBASE switch with 10 divisions of cursor separation.	1. Open at S704. 2. U1001, U1006, U1013 to U1016 circuitry. 3. Q1001 to Q1006 circuitry. 4. Improper adjustment of R1035. 5. R1035 to R1039.

PROBLEM	POSSIBLE CAUSE
TIME display NUMBERS are inaccurate (when compared to Laboratory Standards) at 10 divisions of cursor separation in A-B mode for any A TIMEBASE position.	1. Improper adjustment of R1035, R1062 to R1064. 2. VARIABLE TIME control not in detented position. 3. U1013 to U1015 circuitry.
TIME display NUMBERS are inaccurate (when compared to Laboratory Standards) in B TIMEBASE position with waveforms superimposed:	
For more than 4 divisions of cursor separation.	1. Improper adjustment of R1062 to R1064. 2. U1007, U1008 circuitry. 3. R1037 to R1039. 4. C1004, C1014 to C1017. 5. D1004, D1005.
For less than 4 divisions of cursor separation with greater than 100 counts.	1. Improper adjustment of R1073. 2. U1016. 3. R1071 to R1074. 4. C1004. 5. Open in coax cable shield wires.
FREQ display NUMBERS are inaccurate (when compared to Laboratory Standards).	1. Improper adjustment of R1073. 2. R1071 to R1074. 3. U1103.
TIME or FREQ indicators are improper or not lighted.	1. U1106 to U1114 circuitry. 2. RP1105, RP1107, RP1108. 3. Q1113 circuitry. 4. V1211 to V1216.

Waveforms

Refer to the Waveform illustrations (Illustration Booklet, Page 20) and to Table A (Illustration Booklet, Page 21).

The waveforms shown correspond to the proper operation of the circuitry listed in Table A. Each numbered step corresponds to the same numbered location shown on the Schematic. These waveforms are also referred to in the "Area of Possible Problem" column of the "Initial Tests" section of this Manual. They are provided to help verify circuit operation in addition to DC voltmeter readings and/or visual checks, in the event you are not sure about the results you obtain in any of the steps.

To check for the presence of the following waveforms, you need a DC-coupled oscilloscope that has a vertical calibration at 0.5 V/DIV, 1 V/DIV, 2 V/DIV, and 5 V/DIV and a timebase (horizontal) calibration of 10 μs/DIV, 5 ms/DIV, 100 ms/DIV, and 200 ms/DIV. You must also use a high impedance (10 MΩ recommended), low capacitance probe with the oscilloscope.

NOTE: You cannot use the same oscilloscope (to which the Module is attached) to make these tests.

( ) Turn the power (INTENSITY) switch On.

( ) Set the A TIMEBASE switch to 1 ms.

( ) Push the A-B switch.

( ) Pull out the B TIMEBASE switch and set it to 50 μs.

( ) Set the VARIABLE TIME control to its detent position.

( ) Push the TIME and TRACKING switches.

( ) Set the DTP control fully counterclockwise.

( ) Set the Δ DELAY control fully clockwise.

Perform each of the following steps at each waveform step:

1. Adjust the oscilloscope for the designated voltage settings for the waveform that you will observe. Adjust the vertical position (zero) level to some convenient point. (NOTE: The dot on the left edge of each waveform indicates the DC "zero" level to which it is referenced.

2. Connect the oscilloscope ground lead to the GND connector listed in Table A.

3. Connect or touch the oscilloscope probe to the indicated test point.

4. Adjust the triggering controls of the oscilloscope until you obtain a clear presentation.

5. If you obtain the proper waveform, proceed to the next step. If you do not obtain the proper waveform, make sure you have the correct test connections. If you still cannot obtain the proper waveform, refer to the information in the "Comments" column of the chart to determine which circuit areas could be at fault.

Logic Charts

Sections of the VOLTS/DIV and TIME/DIV switches have combinations of closures that are determined by the range you have selected. In addition, U1001, U1112, and U1119 are read-only-memory (ROM) integrated circuits that have many possible output voltage combinations. These combinations are determined by their input voltage combinations (called a truth table).

The Logic Charts in this section indicate the switch closures and the ROM outputs that are used in the Module circuitry. This information will aid you when you perform some detailed troubleshooting. The charts indicate the voltage levels that correspond to a logic high (H) and a logic low (L) for these components in reference to the indicated ground circuit.

When you trace the operation of a circuit, be sure to consider how these logic signals are used as inputs or control signals to the associated circuitry.

LOGIC CHART I

Logic ground : CHASSIS GND.
Logic low (L) : Less than +0.5 volt DC.
Logic high (H) : Greater than +3.0 volts DC.

Comments: U1001 and the U1106 through U1111 circuitry act as a pull-up to the data signals of the A Timebase switch. If S704 is open, all U1001 inputs are high.

NOTE: For clarity, only the low (L) locations are shown. All others are high (H).

A TIMEBASE position	U1001 Inputs				
	Pin 14 "A5"	Pin 13 "A4"	Pin 12 "A3"	Pin 11 "A2"	Pin 10 "A1"
100 ms	L	L	L	L	L
50 ms	L	L	L	L	
20 ms	L	L	L		L
10 ms	L	L	L		
5 ms	L	L		L	L
2 ms	L	L		L	
1 ms	L	L			L
.5 ms	L	L			
.2 ms	L		L	L	L
.1 ms	L		L	L	
50 μs	L		L		L
20 μs	L		L		
10 μs	L			L	L
5 μs	L			L	
2 μs	L				L
1 μs	L				
.5 μs		L	L	L	L
.2 μs		L	L	L	
.1 μs		L	L		L
X-Y		L	L		
200 ms*		L		L	L

* where applicable

LOGIC CHART II

Logic ground : CHASSIS GND.
Logic low (L) : Less than +0.25 volt DC.
Logic high (H) : Greater than +0.5 volt DC.

Comments: RP1001 acts as a pull-up at the outputs of U1001. Output highs (H) are limited by the base-to-emitter voltages of Q1001 through Q1006.

NOTE: For clarity, only the low (L) locations are shown. All others are high (H). Also, only legal input codes (21 of the 32 possible) are shown in the upper part of the chart.

U1001								
INPUT	OUTPUT							
A TIMEBASE position "A5" to "A1"	Pin 9 "Q8"	Pin 7 "Q7"	Pin 6 "Q6"	Pin 5 "Q5"	Pin 4 "Q4"	Pin 3 "Q3"	Pin 2 "Q2"	Pin 1 "Q1"
100 ms	L	L			L		L	
50 ms	L	L			L	L		
20 ms	L	L			L			L
10 ms	L	L			L		L	
5 ms	L	L			L	L		
2 ms	L	L			L			L
1 ms	L	L		L			L	
.5 ms	L	L		L		L		
.2 ms	L	L		L				L
.1 ms	L	L		L			L	
50 µs	L	L		L		L		
20 µs	L	L		L				L
10 µs	L	L	L				L	
5 µs	L	L	L			L		
2 µs	L	L	L					L
1 µs	L	L	L				L	
.5 µs	L	L	L			L		
.2 µs	L	L	L					L
.1 µs	L	L	L				L	
X-Y	L	L	L				L	
200 ms*	L	L	L		L			L

* where applicable

All H (Illegal)	L	L	L	L	L	L	L	L

LOGIC CHART III-A (TIME operation)

Logic ground : A/D GND.
Logic low (L) : Less than +0.5 volt DC.
Logic high (H) : Greater than +3.0 volts DC.

Comments: Highs (H) at inputs A1 through A8 are through pull-up resistors. Highs (H) at outputs Q1 through Q7 are through LED pull-ups that have a voltage drop of 1.7 volts.

Ground TPD to obtain a high (H) at A8. For a low (L) at A8, the low outputs of Q1 through Q4 move to the next higher output. That is, the L at Q1 is at Q2, Q2 is at Q3, and Q3 is at Q4. This causes the display decimal point to "shift right."

For the TIME/FREQ function, the enable signal from Q8 to pin 15 of U1119 is high (H) and all of the outputs of U1119 are open-circuited. For the EXT VDC or VDC (internal) functions, a high (H) at A6 and A7 of U1112 causes the Q8 output to be low (L), and all other outputs are open-circuited. See the chart below.

NOTE: For clarity, only the low (L) output locations are shown. all others are high (H). Also, only legal codes (23 of the possible 256) are shown in the upper part of the chart.

U1112											
INPUT				OUTPUT							
Other Inputs			A TIMEBASE position	Pin 9	Pin 7	Pin 6	Pin 5	Pin 4	Pin 3	Pin 2	Pin 1
"A8"	"A7"	"A6"	"A5" to "A1"	"Q8"	"Q7"	"Q6"	"Q5"	"Q4"	"Q3"	"Q2"	"Q1"
H	H	L	100 ms				L				L
H	H	L	50 ms				L				L
H	H	L	20 ms			L			L		
H	H	L	10 ms			L			L		
H	H	L	5 ms			L			L		
H	H	L	2 ms			L				L	
H	H	L	1 ms			L				L	
H	H	L	.5 ms			L				L	
H	H	L	.2 ms			L					L
H	H	L	.1 ms			L					L
H	H	L	50 µs			L					L
H	H	L	20 µs		L				L		
H	H	L	10 µs		L				L		
H	H	L	5 µs		L				L		
H	H	L	2 µs		L					L	
H	H	L	1 µs		L					L	
H	H	L	.5 µs		L					L	
H	H	L	.2 µs		L						L
H	H	L	.1 µs					L	L	L	L
H	H	L	X-Y					L	L	L	L
H	H	L	200 ms*				L				L
H	H	H	Any	L							
L	H	H	Any	L							

* where applicable

H	L	L	Any					L	L	L	L
L	L	L	Any					L	L	L	L
	(Illegal)										

LOGIC CHART III-B (FREQ operation)

Logic ground : A/D GND.
Logic low (L) : Less than +0.5 volt DC.
Logic high (H) : Greater than +3.0 volts DC.

Comments: Highs (H) at inputs A1 through A8 are through pull-up resistors. Highs (H) at outputs Q1 through Q7 are through LED "pull-ups" that have a voltage drop of 1.7 volts.

Ground TPD to obtain a high (H) at A8. For a low (L) at A8, the low outputs of Q1 through Q4 move to the next lower output. That is, the L at Q4 is at Q3, Q3 is at Q2, and Q2 is at Q1. This causes the decimal point to "shift left."

For the TIME/FREQ function, the enable signal from Q8 to pin 15 of U1119 is high (H) and all of the outputs of U1119 are open-circuited. For the EXT VDC or VDC (internal) functions, a high (H) at A6 and A7 of U1112 causes the output of Q8 to be low (L) and all other outputs are open-circuited. See the chart below.

NOTE: For clarity, only the low (L) output locations are shown. All others are high (H). Also, only legal input codes (23 of the 256 possible) are shown in the upper part of the chart.

U1112											
INPUT				OUTPUT							
Other Inputs			A TIMEBASE								
Pin 19 "A8"	Pin 18 "A7"	Pin 17 "A6"	position "A5" to "A1"	Pin 14 "Q8"	Pin 13 "Q7"	Pin 12 "Q6"	Pin 11 "Q5"	Pin 9 "Q4"	Pin 8 "Q3"	Pin 7 "Q2"	Pin 6 "Q1"
H	L	H	100 ms				L		L		
H	L	H	50 ms				L		L		
H	L	H	20 ms				L	L			
H	L	H	10 ms				L	L			
H	L	H	5 ms				L	L			
H	L	H	2 ms			L				L	
H	L	H	1 ms			L				L	
H	L	H	.5 ms			L				L	
H	L	H	.2 ms			L			L		
H	L	H	.1 ms			L			L		
H	L	H	50 µs			L			L		
H	L	H	20 µs			L		L			
H	L	H	10 µs			L		L			
H	L	H	5 µs			L		L			
H	L	H	2 µs		L					L	
H	L	H	1 µs		L					L	
H	L	H	.5 µs		L					L	
H	L	H	.2 µs		L				L		
H	L	H	.1 µs					L	L	L	L
H	L	H	X-Y					L	L	L	L
H	L	H	200 ms*				L		L		
H	H	H	Any	L							
L	H	H	Any	L							

* where applicable

H	L	L	Any					L	L	L	L
L	L	L	Any					L	L	L	L
	(Illegal)										

LOGIC CHART IV

Logic ground : CHASSIS GND.
Logic low (L) : Less than +0.5 volt DC.
Logic high (H) : Greater than +3.0 volts DC.

Comments: RP1003 (togther with R1082/R1083 or R1084/R1085) acts as a pull-up on closures of the Y1 or Y2 VOLTS/DIV switch. If S401 or S501 is unplugged, no voltage is present at S401 or S501, respectively.

Y1 (or Y2) VOLTS/DIV position	U1017	
	"YA" Pin 4 (or 1)	"YB" Pin 8 (or 11)
2 mV to 50 mV	H	L
100 mV to 500 mV	L	L
1 V to 10 V	L	H

Logic Chart IV

LOGIC CHART V
(Illustration Booklet, Page 22)

Logic ground : A/D GND.
Logic low (L) : Less than +0.5 volt DC.
Logic high (H) : Greater than +3.0 volts DC.

Comments: Highs (H) at the inputs A1 through A5 are through pull-up resistors. Highs (H) at outputs Q1 through Q8 are through LED "pull-ups" that have a voltage drop of 1.7 volts.

Push the CHAN switch in to obtain a high (H) at A3. The logic codes shown (16 of the 32 possible) are for Y2. For Y1, push the CHAN switch to out to obtain a low (L) at A3. Q7 output then follows the code shown for Q8, and Q8 output is always high. Codes for Q6 to Q1 (except as shown) are the same.

For the TIME/FREQ function, the enable signal at pin 15 of U1119 is high (H) and all of the outputs of U1119 are open-circuited.

For the EXT VDC or VDC (internal) functions, a high (H) at A6 and A7 of U1112 causes the output of Q8 to go low and all other outputs are open-circuited.

NOTE: For clarity, only the low (L) output locations are shown. All others are high (H).

CIRCUIT BOARD CLEANING

Certain areas of the main circuit board contain circuitry that has very high impedance requirements to operate properly. The solder-resist coating provides the necessary inter-foil isolation, but the surface of the resist can become contaminated by skin oils, conductive dusts, excess solder rosin, etc. You can use the following procedure to remove some or all of the effects of this contamination.

Use the following procedure to clean a contaminated main circuit board:

1. Remove the circuit board assembly from the Module chassis. Then remove the metalized shield from the foil side.

CAUTION: Do not let water get into the switches when you perform the next step.

2. Use **demineralized** water and a soft brush to clean the entire foil side of the main circuit board. Be sure to brush all foil areas in and around the switches and in the areas of integrated circuits U1101 through U1103.

3. Bake the circuit board assembly at 150° F for 5 hours. CAUTION: Allow the circuit board assembly to cool before you reinstall the shield.

4. Remount the circuit board assembly to its chassis.

5. Immediately recalibrate the Module.

SPECIFICATIONS

Accuracy specifications apply at 22° C
(72° F) after a 30 minute warm-up period.

TIME

Operation	Displays time between positioned cursors.
Ranges	± 1.000 second to ± 2.000 microseconds full scale in a 1000, 2000, 500 count sequence. On each range, the display auto-ranges by a factor of 10 to provide higher resolution below 200 counts of full scale, except auto-ranging occurs at 100 counts.
Decimal Point	Automatic placement where required.
Indicators	Automatic lighting of "s" (seconds), "ms" (milliseconds), or "μs" (microseconds) as required.
Accuracy	±(2% of reading + 1 count), except 3% when auto-ranging to a higher resolution.
Temperature Coefficient	± (0.1% of reading + 0.1 count) /° C.

FREQ (Frequency)

Operation . . . . Displays the frequency that corresponds to a single cycle between positioned cursors.

Ranges . . . . ±1.000 Hz to ±0.500 MHz for cursors positioned 10 divisions apart with a 1000, 500, 2000 count sequence.

On each range, the display auto-ranges by a factor of 10 to provide a higher measurement range for displays above 2000 counts of the 10-division display.

Maximum display is 19.99 Hz on the 100 ms/DIV range to 19.99 MHz on the 0.2 μs/DIV range.

Decimal Point . . . . Automatic placement where required.

Indicators . . . . Automatic lighting of "Hz", "kHz", or "MHz" as required.

Accuracy . . . . ±(3% of reading + 1 count).

Temperature Coefficient . . . . ±(0.1% of reading + 0.1 count) /° C.

VDC (internal)

Operation . . . . Displays the DC voltage at the Y1 or Y2 input (switch-selected) when the corresponding DC-GND-AC switch is set to DC. Displays zero when the switch is set to GND or AC.

Ranges . . . . ±2 volts on the 2 mV/DIV to 50 mV/DIV ranges; ±20 volts on the 0.1 V/DIV to 0.5 V/DIV ranges; and ±200 volts on the 1 V/DIV to 10 V/DIV ranges.

On each range, the display auto-ranges by a factor of 10 to provide higher resolution below 200 counts. Auto-ranging occurs at 100 counts.

The full-scale voltage of the range is increased by 10 if you use a X10 probe.

Decimal Point . . . . Automatic placement where required and shifts by a factor of 10 (switch-selected) if you use a X10 probe.

Indicators . . . . "Y1" or "Y2" for channel; "X1" or "X10" for probe.

Accuracy	Built-in reference calibration: ±(1% of reading + 2 counts). Laboratory standards calibration: ±(0.75% of reading + 2 counts). For voltages applied directly to the Y1 or Y2 inputs: Add the tolerance of a X10 probe, if you use one.
Maximum Input Limit	400 volts DC (or DC + peak AC).
NMRR (20 Hz to 1 MHz)	Greater than 50 dB, within maximum input limits.
CMRR	Not applicable, since measurement circuitry is referenced to earth ground.
Temperature Coefficient	±(0.025% of reading + 0.5 count)/° C.

EXT VDC

Operation	Displays the DC voltage that is applied to the IN and COM jacks on the side panel.
Ranges	±2 volts, ±20 volts, ±200 volts, and ±2000 volts; auto-ranging.
	The display auto-ranges to the next higher range for greater than 1999 counts and to the next lower range for less than 100 counts.
Decimal	Automatic placement where required.
Accuracy	Built-in reference calibration: ±(0.5% of reading + 1 count), except 2 counts on the 2-volt range. Laboratory standards calibration: ±(0.25% of reading + 1 count), except 2 counts on the 2-volt range.
Maximum Input	±1000 volts DC (or DC + peak AC) on any range.
NMRR (50 Hz to 1 kHz)	Greater than 50 dB on the 2-volt and 20-volt ranges; greater than 40 dB on the 200-volt and 1000-volt ranges.
CMRR (1 kΩ unbalanced, COM driven, up to 500 volts maximum)	Greater than 100 dB at DC; greater than 80 dB at 50 and 60 Hz.

Power Line Isolation	COM input may float 500 volts (peak) from earth (power line) ground.
Temperature Coefficient	±(0.025% of reading + 0.1 count)/° C.

TRACKING (Time and Freq.)

ON	The DTP control on the Oscilloscope positions both cursors in tandem; the Δ DELAY control on the Module positions only one cursor.
OFF	The DTP and Δ DELAY controls position cursors separately and independently.

GENERAL

Display	3-1/2 digit (1999 maximum count), 0.43", 7-segment LED (light-emitting diode).
Sampling Rate	2-1/2 per second.
Polarity Indication	Automatic minus (−) for negative, positive (+) is implied.
Overrange Indication	Displays "1" or "−1" in the left-most digit and decimal point (as applicable); three right-most digits are blanked.
Operating Temperature	50° F to 104° F (10° C to 40° C).
Dimensions	1-1/2" high × 10-3/4" wide × 9-3/4" deep (3.8 × 26.9 × 24.4 cm). The Module increases the height of the Oscilloscope to 7-1/2" (19.1 cm).
Weight	3.2 lbs. (1.45 kg). The Module increases the weight of the Oscilloscope to 26.1 lbs. (11.8 kg).

The Heath Company reserves the right to discontinue products and to change specifications at any time without incurring any obligation to incorporate new features in products previously sold.

CIRCUIT DESCRIPTION

Refer to the Block Diagram (Illustration Booklet, Page 23) and the Schematic (fold-in) while you read this "Circuit Description." The component numbers are arranged in the following groups to help you locate specific parts on the Schematic and circuit boards:

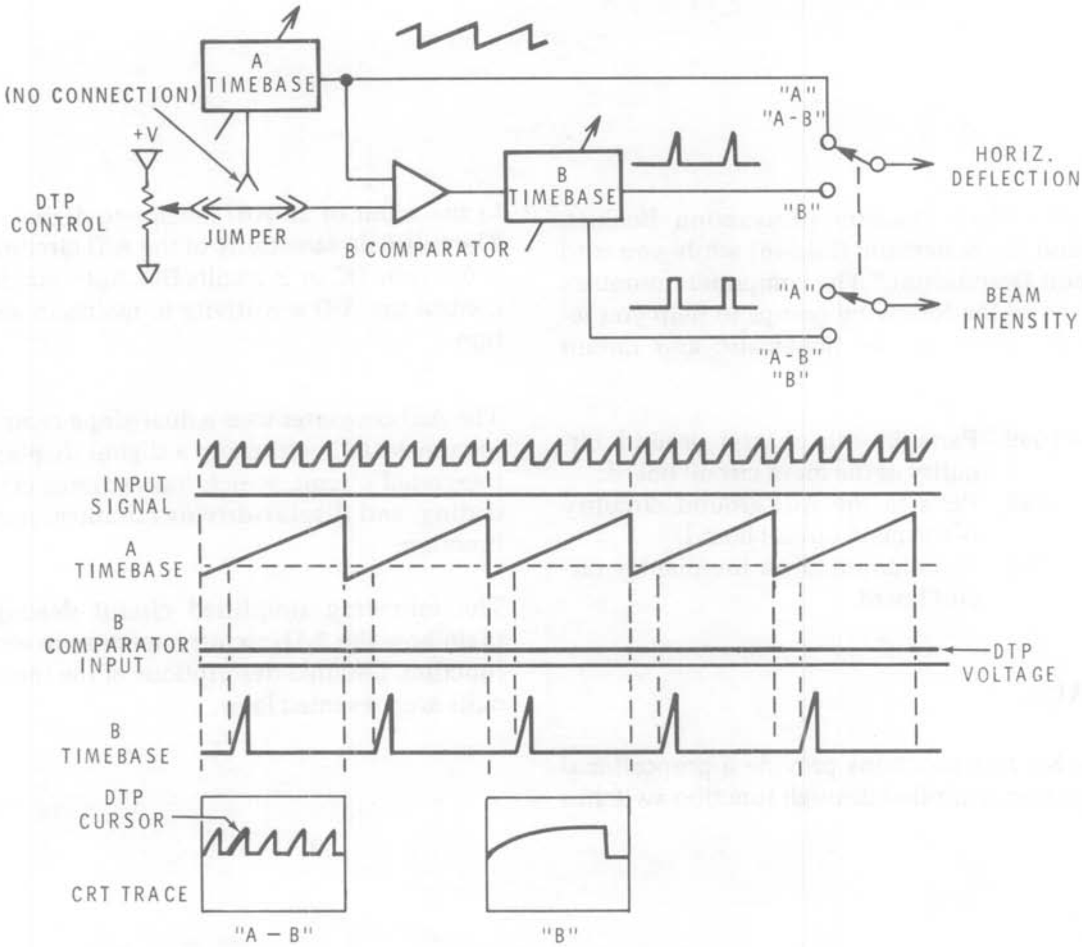
1000 — 1099	Parts in the chassis ground circuitry of the main circuit board.
1100 — 1199	Parts in the A/D ground circuitry of the main circuit board.
1200 — 1299	Parts mounted on the display circuit board.

GENERAL

All of the Module functions provide a proportional DC voltage that is applied through function switches to the input of an A/D (analog-to-digital) converter. The fullscale sensitivity of the A/D circuitry is either ±0.2 volts DC or ±2 volts DC. Auto-ranging circuits control the A/D sensitivity to maintain good resolution.

The A/D converter uses a dual-slope ramp technique to convert DC voltages to a digital display. A single integrated circuit, which incorporates counting, decoding, and display-driving circuitry, performs this function.

The following simplified circuit descriptions explain how the A/D circuitry operates in each Module function. Detailed descriptions of the individual circuits are presented later.



PICTORIAL 9-1

SIMPLIFIED TIME, FREQ CIRCUIT

When you use the Oscilloscope for normal delayed-sweep (A-B) measurements without the Module, the Oscilloscope uses the A Timebase, B Timebase, and B Comparator circuitry shown in Pictorial 9-1. Also shown in the Pictorial are the associated waveforms.

Each time the A Timebase sweeps, the sweep voltage starts at a low value and increases. This voltage is applied to one input of the B Comparator and a DC voltage from the DTP control is applied to the other input. When the sweep voltage equals the DC voltage, the B Comparator triggers the B Timebase and the A Timebase is intensified (brightened). When you select the B Timebase, the CRT beam sweeps for only the brief period of the B Timebase. This, as shown, allows you to view a highly magnified portion of the input signal.

When you make delayed-sweep measurements with the Module, the direct connection between the DTP control and the B Comparator is opened and some additional circuitry is added as shown in Pictorial 9-2 (Illustration Booklet, Page 24).

The voltage from the DTP control is now applied to the buffer circuit (U1003), which provides a low-impedance output that is equal to the DTP voltage. The output of the buffer is connected to the center of two "batteries" in the Δ Delay Bridge circuit and results in the voltage being V(DTP) + 6V at the top of the Δ Delay control and V(DTP) − 6V at the bottom of the control. You can set the wiper of the Δ Delay control to any voltage above or below the DTP voltage (for the full DTP voltage range). When the control is at the center of its range, the wiper voltage is equal to the DTP voltage.

The circuitry of U1005 buffers the Δ Delay voltage (D1003 clamps any negative value) and applies the voltage to one input of electronic switch U1007. The DTP voltage is applied to the other input. Diodes clamp any negative voltage in the U1005, U1007 circuitry. Voltage follower U1008 buffers the output voltage from the electronic switch and applies it to one input of the B comparator.

At the completion of each A Timebase sweep, the "cursor toggle" signal causes flip-flop U1002 to alternate the electronic switch to the other position. Therefore, on each odd sweep, the DTP voltage triggers the B Timebase and on each even sweep, the Δ Delay control voltage triggers the B Timebase. For each pair of odd and even sweeps, two intensified areas (cursors) show on the CRT. For faster sweep rates, they appear to be "on" together. You can position these cursors on a waveform to measure the time between two points, or at similar points on a repetitive signal. The waveforms on Pictorial 9-2 show the result of this circuit. When you select the B Timebase (B), the two magnified cursor displays are both shown on the display. For highly precise measurements, the Δ Delay control is set to superimpose the displays. The cursors are then positioned an exactly whole number of cycles apart.

Since the A Timebase sweep voltage ramp is very linear versus time, the coincidence of the sweep voltage with these two DC voltages results in cursor positions that are also proportional to the sweep time. The cursor voltages may be varied so the cursors can be superimposed to "zero" time, or to the full width of the graticule.

As Pictorial 9-2 shows, the difference between the Δ Delay and DTP voltages is applied to a precision resistive divider. When the proper difference voltage to separate the cursors by 10 divisions is applied (approximately ±6 volts), the divider circuit provides 2, 1, or 0.5 volts as shown. The setting of the A Timebase switch determines which of these voltages is applied to the A/D converter and corresponds to the 2, 1, or 5 position. This allows 10 divisions of cursor separation on the A Timebase ranges to be digitally displayed by the converter as 2000, 1000, or 500 counts. Proper positioning of the decimal point supports the display along with time-related indicators to provide a direct-reading display.

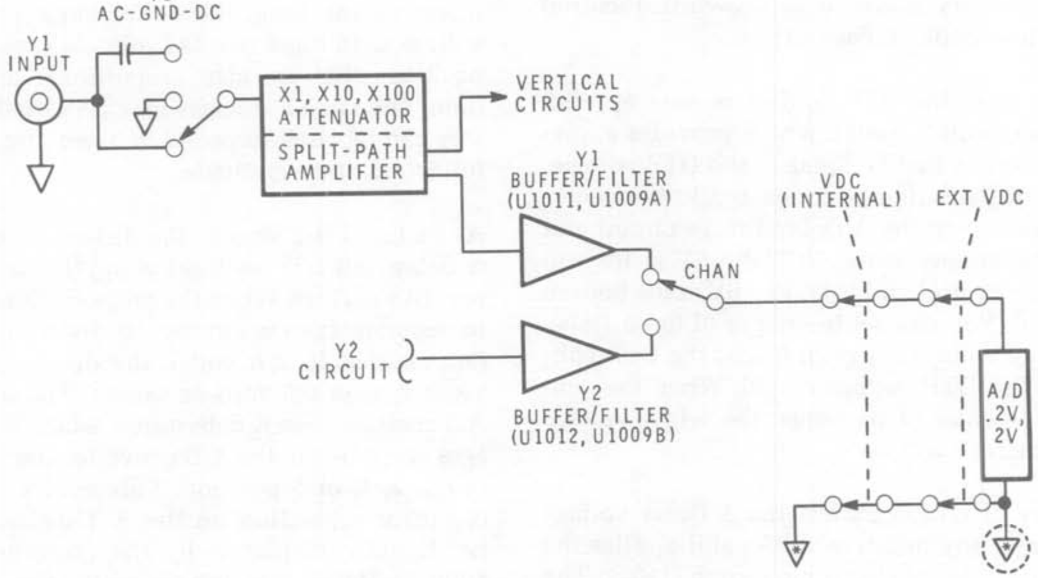
The above description shows how time measurements are made in which the A/D circuitry displays counts that are proportional to the time-related input voltage. In addition, the A/D circuitry can display counts that are inversely proportional to an input voltage. Since frequency is inversely proportional to time, this capability provides a means to display frequency as well as time. This is decribed in more detail later.

SIMPLIFIED VDC (internal) CIRCUIT

Pictorial 9-3 shows the VDC (internal) circuitry that allows you to measure DC voltages at the Y1 or Y2 input connectors.

Any voltage at either input passes through the AC-GND-DC switches to the Attenuator circuits. Depending upon the setting of the Volts/Div switch, these circuits provide input voltages to the split-path amplifier, which are × 1 (direct), × 1/10, or × 1/100 of the voltage present at the input connectors.

The DC component coming from the split-path amplifiers is filtered and routed to the U1011, U1012 buffer circuitry in the Module. In these circuits, the U1009 active filters provide a very great reduction of any AC component to obtain maximum display stability. The Chan switch applies one of these buffer outputs to the A/D converter for measurement. Proper decimal point location and indicator lights provide a direct-reading display.



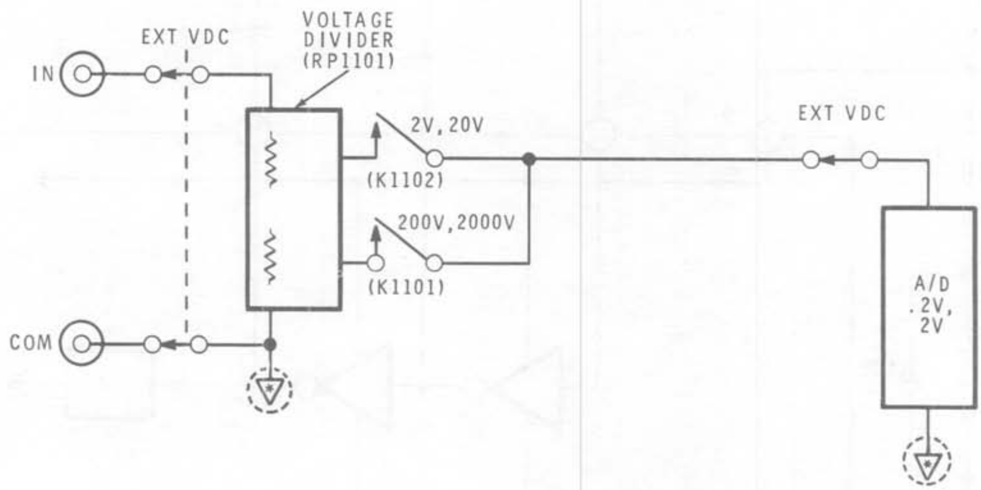
PICTORIAL 9-3

SIMPLIFIED EXT VDC CIRCUIT

The EXT VDC function of the Module allows you to measure external DC voltages through the IN and COM jacks as shown in Pictorial 9-4.

The high-precision voltage divider circuit, RP1101, provides output voltages at 1/10 and 1/1000 of the input voltage. For the 2 V or 20 V measurement ranges, the upper relay (K1102) closes and the sensitivity of the A/D circuit is ±0.2 V or ±2 V, respectively. For the 200 V or 2000 V (limited to 1000V) ranges, the lower relay (K1101) closes and the A/D sensitivities are again either ± .2 V or ± 2 V. Proper decimal point position provides a direct-reading display.

The above simplified descriptions showed you the general operation of each Module function. The individual circuits are described in detail below. Since the A/D converter circuitry is used for each function, it will be described first.

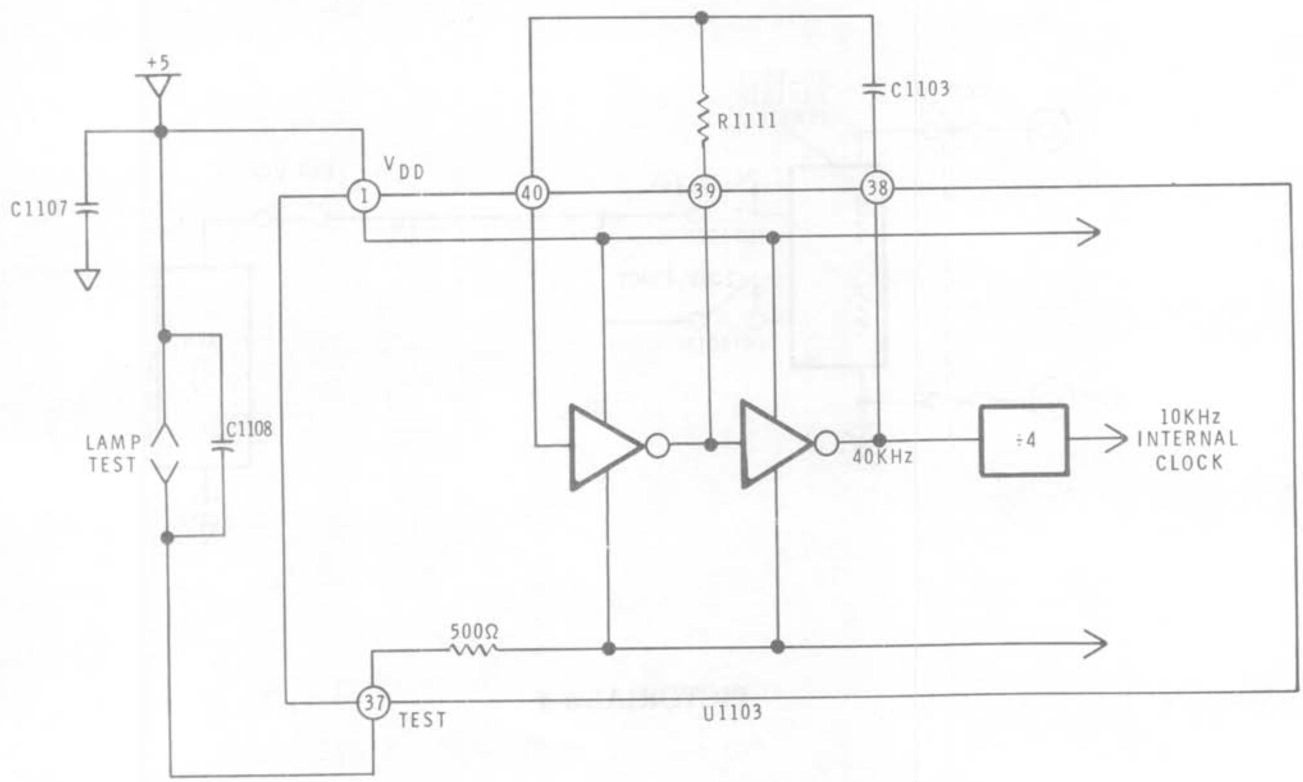


PICTORIAL 9-4

A/D CONVERTER

Most of the A/D circuitry is contained in integrated circuit U1103. The following description shows you how this circuit operates.

The simplified oscillator shown in Pictorial 9-5 controls the timing sequence of the entire A/D converter. Resistor R1111 and capacitor C1103 cause this oscillator to operate at 40 kHz, which is internally divided to provide a 10 kHz "clock" signal that is used by the digital and timing circuitry within the A/D converter. This frequency provides 2-1/2 conversions per second (400 millisecond period) and has sufficient speed to respond to measurement trends and also suppresses 50 and 60 Hz noise. The Lamp Test pins on the circuit board allow you to check the display segments. These pins short the supply voltage to the oscillator, which stops the 40 kHz oscillator and causes the display to indicate "−1888".



PICTORIAL 9-5

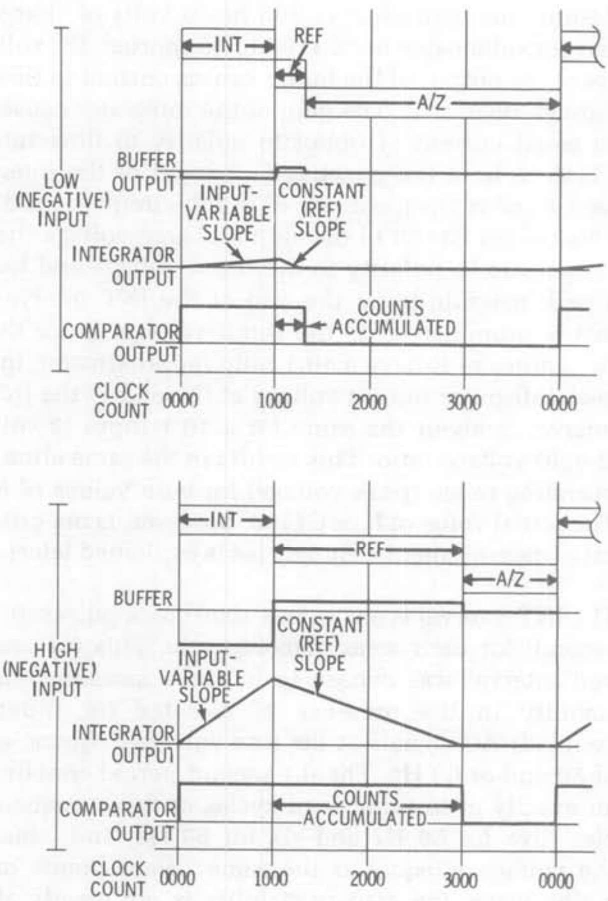
The 10 kHz clock provides the timing intervals shown in Pictorial 9-6 for the switching circuit shown in Pictorial 9-7.

The three sequential time intervals in each measurement cycle are: integration of the input signal (INT), application of a reference voltage (REF), and offset self-correction interval (auto-zero, or A/Z). These time intervals are each described below.

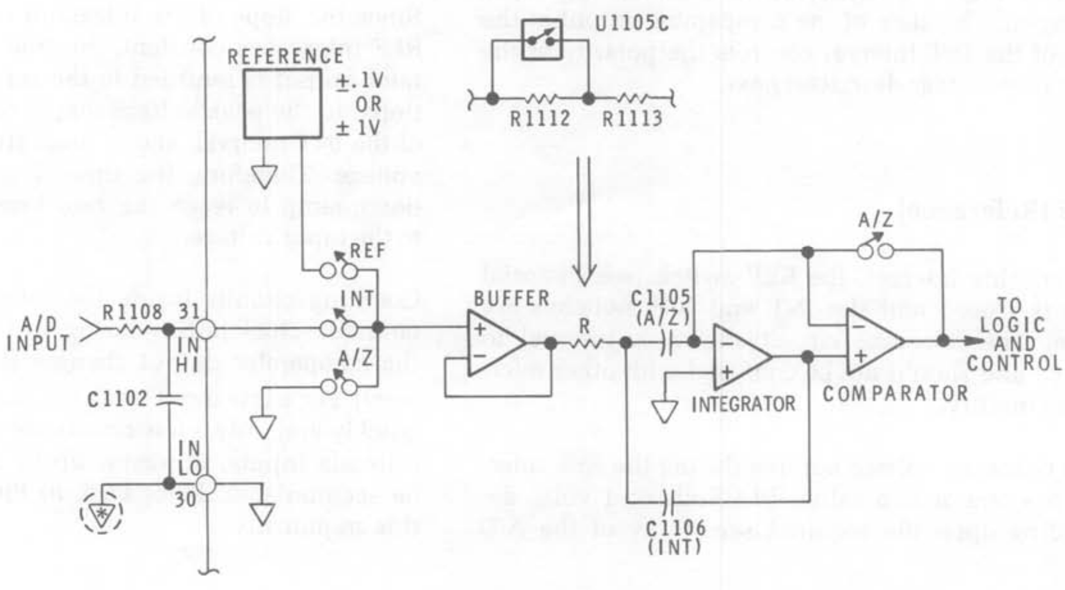
INT (Integration)

At the beginning of this interval (internal clock counters at 0000), the INT switch closes and the REF and A/Z switches are open.

The A/D input voltage, which is filtered by R1108 and C1102 to reduce any AC component that may be superimposed on the DC you wish to measure, is applied to U1103 pin 31 (IN HI). Pin 30 of this IC (IN LO) is connected to the A/D ground circuit. Any voltage that is present at pin 31 is coupled through a high-input impedance, unity gain buffer to resistance R. This resistance has two values that are consistent with the two sensitivities of the A/D converter and depend upon the condition (open or closed) of U1105C. The value of R is R1113 for 0.2-volt sensitivity or R1112 in series with R1113 for 2-volt sensitivity.



PICTORIAL 9-6



PICTORIAL 9-7

Assume that capacitor C1106 has 0 volts of charge and consider capacitor C1105 to be shorted. DC voltage at the output of the buffer causes current to flow through resistor R. The gain of the integrator causes an equal current of opposite polarity to flow into C1106 to hold the negative (−) input of the integrator equal to the positive (+) input (circuit ground). This causes C1106 to develop a charge voltage that is opposite in polarity to the input voltage and has a peak magnitude (at the end of the INT interval) that is proportional to the input voltage. Since the two values of R have a 10:1 ratio (approximate), the peak integrator output voltage at the end of the INT interval is about the same for a 10:1 input (2-volt, .2-volt) voltage ratio. This results in the same circuit operating range (peak voltage) for both values of R. The actual value of R or C1106, however, is not critical to measurement accuracy (as is explained later).

The INT interval is a constant 1000 clock pulses (0.1 second) for each measurement cycle. This 0.1 second interval was chosen to improve measurement stability in the presence of radiated (or input-coupled) AC signals at the line voltage frequencies of 50 and/or 60 Hz. The 0.1 second period contains an exactly even number of cycles at these frequencies (five for 50 Hz and six for 60 Hz) and, since the voltage is equal at the same (even) points on a sine wave, the display stability is not greatly affected by the presence of AC on the DC. At the end of the INT interval, the comparator output is either high or low, depending upon the polarity of the integrator output voltage (even for very low A/D input voltages). The state of the comparator output at the end of the INT interval controls the polarity of the reference voltage described next.

REF (Reference)

During this interval, the REF switch (see Pictorial 9-7) is closed and the INT and A/Z switches are open. The reference circuit shown is internal to U1103 and should not be confused with other reference circuitry.

The reference voltage applied during the REF interval has one or two values (0.1 volts or 1 volt), depending upon the required sensitivity of the A/D converter. This voltage may be either + or −, depending upon the polarity of the A/D converter input. The circuitry which provides this voltage is described later.

The polarity of the reference voltage is determined as a result of the comparator output (logic level) at the end of the preceding INT interval, and is opposite in polarity to the input voltage. In a manner similar to the previous INT operation, this voltage causes the integrator output to down ramp from its peak back to a zero level. When it reaches the zero level, the comparator output changes state, which is a signal that the REF interval is complete.

The difference between the INT and REF intervals is that during the INT interval, the slope of the integrator output (to the peak value) is proportional to the input voltage. During the REF interval, however, the slope is proportional to the REF (constant) voltage.

Note that the change in the buffer input voltage (A/D input during INT; reference voltage during REF) is the only change during these intervals. For this reason, the measurement results (display) depends only upon the A/D converter input and the reference voltages. The actual value of R or C1106 is unimportant since the same parts are used for both the up-ramp and the down-ramp. This also cancels any long-term or temperature-related changes in these parts.

Since the slope of the integrator output during the REF interval is constant, the time when the integrator output is returned to the zero level is proportional to the peak voltage that is reached at the end of the INT interval, and is proportional to the input voltage. Therefore, the time it takes for the REF down-ramp to reach the zero level is proportional to the input voltage.

Counting circuits inside the integrated circuit accumulate clock pulses during the REF interval, until the comparator output changes state (reaches zero level). For a low input level, the zero level is reached quickly and only a few counts are accumulated. For fullscale inputs, however, up to 2000 counts may be accumulated. Refer back to Pictorial 9-6 to see this graphically.

The circuit operation, as described earlier, depends only upon the A/D input and reference voltages. The following equation shows this mathematically:

$$\text{Counts Displayed} = \frac{(\text{IN HI} - \text{IN LO})}{(\text{REF HI} - \text{REF LO})} \times 1000$$

where IN HI − IN LO = A/D input = V_{IN} and REF HI − REF LO = reference voltage = V_{REF}

The following equation further simplifies this relationship:

$$\text{Display Reading} = \frac{V_{IN}}{V_{REF}} \times 1000$$

Since V_{REF} is normally either 0.1 or 1 volt, a V_{IN} of 0.2 volt or 2 volts produces a 2000 count display. If 2000 counts are accumulated and the integrator output has not returned to the zero level, the comparator output does not change states. This is used to indicate an overrange condition.

The number of counts that are accumulated is stored internally, while other storage circuits register the polarity (or if an overrange occurred). The count and polarity (and overrange) information is then decoded to drive the LED display. The duration of the REF interval varies from 0 counts (0 seconds) to 2000 counts (0.2 seconds). The auto-zero interval begins immediately upon completion of the REF interval and is described next.

A/Z (Auto-Zero)

Without correction circuitry, the operation of the A/D circuit would be highly sensitive to some variable conditions such as temperature, semiconductor error voltages, etc. The integrated circuit automatically performs a self-correction on each measurement cycle and almost completely eliminates the effects of these variables.

During the A/Z interval, the A/Z switches shown in Pictorial 9-7 (Page 143) are closed and the INT and REF switches are open. The switch that closes to ground at the buffer input causes its output (one end of C1105) to be equal to any offset voltage error in the buffer. The switch that closes across the comparator (and integrator) causes the other end of C1105 to be at a voltage that is equal to the total offset voltages of these circuits (and any current-induced error voltages). The end-to-end voltage on C1105 at the end of the A/Z interval is therefore equal to the sum of all of these errors, and offsets the operation of the circuit by this amount during the next INT and REF intervals. Since the integrator and A/Z switches are very high resistance semiconductor circuits, there is no discharge path that would affect this voltage during the INT and REF intervals. Any input to C1105 is not reduced at its output and, therefore, C1105 appears as a short circuit during the INT and REF intervals. This auto-zeroing action makes U1103 seem to have perfect circuitry during each measurement cycle.

The A/Z interval begins at the end of the combined INT and REF intervals (1000 to 3000 clock cycles) and ends when the internal clock counter circuits increment from 3999 to 0000. A new INT interval begins and the measurement cycle repeats.

The only component parameters that have an effect on this circuit's measurement performance are the long-term stability of the reference voltage (after calibration), any temperature-induced changes in this voltage (high-stability components are used), the leakage resistance of C1105 and C1106 (which is very large), and any stray leakage currents on the circuit board (which has a very high resistance coating). These all combine to provide a very stable measurement circuit.

A/D DISPLAY and SUPPLY VOLTAGE CIRCUIT

As you can see from the Schematic, numeric LED displays V1201 through V1205 are powered from the +4 volt supply. Each display segment that is connected to U1103 is returned (pin 21) to the power supply ground through current-regulating drivers (FET's) inside U1103. This display drive technique minimizes variations in brightness for any +4-volt supply variation.

Decimal numbers are shown on V1201 to V1203 as lighted combinations of the seven segments, while V1204 contains a 1 that is continuously lighted through resistors R1135 and R1136. A signal coming from U1103 (pin 19) is applied through Q1105 (which will be explained later) and biases Q1106 on for displays between 000 and 999. This signal, through resistors R1131 - R1134, produces 0 (C and 1) in display V1204 so the display can indicate 0000 through 0999. For displays greater than 0999, the signal from pin 19 is applied through Q1105 to Q1106 and turns Q1106 off. This causes V1204 to display a 1 for displays 1000 through 1999.

Display V1205 has a segment that can indicate a negative value. Pin 20 (SIGN) of U1103 directly drives this segment, which is also driven by the auxiliary minus (−) driver. (The auxiliary minus driver and decimal point circuitry will be described later.)

The measurement circuits of U1103 are powered (VDD at pin 1) by the +5-volt supply, which is filtered by C1109, and by the −5-volt supply (pin 26), which is filtered by C1107. The internal digital supply voltage (V_{DD} to test) is filtered by C1108.

A/D AUTO-REFERENCE CIRCUIT (U1101 & U1102)

Earlier in this circuit description, a simplified reference voltage circuit was described. Pictorial 9-8 (Illustration Booklet, Page 24) shows the actual circuitry. The following paragraphs describe the operation of the auto-reference circuit for both Time and Frequency (FREQ) functions.

For T (time) measurements, auto-ranging circuits (described later) apply a +0.1V or a +1.0V reference voltage (V_R) to the auto-reference circuit. Since these voltages are both positive, the output of U1101A is driven fully positive (resistors R1102 through R1104 have little effect). This positive voltage is applied to U1101B and causes its output to be driven fully negative (resistors R1105 through R1107 have little effect).

The positive output of U1101A causes the U1102 plus (+) switches to be closed and the negative output of U1101B causes the minus (−) switches to be open. This connects pin 36 (REF HI) of U1103 to the +0.1V or +1.0V reference voltage and connects pin 35 (REF LO) to the A/D ground. Capacitor C1101 filters the reference voltage at U1103.

During time measurements, the reference voltage applied to the auto-reference input is the Δ Delay-related time voltage (V_T) which is applied to pin 31 (IN HI) of U1103. As was described earlier, this is either ± 2.0, 1.0, or 0.5 volts for 10 divisions of cursor separation on the corresponding A Timebase switch settings.

For $\frac{V_{IN}}{V_{REF}} \times 1000$, this develops:

$$\frac{2.0}{1.0} \times 1000 = 2000, \text{ or } \frac{1.0}{1.0} \times 1000 = 1000,$$

$$\text{or } \frac{0.5}{1.0} \times 1000 = 500$$

display counts. For a V_{IN} that is 1/10 of these, the +0.1 volt reference also produces 2000, 1000, or 500 counts.

For F (frequency) measurements, the SW1001/SW1002 switch circuitry shown in Pictorial 9-8 applies the 0.1 or 1.0-volt reference voltage to the IN HI (V_{IN}) input and the (variable) time voltage (V_T) to the auto-reference circuit input. For positive time voltages, the voltages at U1101 and the switches in U1102 are the same as before. This function does, however, invert the equation for display counts. Therefore, for the 2.0, 1.0, or 0.5-volt "time" voltages and the +1.0-volt reference voltage, the display count is

$$\frac{1.0}{2.0} \times 1000 = 500, \text{ or } \frac{1.0}{1.0} \times 1000 = 1000,$$

$$\text{or } \frac{1.0}{0.5} \times 1000 = 2000$$

This is the method used to convert time measurements to frequency measurements.

During negative time voltages, the output of U1101A is driven fully negative and the output of U1101B is fully positive. This opens the plus (+) switches and closes the minus (−) switches. Pin 36 (REF HI) is now connected to A/D ground and pin 35 (REF LO) is connected to the negative time voltage. This circuit action thus always maintains the REF HI to REF LO voltage as positive.

For positive time voltages decreasing toward zero, the negative voltage at pin 7 of U1101B causes pin 2 of U1101A to be slightly negative due to the R1106/R1103 voltage divider. When the time voltage also becomes slightly negative, the outputs of U1101A and B quickly change polarity and the voltage at pin 2 becomes slightly positive. This "hysteresis" voltage speeds the change in polarity by reinforcing the input polarity change.

For the frequency function, both the V_{IN} and V_{REF} polarities are positive at U1103 for either time voltage polarity. The SIGN output (pin 20) is off (pulled to +5-volts by a weak current source in U1103). To indicate a negative voltage at the auto-reference input, the positive voltage at the output of U1102B (through R1126) biases auxiliary driver Q1101 on and lights the minus (−) segment of V1205 (through R1127).

For VDC functions, the V_{REF} voltage is either +0.1 or +1.0 volt. This voltage is provided by circuitry that will be described later. The auto-reference circuit operates accordingly.

As a result of the auto-reference circuit operation, the REF HI to REF LO voltage is always positive and is 0.1 or 1.0 volt, or the time voltage. During the A/Z interval, the A/Z switches within U1103 connect C1104 to the REF HI and REF LO inputs, and C1104 charges (+ at pin 34 to − at pin 33) from the V_{REF} input. During the REF interval, either the +REF switches are closed, which connect C1104 directly as a positive voltage source to the buffer input, or the −REF switches close and connect C1104 upside-down as a negative voltage source. This operation provides the required positive or negative reference voltage for the internal circuitry in U1103, as was described earlier.

If U1101 is removed form the circuit, resistors R1104 and R1107 establish a positive (+) switch condition in U1102.

A/D AUTO-RANGING CIRCUIT (U1121 & U1123)

When higher or lower A/D sensitivity is required on any range, overrange and underrange signals must be generated. Overrange is automatically defined by U1103, which lights a 1 in V1204 and blanks V1201 through V1203. An underrange level is set by the circuitry for any display less than 100 counts. If a more sensitive range is available, this maintains at least a 1% (1 in 100 counts) display resolution. These signals are not directly available from U1103 and must be decoded from the outputs of the display segments.

If a display segment is off, circuitry within U1103 pulls the segment to +5 volts. When the segment is on, however, the voltage drop across the LED (approximately 1.7 volts, from the +4-volt supply) and results in a segment output voltage (from U1103) of approximately +2.5 volts. The on and off states of 3B, 3E, and 3G segment outputs applied to V1203, and the (combined) B and C segment outputs (4BC) are decoded to provide up-range (display greater than 1999) and down-range (display less than 100) signals. Since the 4BC output does not drive the LED segment directly, its low is 0 volts.

In the Q1102 to Q1105 translator circuits, the bases of the transistors are held (through one of the resistors in RP1103) at +3.0 volts. For a +5-volt segment output voltage, the corresponding transistor is biased on and its collector is at +5 volts. For a +2.5-volt (or 0 volt) segment output voltage, the transistor is off and the collector circuit is pulled to −5 volts (through one of the resistors in RP1102). This level sensitive operation provides the 3B, 3E, 3G, and 4BC logic signals to U1121.

The 3B and 3G signals at the inputs of U1121A are high **only** if V1203 is blanked, since one or both of these segments is lighted for 0 through 9. A low at the output of U1121A is the required up-range signal. Resistor R1141 and capacitor C1112 provide a small amount of noise filtering.

The output of U1121B is high whenever 3E is low (the e segment in V1203 is lit). When this occurs with a high at 4BC and 3G (the g segment in V1203 and the 1 segment in V1204 are not lit), the display number must be 0099 or less. This produces a low at the output of U1121C, which is the required down-range signal. Resistor R1143 and capacitor C1114 provide filtering for a glitch that occurs at the inputs of U1121C because U1121B delays the 3E signal so it cannot be decoded simultaneously with the 3G and 4BC signals.

Since the up-range and down-range conditions cannot both occur at the same time, only one of the outputs of U1121A or U1121C is low at any time. U1122A and U1122D are used only for EXT VDC function, which is described later.

The state of the outputs of the latch circuit formed by U1123B and U1123C depends upon whether an up-range or down-range signal occurred last. The output of U1123B goes high when an up-range occurs, and stays high by the action of the latch. The output of U1123C goes high and stays high when a down-range occurs. These outputs are normally complimentary and not high together. When power is first applied to this circuitry, a low coming from C1116 causes the latch (and other latching circuitry) to reset. Resistor R1153 charges C1116 within 1.0 second to enable the circuit. Diode D1103 quickly discharges C1116 when the power is turned off.

For time (and VDC) measurements, the display count is proportional to the V_{IN} input. For fullscale measurements, the A/D sensitivity is 2 volts and the V_{REF} voltage is 1.0 volt. When the V_{IN} voltage decreases to 0.1 volt, the display count is 0100. Autoranging to a 0.2 volt A/D sensitivity (with a V_{REF} of 0.1 volt) would improve resolution to 1000 counts. For the time (and VDC) function, the $\overline{F}$ signal is high and Q1114 is off. The control input to U1122B (pulled to −5 volts by R1147) causes it to be open and the SC (sensitivity control) signal comes from the output of U1123C (R1146 has little effect). This is the output that goes high when a down-range signal occurs and is now used to cause the sensitivity of the A/D circuit to be 0.2 volts (this will be described later). Later when an up-range occurs, the outputs of U1123B and U1123C reverse and the SC signal becomes low. This causes the sensitivity of the A/D circuit to be 2 volts.

For the frequency (FREQ) function, the display count is inversely proportional to the time voltage at the input of the auto-reference circuit. A full-scale input again requires a 1.0-volt reference voltage, but when the time voltage decreases, the display count increases. Therefore, when overrange occurs and an up-range signal is generated, the high at the output of U1123B must make the sensitivity of the A/D circuit 0.2 volts.

For the frequency function, the $\overline{F}$ signal is low and Q1114 (through R1145) is biased on so it has +5 volts on the collector. This causes U1122B to be closed and the SC signal comes directly from the output of U1123B, which overrides any signal from the output of U1123C. This provides the required opposite control operation.

This completes the description of the A/D measurement, reference, and auto-ranging circuitry. The input, scaling, and reference circuitry for the individual functions are described next.

DTP VOLTAGE FOLLOWER CIRCUITS (U1003)

Voltage from the DTP control is applied to pin 3 of U1103 and is filtered by R1016 and C1005. Resistor R1017 and capacitor C1007 provide AC and DC feedback to pin 2 of this unity-gain circuit. Capacitor C1008 provides a high degree of AC and noise filtering at the output, while R1018 decouples this high capacitance from the output of the operational amplifier. Capacitor C1006 provides frequency compensation.

Δ DELAY BRIDGE CIRCUIT

This circuit is formed by U1004A, U1004B, R1028, and SW1006 and their associated circuitry. Except for polarity, the circuits for U1004A and U1004B are identical.

For the U1004A positive current source, R1011 and R1012 divide the +15-volt supply to provide 2.5 volts across R1011, which is applied to the IC at pin 3. Current through R1015 produces a proportional voltage drop that is applied at pin 2. The output of U1004A (pin 1) biases Q1009 (through R1014) to maintain equal input voltages at pins 2 and 3. This maintains the current through Q1009 at a constant value and is independent of the collector voltage of Q1009. The circuit formed by Q1011 operates in an identical manner, with R1025 providing a slight adjustment of the negative current source versus the DTP voltage.

Transistors Q1009 and Q1011 drive R1026/R1027 which are in parallel with R1028 (when SW1006 is on). Any voltage change at the junction of R1026 and R1027 directly changes the voltage at each end of R1028 by the same amount. This makes R1028 appear to be connected to isolated batteries as was mentioned earlier.

The above description shows how "tracking" cursor voltages are provided. When SW1006 is off, R1028 is connected to fixed 0 volt and +6-volt levels and the Δ Delay cursor can be set separately from the DTP cursor.

Δ DELAY VOLTAGE FOLLOWER CIRCUIT (U1005)

The Δ Delay voltage from R1028 is filtered by R1033 and C1009 before it is applied to pin 3 of U1005. Resistor R1034 provides impedance matching feedback (equal to R1033) in this unity-gain circuit. Capacitor C1011 provides frequency compensation. For low DTP voltages, the Δ Delay voltage can be negative, although this is an abnormal input to the Oscilloscope's B Comparator. Higher negative voltages are clamped by D1003 at pin 3. The output of U1005 is applied to one side of the electronic switch circuit formed by U1007 and the T and F scaling circuit.

ELECTRONIC SWITCH CIRCUIT (U1007 & U1008)

The Δ Delay and DTP voltages are the inputs to this circuit. R1042, C1014, C1015, and D1004 provide filtering for the Δ Delay voltage and clamp against any negative voltages. R1043, C1016, C1017, and D1005 provide the same function for the DTP voltage. For time and frequency measurements, either switches U1007A/U1007D or switches U1007B/U1007C alternately close and apply a two-level square-wave voltage to pin 3 of U1008. The feedback circuitry for U1008 is self-contained and the output (pin 6) is equal to the two-level input and drives the input of the B Comparator through R1009 and C1004. This circuit provides a slight delay on the overshoot at the output of U1008 for the fastest settings of the A Timebase switch.

Flip-flop U1002A receives a cursor toggle pulse (through the noise filter formed by R1001 and C1001) at the end of each sweep of the A Timebase. The Q and $\overline{Q}$ outputs (pins 15 and 14) drive switch driver circuits Q1007 and Q1008 through speed-up networks C1002/R1004 and C1003/R1005. These transistors invert and level shift the 5-volt TTL outputs of U1002A to drive the +15-volt U1007 circuitry.

For the time and frequency functions, the T and F control signals, which are coupled through D1001 or D1002, enable the U1002 circuit by applying a high at pin 3. When neither of these signals is high, R1003 pulls pin 3 low and causes U1007 to continuously select the DTP voltage to drive the input of the B comparator. The parallel connection of U1002A and U1002B has no effect on circuit operation.

T & F SCALING AND GAIN-SELECT CIRCUIT (U1006)

The voltage difference between the Δ Delay and DTP voltages for 10 divisions of cursor separation is approximately ±5.5 volts. To display this as either 2000, 1000, or 500 counts, the voltage difference is divided by resistors R1035 through R1039. R1035 provides a coarse adjustment, while R1036 through R1039 are high precision parts. One of the U1006B, C, or D (GAIN) switches is closed for each position of the A Timebase switch. This provides the 2.0, 1.0, or 0.5 time voltages (V_T) to switches SW1001 and SW1002.

T & F REFERENCE SOURCE CIRCUIT (U1013 through U1016)

Circuitry inside U1013 (biased by R1058) provides a high-stability zener voltage of 1.2 volts, which is bypassed by C1028. This is applied to the divider circuit formed by R1059 through R1065 and provides three separately adjustable 1.0-volt outputs. One of these outputs is switched through U1014B, C, or D to the U1015A circuit. The voltage selected depends upon the setting of the A Timebase switch. In the Oscilloscope's A Timebase sweep circuitry, there are a series of precision timing resistors that are used in a repeated fashion for each of the three timing capacitors (CA, CB, or CC). The 1.0-volt output that is switched to U1015A corresponds to the timing capacitor (CAP) for the present setting of the A Timebase switch.

The input voltage to U1015A, is filtered by R1067 and C1029, and is buffered to provide a low-impedance 1.0-volt output to R1071 through R1074. R1068 provides unity-gain feedback, while D1006 allows only positive voltages to be applied to U1016. The voltage divider circuit provides either 1.0 volt directly at R1071, or 0.1 volt at the wiper of R1073 as a reference voltage to the A/D circuitry. R1073 provides a calibration for low time voltages (or high frequency displays).

When a 1.0-volt V_{REF} is required by the A/D circuit, the SC control signal is at −5 volts. This negative voltage is applied to U1015B (pin 5) through R1079 and causes the output at pin 7 to be fully negative. D1007 is reverse-biased and U1016D is open, with 0 volts at pin 12 (pulled low by R1076). The low at pin 13 causes U1016A to be open. When U1016D is open, R1075 pulls pin 5 of U1016B to +15 volts, which closes U1016B and applies 1.0 volt (V_R) to SW1001 and SW1002.

When a 0.1 volt V_{REF} is required by the A/D circuit, SC is at +5 volts and the circuit formed by U1015 and U1016, with opposite logic levels, selects the 0.1 volt reference from U1016A to SW1001 and SW1002.

CAP/GAIN ROM CIRCUIT (U1001)

Each position of the A Timebase switch has separate conditions as to which timing capacitor is selected and which full-scale count (2000, 1000, or 500) is applicable. To control the necessary U1006 and U1014 switches, the A Timebase switch provides BCD (binary coded decimal) logic signals to the inputs of U1001. Each input state causes a programmed output state to drive Q1001 through Q1006.

When one of the outputs of U1001 (Q1 through Q6) is high (actually open-circuited), the associated resistor in RP1001 biases the transistor fully on. The low at the collector causes the associated U1006 or U1014 switch to be open. For a low at the output of U1001, the transistor is off and the associated resistor in RP1002 pulls the switch control input to +15 volts and closes the switch.

The BCD signals from the A Timebase switch also control other circuitry to provide the proper decimal point and indicators as described later.

TIME & FREQ FUNCTION SWITCHING

For the selected function, switch SW1001 or SW1002 does four things. First, it provides the appropriate T or F control signal to U1002 and an input to the decimal point and indicator circuitry. Second, it applies a voltage to the A/D input (V_T for time and V_R for frequency). Third, it applies a voltage to the auto-reference circuit (V_R for time and V_T for frequency). And last, both connect the A/D ground circuit to the output of U1003 (TPA) which provides a zero voltage level to which the A/D measurements are referred.

VDC (internal) BUFFER CIRCUIT (U1011 & U1012)

As was previously described, all DC voltages at the Y1 and Y2 Oscilloscope inputs are scaled by the attenuators and buffered by the split-path amplifier. The voltages from these circuits are then applied to U1011 and U1012. Since each circuit is identical, only the circuitry of U1011 will be described.

The DC voltage to be measured may have a substantial amount of AC superimposed on it. This is filtered at the output of the split-path circuit and by R1044 and C1018. U1009A provides an additional, very high, degree of filtering action to provide a stable measurement display. U1009A operates with 0 volts of DC at its output (R1046 provides unity-gain feedback) and has a very high AC gain. Any AC voltage at pin 3 of U1011 is AC-coupled through C1019 to pin 2 of U1009A. The output of U1009A, through C1021, provides any AC current required to counteract AC voltage at the input of U1011. This circuit operates with a high degree of filtering for frequencies above 20 Hz.

U1011 is an FET-input buffered operational amplifier that has very high input impedance. Therefore, the voltage to R1044 is not reduced by R1044 and R1045. The DC gain of the split-path amplifier may not be unity and may also have a DC offset (with the AC-GND-DC switch set to GND). R1047 (the Y1 Zero control) allows the output of U1011 to be 0 volts for 0 volts from the attenuator and corrects for any Oscilloscope or Module offset. R1048 (the Y1 CAL control) provides control of the feedback for U1011 and allows a gain adjustment range (1.0 to 1.11) to correct for non-unity-gain in the split-path amplifier.

One of the outputs from U1011 or U1012 is selected by SW1005 (CHAN), filtered by R1057, C1025, and applied to SW1003.

VDC (internal) DATA SELECTOR CIRCUIT (U1017)

For each Oscilloscope attenuator ratio (× 1, × 10, or × 100), a two-bit BCD code is provided to the switches in U1017. When the Y1 input is selected by SW1005, switches U1017B and C are closed and connect the inputs of Q1012 and Q1013 to Y1A and Y1B. When either or both are low, Q1012 and/or Q1013 are on and apply +5 volts on the $\overline{YA}$ and $\overline{YB}$ outputs. When the signals at Y1A and/or Y1B are high (actually open-circuited), the pull-up action of R1082 and R1084, along with resistors in RP1003, cause Q1012 and/or Q1013 to be off (open circuit at $\overline{YA}$ and/or $\overline{YB}$). R1086 and R1087 provide the pull-down functions for the Y1 and Y2 control signals.

Along with the $\overline{YA}$ and $\overline{YB}$ signals, direct voltages from SW1005 (Y1) and SW1004 (x 10) are provided to the circuits that control the decimal points and indicators. These are described later.

Switch circuit SW1003 connects the selected Y1 or Y2 voltage to be measured to the A/D input. It also connects a reference voltage (+0.1 or 1.0 volt) to the auto-reference circuit. Last, it connects the A/D ground to the Oscilloscope (earth) ground. The source of the reference voltage is described later.

TIME, FREQ, & VDC (internal) POWER SUPPLIES

The input, control, and switching circuitry for these functions are all powered by +15 volts, −15 volts, and +5 volts coming from the power circuits in the Oscilloscope. L1001 through L1004 and C1031 through C1064 decouple and filter these supplies to prevent interference to and from the Module circuits.

EXT VDC ISOLATION CIRCUITS

To make floating DC voltage measurements, it is necessary to completely isolate and electrically separate the A/D circuitry from the Oscilloscope circuitry. This is accomplished by SW1007 and optoelectric isolator ICs U1106 through U1111 and U1113 through U1118. These ICs contain an LED and optotransistor which are electrically isolated from each other. When current is applied to the LED (limited by resistors RP1004 through RP1006), the light that is emitted energizes the base junction of the transistors and it is biased on. By using these ICs, the BCD signals from the A Timebase switch, the T and F control signals, and the $\overline{YA}$, $\overline{YB}$, Y1, and × 10 signals are transmitted to the A/D circuitry.

For the EXT VDC function, the V_T, V_R, V_Y, V_L, and SC signal circuits are all opened and isolated. The IN and COM inputs are connected into the A/D circuitry.

The optoisolator, switch, and foil separation of the A/D circuitry allows the A/D ground to float as much as 500 volts from Oscilloscope (earth) ground.

The section of SW1007, which open-circuits the LEDs in U1113 through U1118, provide a special circuit condition that is described later.

VDC (internal) & EXT VDC REFERENCE CIRCUIT (U1104 & U1105)

For a floating A/D circuit, a separate reference circuit is required. U1104 is a high-stability, 1.2-volt zener (like U1013) that is biased by R1114 and then applied to the voltage divider formed by R1117 through R1124. This circuit provides +0.1 or +1.0 volt at U1105A and B. The U1104 voltage is bypassed by C1111.

When the SC signal is high (+5 volts), U1105B is closed to connect +0.1 volt to the input of the auto-reference circuit (through SW1007). U1105D is also closed and connects a low (−5 volts) to pin 13 of U1105A to make it open. The high from SC causes U1105C to close across resistor R1112 and, with the 0.1-volt V_{REF}, establishes a 0.2-volt A/D sensitivity.

When the SC control signal is low (−5 volts), U1105D is open and U1105A is closed with its control input pulled to +5 volts by R1125. U1105B and C are both open, and the A/D circuit has a sensitivity of 2 volts.

Note that a high on the control input of U1105C causes it to close across R1112 whenever the SC signal is high for any function (not just for the VDC functions).

For testing purposes, the A/D jumper can be set to +5 volts or to −5 volts so you can manually set the A/D sensitivity to 0.2 volts or 2 volts.

The resistors in the voltage divider formed by R1115 and R1116, along with U1104, were temperature-aged and factory-measured to provide built-in calibration voltages at the HI CAL and LO CAL test points.

EXT VDC DIVIDER CIRCUIT (RP1101)

DC voltages from the IN socket are applied to the voltage divider formed by RP1101 and R1101 to provide a tap point at pin 5 that is 1/10 the input voltage. For A/D sensitivities of 0.2 volt and 2 volts, this provides EXT VDC ranges of 2 volts and 20 volts. The tap point at pin 3 is at 1/1000 of the input voltage. For A/D sensitivities of 0.2 volt and 2 volts, this provides EXT VDC ranges of 200 volts and 2000 volts (limited to 1000 volts). The A/D input is connected through SW1007, the CAL jumper, and one of the contacts of K1101 or K1102 to a divider tap point. K1102 is closed on the 2 volt and 20 volt ranges and K1101 is closed on the 200 volt and 2000 volt ranges.

The CAL jumper allows you to directly connect the A/D input to the LO CAL and HI CAL test points for calibration of the 0.2-volt and 2-volt sensitivities.

EXT VDC RELAY CIRCUIT

Transistors Q1107 to Q1109 drive relays RY1101 and RY1102. When you select the EXT VDC function, Q1107 is biased on (by circuitry that will be described later) and +5 volts is applied to RY1101 and RY1102. On the 2-volt and 20-volt ranges, the HV signal from U1124B is low and Q1108 is off. This allows current to flow (below the activation level for RY1101) through RY1101 and RP1104 (7 and 8) to Q1109 and biases it on, which energizes RY1102 and K1102 is closed. On the 200 volt and 2000 volt ranges, the HV signal is high and Q1108 is biased on (through RP1104 4 and 3). This energizes RY1101 and closes K1101, while it shunts the base circuit of Q1109 and turns it off.

D1101 and D1102 provide switching transient protection from RY1101 and RY1102 to Q1108 and Q1109.

EXT VDC RELAY AUTO-RANGING CIRCUIT (U1124)

For the EXT VDC function, the 2 volt range is initially established with K1102 closed and the A/D has a sensitivity of 0.2 volt. When a voltage between 2 volts and 20 volts is applied between the IN and COM jacks, the 0.2 volt sensitivity is overranged and the 2 volt sensitivity is selected by U1121 and U1123 B and C. When a voltage greater than 20 volts is applied, the 2 volt sensitivity becomes continuously overranged. The up-range (low) signal from U1121A pin 9 causes U1122A to open. C1113 was previously held at −5 volts (discharged) when U1122A was closed, but now charges towards +5 volts through R1142.

The low at pins 3 and 4 of U1123B causes a high at pin 6 (and at pin 11). With pins 12 and 13 also high, pin 10 goes low to select the 2-volt sensitivity. With the HV signal being low, the LV signal is high at pin 8 of U1124A. When C1113 causes pin 2 to reach a high level, all three inputs of U1124A are high and causes the output at pin 9 to go low. This forces a high at the output of U1124B (HV), which selects the 200 volt and 2000 volt ranges. With U1122D closed, pin 2 of U1123A is low and its output is high. When all inputs of U1124C are high, its output goes low and reinforces the high output at U1124B.

The 2 volt A/D sensitivity and the HV ranges that are selected just after U1124B and C latches provides the 2000-volt range. The overrange condition is no longer present and U1122A again closes to discharge C1113 and stabilize the display. If the display is greater than 100 counts (100 volts), no further change occurs. If the display is now less than 100 counts, the down-range signal at pin 10 of U1121C latches U1123B and C to select the 0.2-volt A/D sensitivity, which provides the 200-volt range. The down-range low signal at U1122D (which causes it to open) is not present long enough to allow C1115 to charge and affect the U1124B/C circuit.

When you remove the input voltage, the low down-range signal at U1121C is continuous, U1122D is open, and C1115 is charged through R1144. When it reaches a high level, this combines with the high levels at the other inputs of U1123A to latch the circuit in the original state, with a low at HV. Latch circuit U1123B and C then control the A/D sensitivity to select the 2-volt or 20-volt range as required.

Shorting the SET HV pins together provides a means to manually establish the HV signal, by applying a low to pin 3 of U1124B. R1148 prevents shorting the output of U1124A.

Resistors R1149, R1151, and R1153 establish legal input voltages if U1123 or U1124 is removed from the circuit.

T & F ROM CIRCUIT (U1112)

On all of the ranges of the Module functions, U1103, Q1101, and Q1106 provide display numbers from 0000 to ±1999. So that you can read the display directly, a decimal point and other indicators (as required) must also be lit.

The BCD signals from the A Timebase, as described earlier, are coupled through optoisolators U1106 through U1111 as a logical low (the transistor is on) to the inputs of U1112, for any low TBA to TBE. In addition, the T and F control signals are coupled through U1113 and U1114 as the complementary $\overline{T}$ and $\overline{F}$ signals to U1112. Finally, the SC control signal is applied (through the translator formed by U1122C and Q1113, which is described later) to the remaining input to U1112. Six resistors in RP1105 and two resistors in RP1106 provide pull-ups for the inputs of U1112.

At full scale for the time and frequency functions, on each of the A Timebase switch settings, a specific placement of the decimal point and correct indicator lighting is required. In addition, for close cursor spacing, the decimal point in the display must be shifted. These display elements are powered by a low level at the outputs of U1112, through one of the resistors in RP1107 or RP1108. When any of these outputs is not selected, it is an open circuit.

For the time and frequency functions, the Q8 output of U1112 is high (pulled to +5 volts by RP1105-1/8). This disables U1119 so all of its outputs are open-circuited and do not interfere with the outputs of U1112. The decimal outputs of U1112 (Q1 through Q4), which are connected to V1205 through V1202, light the decimal-point segments when they are low.

The indicators for the time and frequency functions are separately enabled by Q1111 (for time) and Q1112 (for frequency). For example, on the time function, Q1111 is on (biased through R1137) and +5 volts is applied to only the time indicators. No current can flow in the frequency indicators. A low at Q5, Q6, or Q7 output of U1112 lights the "s" (V1211), the "ms" (V1212), or the "µs" (V1213) indicator through one of the resistors in RP1108. Q1112 operates in the same manner for the frequency function to enable the "Hz" (V1214), the "kHz" (V1215), or the "MHz" (V1216) indicators via the Q5, Q6, and Q7 outputs of U1112.

The translator circuit formed by U1122C and Q1113 interfaces ±5 volt logic levels to +5-volt TTL levels. When SC is low (−5 volts), U1122C is open and Q1113 is biased on (low collector voltage) by R1139. When SC is high (+5 volts), U1122C is closed and Q1113 is off. RP1104 pulls the collector circuit to +5 volts. TPD provides a means to manually test the action of the Q1113 circuit.

VOLTS ROM CIRCUIT (U1119)

When neither the time or frequency function is selected, the $\overline{T}$ and $\overline{F}$ signals are both high. This disables both of the Q1111 and Q1112 circuits and also results in an output state of U1112 where the Q1 through Q7 outputs are all off (open circuited) and the output of Q8 is low, which enables U1119.

On the VDC (internal) function, a low is always present at the output of either U1115 or U1116. This prevents the logic extender circuitry formed by Q1115 through Q1117 from affecting the inputs of U1119 (as is explained later), and you can ignore this circuit. The SC-related signal, and the signals from U1115 through U1118, control the inputs of U1119. These inputs cause the VDC (internal) indicators to be powered from the outputs of U1119 (through RP1109) as follows:

A low x10 input to U1118 causes U1112 to light the x1 indicator (from the Q5 output) and a high causes it to light the X10 indicator (from the Q6 output).

A high Y1 input to U1117 causes U1119 to light the Y1 indicator (from the Q7 output) and a low causes it to light the Y2 indicator (from the Q8 output).

The $\overline{YA}$, $\overline{YB}$, x10, and Y1 signals are coupled through U1115 through U1118, and are combined with the SC-related signal from Q1113 to light the correct decimal point. This is based upon the setting of the Volts/Div, Probe, and Chan switches and depends upon the input voltage at Y1 or Y2. The Q1 through Q4 outputs of U1112 do not interfere with the outputs of U1119.

For the EXT VDC function, a special condition at the outputs of Q1113 through Q1118 occurs when SW1007 open-circuits all of the LED's in these circuits. This allows the resistors in RP1106 to pull all six outputs high. C1117 bypasses the $\overline{F}$ output so any common-mode voltage on this function does not affect U1114.

When the outputs of U1115 and U1116 are both high, Q1116 and Q1117 (in the logic extender circuit) are both biased on. This pulls RP1104-2 low, biases Q1107 on, and enables the Q1108 and Q1109 circuitry. Since the emitter of Q1115 is now grounded, the A4 input of U1119 can be controlled by Q1115. Since the A1 to A3 inputs are all fixed high, the combinations of the HV-related signal at A4 with the SC-related input at A5 determines the four decimal point conditions for the EXT VDC function. The decimal point at V1204 for 2 volts, at V1203 for 20 volts, at V1202 for 200 volts, and no decimal point is lit for 2000 volts.

D1104 prevents any reverse current flow from Q1115 into U1118 on the VDC (internal) function.

A/D CIRCUITRY POWER SUPPLY CIRCUIT (U1125 and U1126)

To allow you to make floating measurements, a separate oscilloscope power transformer winding is connected to the Module through P1101.

The full-wave circuits formed by diodes D1105 to D1108 rectifies the AC voltage. The positive half cycles through D1105 and D1106 charge capacitors C1121 and C1122 to approximately +8.3 volts DC. The negative half cycles through D1107 and D1108 charge capacitors C1124 and C1125 to approximately −8.7 volts DC.

The +8.3-volt DC supply is reduced and regulated by U1125 to provide +5 volts DC which is filtered by C1123. Similarly, U1126 regulates the −8.7-volt DC supply to −5 volts DC which is filtered by C1126.

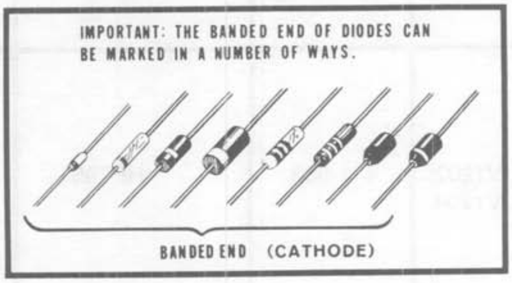
For testing purposes, the "+" and "−" solder pads allow you to disconnect the regulator circuits from the +5 and −5 volt loads. C1127 to C1144 bypass the +5-volt and −5-volt supplies.

The +5-volt supply is reduced by the voltage drop in D1109 to provide the +4-volt supply. This voltage lowers the power dissipation in U1103 for a high-segment display. The +4-volt supply also provides power to the time, frequency, and VDC (internal) indicator circuits. When you push the Off switch, the +4-volt supply to the display is opened to turn it off.

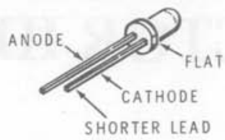
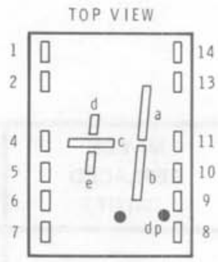
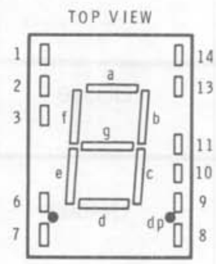
A voltage divider formed by resistors R1157 and R1158 is connected across the +4-volt supply to provide a +3-volt supply. This supply provides bias for the level-sensitive Q1102 to Q1105 circuitry.

SEMICONDUCTOR IDENTIFICATION CHART

DIODES

CIRCUIT COMPONENT NUMBER	HEATH PART NUMBER	MAY BE REPLACED WITH	IDENTIFICATION (TOP VIEW)
D1001, D1002, D1003, D1006, D1007, D1101, D1102, D1103, D1104	56-56	1N4149	
D1004, D1005	56-89	GD510	
D1105 – D1109	57-65	1N4002	

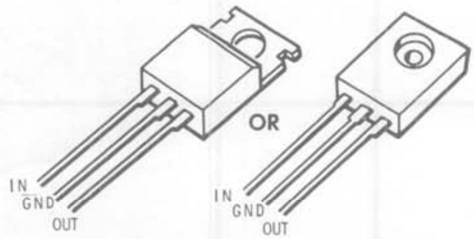
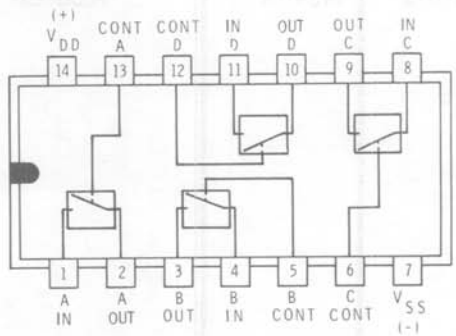
DISPLAYS

CIRCUIT COMPONENT NUMBER	HEATH PART NUMBER	MAY BE REPLACED WITH	IDENTIFICATION (TOP VIEW)
V1206, V1207, V1208, V1209, V1211, V1212, V1213, V1214, V1215, V1216	412-654	HLMP1002 (Selected)	 OR 
V1205	411-855	HP7656	 PIN CONNECTION 1. CATHODE d 2. ANODE d 3. NO PIN 4. CATHODE c 5. CATHODE e 6. ANODE e 7. ANODE c 8. ANODE dp 9. CATHODE dp 10. CATHODE b 11. CATHODE a 12. NO PIN 13. ANODE a 14. ANODE b
V1201, V1202, V1203, V1204	411-853	HP7651	 PIN CONNECTION 1. CATHODE a 2. CATHODE f 3. ANODE 4. NO PIN 5. NO PIN 6. NO CONN. 7. CATHODE e 8. CATHODE d 9. CATHODE dp 10. CATHODE c 11. CATHODE g 12. NO PIN 13. CATHODE b 14. ANODE

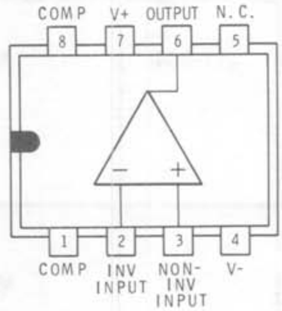
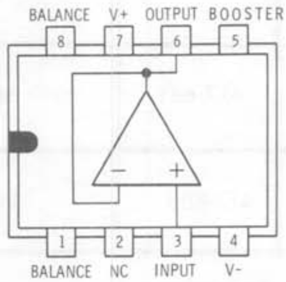
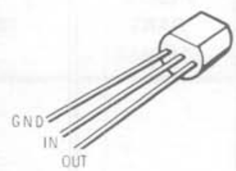
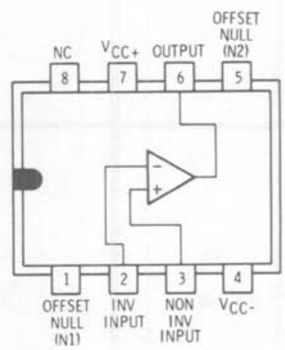
TRANSISTORS

CIRCUIT COMPONENT NUMBER	HEATH PART NUMBER	MAY BE REPLACED WITH	IDENTIFICATION
Q1001 – Q1008 Q1108, Q1109, Q1113, Q1115, Q1116, Q1117	417-864	MPSA05	
Q1012, Q1013, Q1102, Q1103, Q1104, Q1105, Q1107, Q1111, Q1112, Q1114	417-865	MPSA55	
Q1011, Q1101, Q1106	417-881	MPSA13	
Q1009	417-885	MPSA65	

INTEGRATED CIRCUITS

CIRCUIT COMPONENT NUMBER	HEATH PART NUMBER	MAY BE REPLACED WITH	IDENTIFICATION
U1125	442-54	UA7805	
U1006, U1007, U1014, U1016, U1017, U1102, U1105, U1122	442-99	CD4016AE	

Integrated Circuits (Cont'd.)

CIRCUIT COMPONENT NUMBER	HEATH PART NUMBER	MAY BE REPLACED WITH	IDENTIFICATION
U1103, U1105 1003, 1005	442-639	MLM308AN	
U1108 U1008	442-648	LM310	
U1126	442-665	79L05AC	
U1011, U1012	442-679	TL061CP	

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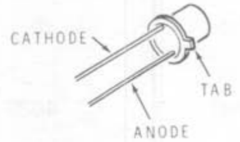
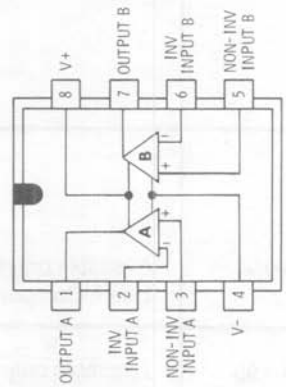
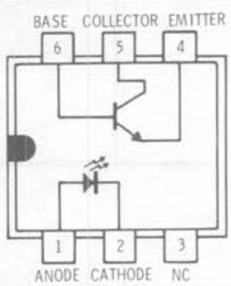
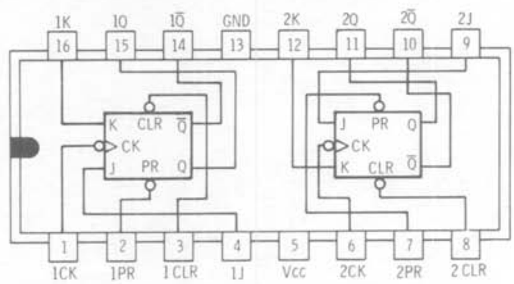
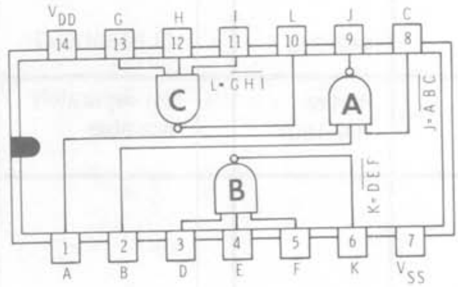
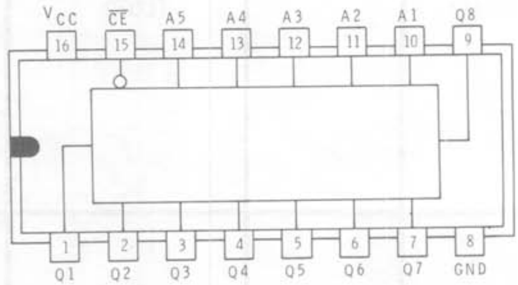
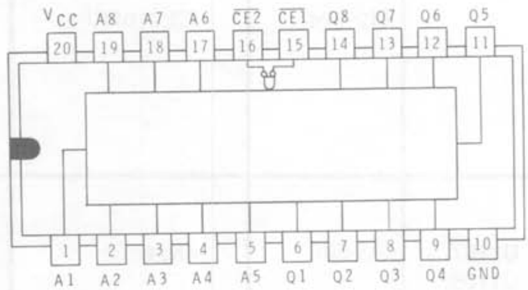
Integrated Circuits (Cont'd.)

CIRCUIT COMPONENT NUMBER	HEATH PART NUMBER	MAY BE REPLACED WITH	IDENTIFICATION
U1013	442-680	ICL8069DC Q	
U1104	Part of 100-1807	Not separately available	
U1004, U1009, U1015, U1101	442-707	LF353/ TL072	
U1103	442-724	ICL7107CPL	
U1106, U1107, U1108, U1109, U1111, U1113, U1114, U1115, U1116, U1117, U1118	443-808	4N26	
U1102	443-829	74LS76	

Integrated Circuits (Cont'd.)

CIRCUIT COMPONENT NUMBER	HEATH PART NUMBER	MAY BE REPLACED WITH	IDENTIFICATION (TOP VIEW)
U1121, U1123, U1124	443-887	4023	
U1001	444-194	Available only from Heath Company	
U1119	444-195	Available only from Heath Company	(same as above)
U1112	444-196	Available only from Heath Company	

CUSTOMER SERVICE

REPLACEMENT PARTS

Please provide complete information when you request replacements from either the factory or Heath Electronic Centers. Be certain to include the **HEATH** part number exactly as it appears in the parts list.

ORDERING FROM THE FACTORY

Print all of the information requested on the parts order form furnished with this product and mail it to Heath. For telephone orders (parts only) dial 616 982-3571. If you are unable to locate an order form, write us a letter or card including:

- Heath part number.
- Model number.
- Date of purchase.
- Location purchased or invoice number.
- Nature of the defect.
- Your payment or authorization for COD shipment of parts not covered by warranty.

Mail letters to: Heath Company
Benton Harbor
MI 49022
Attn: Parts Replacement

Retain original parts until you receive replacements. Parts that should be returned to the factory will be listed on your packing slip.

OBTAINING REPLACEMENTS FROM HEATH ELECTRONIC CENTERS

For your convenience, "over the counter" replacement parts are available from the Heath Electronic Centers listed in your catalog. Be sure to bring in the original part and purchase invoice when you request a warranty replacement from a Heath Electronic Center.

TECHNICAL CONSULTATION

Need help with your kit? — Self-Service? — Construction? — Operation? — Call or write for assistance. you'll find our Technical Consultants eager to help with just about any technical problem except "customizing" for unique applications.

The effectiveness of our consultation service depends on the information you furnish. Be sure to tell us:

- The Model number and Series number from the blue and white label.
- The date of purchase.
- An exact description of the difficulty.
- Everything you have done in attempting to correct the problem.

Also include switch positions, connections to other units, operating procedures, voltage readings, and any other information you think might be helpful.

Please do not send parts for testing, unless this is specifically requested by our Consultants.

Hints: Telephone traffic is lightest at midweek — please be sure your Manual and notes are on hand when you call.

Heathkit Electronic Center facilities are also available for telephone or "walk-in" personal assistance.

REPAIR SERVICE

Service facilities are available, if they are needed, to repair your completed kit. (Kits that have been modified, soldered with paste flux or acid core solder, cannot be accepted for repair.)

If it is convenient, personally deliver your kit to a Heathkit Electronic Center. For warranty parts replacement, supply a copy of the invoice or sales slip.

If you prefer to ship your kit to the factory, attach a letter containing the following information directly to the unit:

- Your name and address.
- Date of purchase and invoice number.
- Copies of all correspondence relevant to the service of the kit.
- A brief description of the difficulty.
- Authorization to return your kit COD for the service and shipping charges. (This will reduce the possibility of delay.)

Check the equipment to see that all screws and parts are secured. (Do not include any wooden cabinets or color television picture tubes, as these are easily damaged in shipment. Do not include the kit Manual.) Place the equipment in a strong carton with at least THREE INCHES of *resilient* packing material (shredded paper, excelsior, etc.) on all sides. Use additional packing material where there are protrusions (control sticks, large knobs, etc.). If the unit weighs over 15 lbs., place this carton in another one with 3/4" of packing material between the two.

Seal the carton with reinforced gummed tape, tie it with a strong cord, and mark it "Fragile" on at least two sides. Remember, the carrier will not accept liability for shipping damage if the unit is insufficiently packed. Ship by prepaid express, United Parcel Service, or insured Parcel Post to:

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