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RELIABILITY DEPARTMENT

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Evaluation Report

RELIABILITY DEPARTMENT

TEST REPORT TR 7-0024

J.P.L. Task No. 13

EVALUATION TEST PERFORMED BY

LIBRASCOPE RELIABILITY DEPARTMENT

ON

TEXAS INSTRUMENT SOLID CIRCUITS,

Types SN510, SN512, and SN515

VOLUME I OF III

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ABSTRACT:

The object of this test was to evaluate the effects of Thermal, Life and Mechanical environments on 60 Texas Instrument SOLID CIRCUIT Series 51 integrated circuits. The test specimens - i.e. - SN510, Flip Flop; SN512 "NOR" or "NAND" Gate; and SN515, "Exclusive "OR" Gate were subjected to the following environments:

Thermal Sterilization at 145°C for 3 cycles.
Thermal Cycling from 125°C to -55°C for 5 cycles.
Humidity per MIL-E-5272C (ASG) Procedure I.
High Temperature Operating Life at 100°C for 2000 hours.
High Vacuum Operating Life at 10^{-4} mm Hg for 500 hours.

Shock at 300 G's, 3 m sec, for 5 impacts in the X, Y and Z directions.
Vibration at 35 G's peak for 3 sweep cycles from 30 cps to 3000 cps in the X, Y and Z directions.

Certain measurement results during Thermal environments were analyzed by the 2^n factorial statistical method. Life environment measurements were analyzed to the JPL Specification ZPP 2040 GEN A statistical format. Results of this analysis are presented in Appendix B of the report.

All test specimens passed the thermal environmental tests with a minimum of parameter deviations recorded except units #8, #13 and #18 of the Type SN515 which failed to pass maximum parametric deviation criteria during the thermal cycling tests. It should be noted, however, that the specified units above met specification requirements supplied by the manufacturer and were functionally qualified units.

All test specimens passed the dual-sequential life test specified in this report. Indications of random errors in the operation of the units were observed but could not be traced to cause, due to limitations in test circuitry.

All test specimens passed the mechanical environmental tests specified in this report.

Test specimens Units #1,#2,#3,#4,#5,#7,#8,#9,#11,#12,#14,#15 and #20 of Type SN510 and Units #8,#10,#13 and #18 of Type SN515 failed to pass maximum parametric deviation criteria during the final measurements; however, the specified units above met manufacturers specification requirements and were all functionally qualified units.

Test specimen Unit #19 of Type SN510 failed initial tests because of internal bonding defects. Failure was judged to be the responsibility of the manufacturer.

It is concluded that the test specimens passed the environmental tests to which they were subjected. Further testing is recommended, particularly in the area of monitored active circuit environmental life tests.

1.0 INTRODUCTION:

1.1 Objective:

The objective of this test was to obtain qualifying information on the resistance of Texas Instruments Solid Circuit Networks to thermal, life and mechanical environments.

Investigated were the performance of three types of integrated networks (i.e. SN510, Diffused Silicon Bistable Network; S/N512, Diffused Silicon "NOR" or "NAND" Logic Network; and S/N515 Diffused Silicon "Exclusive OR" Network) when subjected to Thermal Sterilization, Thermal Cycling, Humidity, Mechanical Shock and Vibration environments. The specimens were also observed during life tests at high temperature and at vacuum environments.

1.2 Scope:

The test specimen sample size consisted of 20 each of the S/N 510, S/N512, and S/N 515 types. The test design was intended to subject a segment of the test specimens to a sequenced thermal environment of Thermal Sterilization, Thermal Cycling and Humidity; all test specimens to High Temperature Operating Life and High Vacuum Operating Life and lastly a segment of the test specimens to the mechanical environments of shock and vibration.

The tests were initiated on 12/1/62 and ended 11/29/63. All tests and measurements were performed at the Librascope Reliability Test Laboratory.

2.0 PARTS DESCRIPTION:

2.1 Electrical Characterization:

The electrical parameters designated as design parameters, characterize the operation of the integrated micrologic (single substrate) as a functional operational unit, as opposed to discrete component parameter measurements. The electrical parameters designated as failure analysis parameters are based on discrete component characteristics for unit malfunction analysis. The measurement parameters selected for each circuit are based on engineering judgement of the significance of these parameters to the areas of possible malfunction. Also, does the parameter yield sufficient information for analysis; and to indicate the mode or mechanism of such a failure.

The circuit diagrams shown for each device type reflect the measurement circuitry only. The selective switching for the test unit is shown as Appendix I. The parameters listed in paragraphs 2.2, 2.3 and 2.4 are characteristic of the units under test. They describe the mode or trends of operation of the unit, as detailed as the unit will permit. Therefore, these were the parameters selected to evaluate the units.

2.1.1 Electrical Measurement - Flip-Flop, S/N 510:

2.1.1.1 Design Parameters:

2.1.1.1.1 Minimum clock pulse voltage - V_{CP} Min.

2.1.1.1.2 Minimum set and reset voltages - V_S Min. and V_R Min.

2.1.1.1.3 Output Voltage - V_Q & $V_{\bar{Q}}$

2.1.1.1.4 Switching Times - t_r , t_f , t_s , t_d , t_f'

2.1.1.2 Failure Analysis Parameters:

2.1.1.2.1 Load Resistance - R_L

2.1.1.2.2 Leakage Current - I_R

2.1.2 Electrical Measurement - "NOR" or "NAND" S/N 512:

2.1.2.1 Design Parameters:

2.1.2.1.1 Output Voltage - V_G

2.1.2.1.2 Switching Times - t_r , t_f , t_s , t_d , t_f'

2.1.2.2 Failure Analysis Parameters:(Cont).

2.1.2.2.1 Leakage Current - I_{CBO}

2.1.2.2.2 Load Resistance - R_L

2.1.2.2.3 Current Gain - h_{FE}

2.1.2.2.4 Input Resistance - R_B

2.1.3 Electrical Measurement - Exclusive "OR" S/N 515:

2.1.3.1 Design Parameters:

2.1.3.1.1 Output Voltage - V_C, V_D, V_E.

2.1.3.1.2 Switching Times - t_r, t_f, t_s, t_d, t_f'.

2.1.3.2 Failure Analysis Parameters:

2.1.3.2.1 Leakage Current - I_{CBC}

2.1.3.2.2 Load Resistance - R_L

2.1.3.2.3 Current Gain - h_{FE}

2.1.3.2.4 Input Resistance - R_B

2.2 Specifications - SN 510, Diffused Silicon Bistable Network:

2.2.1 Design Electrical Parameters:

Test	Symbol	Vcc = 3V Min.	Vcc = 3V Max.	Vcc = 6V Min.	Vcc = 6V Max.	Unit
Clock Pulse Voltage*	V_{CP}	0.35	1.7	0.40	2.7	V
Set or Reset Voltage* (125°C)	V_S , V_R	1.15	-	2.0	-	V
(-55°C)	V_S , V_R	1.60	-	2.5	-	V
Output OFF (+125°C) N = 0	V_Q, Q-OFF	2.2	-	4.1	-	V
(+125°C) N = 4	V_Q, Q-OFF	1.15	-	2.0	-	V
(-55°C) N = 4	V_Q, Q-OFF	1.60	-	2.50	-	V
Output ON (+125°C)	V_Q, Q-ON	-	0.22	-	0.30	V
(-55°C)	V_Q, Q-ON	-	0.40	-	0.50	V
Switching Times* Repetition Rate		0.8		1.0		Mc
Delay Time	t_d	-	500	-	300	n sec.
Rise Time	t_r	-	500	-	500	n sec.
Storage Time	t_s	-	200	-	200	n sec.
Fall Time	t_f	-	2.5	-	2.5	u sec.
Voltage to set F/F Time	t_f'	-	600	-	600	n sec.

2.2.2 Failure Analysis Electrical Parameters:

Test	Symbol	Condition	Min.	Max.	Unit
Load Resistance	R_L	V = 6V	-	-	Ohms
Leakage Current	I_R	V = 6V	-	-	n a

NOTE: All measurements at an ambient temperature of +25°C unless otherwise specified.

*Clock Pulse: Voltage Level = Vcc/3
Pulse Width = 500 n sec.
Full Time = 100 n sec.
Repetition Rate = 100 Kc (except when noted)

2.3 Specifications - SN 512, Diffused Silicon "NOR" or "NAND" Logic Network:

2.3.1 Design Electrical Parameters:

Test	Symbol	Vcc = 3V Min.	Vcc = 3V Max.	Vcc = 6V Min.	Vcc = 6V Max.	Unit
Input Turn-On (+125°C)	V_{IN-ON}	1.15	-	2.0	-	V
(-55°C)		1.60	-	2.5	-	V
Input Turn-Off (+125°C)	V_{IN-OFF}	-	0.22	-	0.50	V
(-55°C)		-	0.40	-	0.50	V
Output G-On (+125°C)	V_G - ON	-	0.22	-	0.30	V
(-55°C)		-	0.40		0.50	V
Output G-Off (+125°C) N = 0	V_G -OFF	2.5	-	5.0	-	V
(+125°C) N = 5		1.15	-	2.0	-	V
(-55°C) N = 5		1.60	-	2.5	-	V
Switching Time*						
Delay Time	t_d	-	170	-	130	n sec.
Rise Time	t_r	-	200	-	150	n sec.
Storage Time	t_s	-	130	-	110	n sec.
Fall Time	t_f	-	1.6	-	1.4	u sec.
Voltage to Set F/F Time	t_f'	-	550	-	550	n sec.

2.3.2 Failure Analysis Electrical Parameters:

Test	Symbol	Condition	Min.	Max.	Unit
Leakage Current	I_{CBO}	V = 3V & 6V	-	-	na
Load Resistance	R_L	V = 3V & 6V	-	-	ohms
Current Gain	h_{FE}	V = 3V & 6V	-	-	-
Input Resistance	R_B	V = 3V & 6V	-	-	ohms

NOTE: All measurements shall be taken at Ta = +25°C unless otherwise specified.

*Clock Pulse: Voltage Level = $V_{cc}/3$

Pulse Width = 500 nsec.

Fall Time = 100 nsec.

Repetition Rate = 100 Kc

2.4 Specifications: SN 515, Diffused

Silicon "EXCLUSIVE OR" Network:

2.4.1 Design Electrical Parameters

Test	Symbol	Vcc = 3V Min.	Vcc = 3V Max.	Vcc = 6V Min.	Vcc = 6V Max.	Unit
Input Turn-On (+125°C)	V_{IN-ON}	1.15	-	2.0	-	V
(-55°C)		1.60	-	2.5	-	V
Input Turn-Off (+125°C)	V_{IN-OFF}	-	0.22	-	0.30	V
(-55°C)		-	0.40	-	0.50	V
Output Off (+125°C) N = 0	$V_{C,E-OFF}$	2.2	-	4.1	-	V
(+125°C) N = 4		1.15	-	2.0	-	V
Output On (+125°C)	$V_{C,E-ON}$	-	0.22	-	0.30	V
(-55°C)		-	0.40	-	0.50	V
Exclusive Or Output (+125°C) N = 0	V_{D-OFF}	2.5	-	5.0	-	V
(+125°C) N = 5		1.15	-	2.0	-	V
Switching Times*						
Delay Time	t_d	-	150	-	80	n sec.
Rise Time	t_r	-	175	-	110	n sec.
Storage Time	t_s	-	120	-	90	n sec.
Fall Time	t_f	-	1.4	-	1.2	u sec.
Voltage to Set F/F Time	t_f'	-	400	-	450	n sec.

2.4.2 Failure Analysis Electrical Parameters:

Test	Symbol	Condition	Min.	Max.	Unit
Leakage Current	I_{CBO}	V= 3V & 6V	-	-	n a
Load Resistance	R_L	V= 3V & 6V	-	-	ohms
Current Gain	h_{FE}	V= 3V & 6V	-	-	-
Input Resistance	R_B	V= 3V & 6V	-	-	ohms

NOTE: All measurements shall be taken at Ta = +25°C unless otherwise specified.

*Clock Pulse: Voltage Level = Vcc/3
Pulse Width = 500 nsec
Fall Time = 100 nsec
Repetition Rate = 100 Kc

3.0 TEST DESCRIPTION

3.1 Background:

The objectives and purposes of this test are basic and comprehendible. Formulating a measure of the effects of anticipated usage environments on the performance and intrinsic behavior of these single-substrate multi-element devices is not as straightforward. The interactions and combinations of the diffused elements characteristics that are involved in evaluating with performance and internal parameter measurements was recognized in the original test planning. Because of this, the original test plan was sufficiently flexible to accord an opportunity to shift emphasis to optimize measurement procedures.

3.2 Test Design:

3.2.1 Evaluation Program:

The evaluation program was established to investigate three basic "anticipated usage " stress areas. These areas were: thermal environments; life environments; and mechanical environments. Complete initial and final performance and parameter measurements were made and a histogram presentation of this information was programmed.

3.2.1.1 Thermal Environments:

The initial investigation was concentrated in the effects of thermally related environments. A 2 x 3 factorial experiment was designed using a test specimen size of 12 of each type (total sample size = 36). Investigated were the effect of thermal sterilization, thermal cycling , humidity, and the combined effects of the previous environments. 2^n factorial analysis was used to obtain an insight into the effects of this experiment.

3.2.1.2 Life Environments:

All specimens were subjected to operating life tests at high temperature and high vacuum. The principle objective of the design of this test was to obtain maximum operation periods at maximum output loads. Performance and parameter variations were monitored during the tests. Statistical analysis was performed and interpreted to JPL Specification ZPP-2040 GEN A.

3.2.1.3 Mechanical Environments:

On the conclusion of the life environments, a specimen size of 4 of each type (total sample size = 12) were subjected to shock and vibration tests. No statistical analysis was planned for this test since the purpose of the test was primarily to examine for catastrophic failures.

3.2.2 Test Specimen Groups:

The test specimens were divided into 9 test groups as shown below in Chart 1. This grouping was used throughout the test program with the exceptions as noted in the results section of this report.

Type SN510

	Gp1	Gp2	Gp3	Gp4	Gp5	Gp6	Gp7	Gp8	Gp9	Gp10
Unit	9	11	13	15	1	3	5	7	16	18
Unit	10	12	14	17	2	4	6	8	19	20

Type SN512

	Gp1	Gp2	Gp3	Gp4	Gp5	Gp6	Gp7	Gp8	Gp9	Gp10
Unit	9	11	13	15	1	3	5	7	17	18
Unit	10	12	14	16	2	4	6	8	19	20

Type SN515

	Gp1	Gp2	Gp3	Gp4	Gp5	Gp6	Gp7	Gp8	Gp9	Gp10
Unit	9	11	13	16	1	3	5	7	15	17
Unit	10	12	14	18	2	4	6	8	19	20

CHART 1. Test Specimen Groups

3.2.3 Test Sequence:

The environmental and life test program was designed to subject the test groups of paragraph 3.2.2. to conditions as given below. A test flow chart is shown in Chart 2 to clearly delineate the test program.

3.2.3.1 Groups 1 and 2:

High Temperature Operating Life
High Vacuum Operating Life

3.2.3.2 Groups 3 and 4:

Temperature Cycling
Humidity
High Temperature Operating Life
High Vacuum Operating Life

3.2.3.3 Groups 5 and 6:

Thermal Sterilization
High Temperature Operating Life
High Vacuum Operating Life

3.2.3.4 Groups 7 and 8:

Thermal Sterilization
Temperature Cycling
Humidity
High Temperature Operating Life
High Vacuum Operating Life

3.2.3.5 Group 9:

High Temperature Operating Life
High Vacuum Operating Life
Shock
Vibration

3.2.4 Test Special Apparatus

Each of the small (0.125" by 0.250" by 0.035") test specimens were individually mounted on the leads by Cannon Micro-D-Series 15 pin plug. The specimen leads were welded to the plug leads which provided mechanical support and heat conduction for the units during all but the mechanical environments. All measurements on the test specimens were completed by way of a mating Micro-D-Series connector. To simplify the multiple measurements necessary during this test, a centrallized test set was constructed

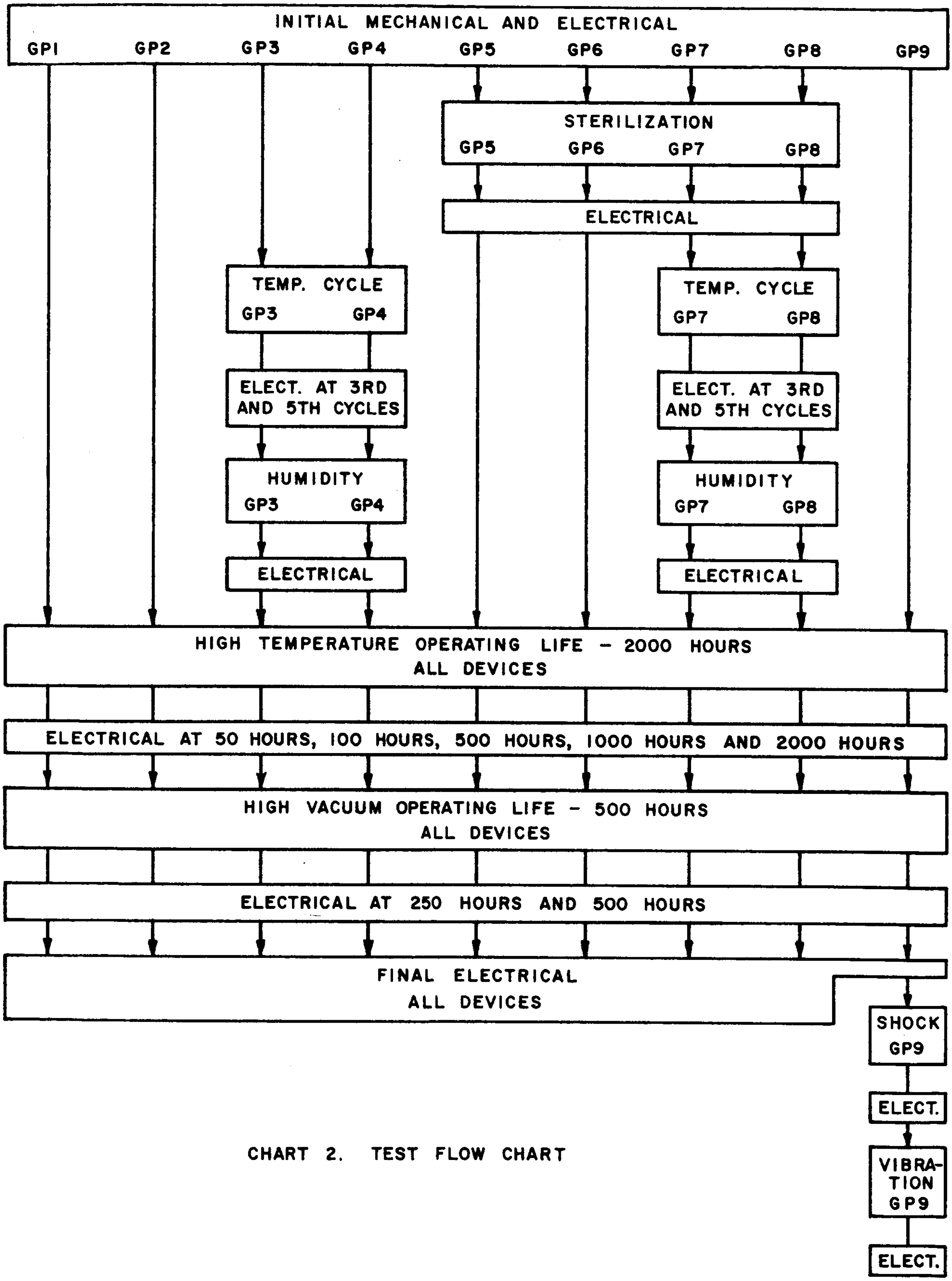


CHART 2. TEST FLOW CHART

to perform most of the measurements. This test set is described in Appendix I.

3.3.0 Measurement Procedures:

3.3.1.0 Electrical Parameter Test Method SN510-Flip/Flop Counter Network:

3.3.1.1 Design Parameters:

3.3.1.1.1 Switching Time Measurement:

3.3.1.1.1.1 The test circuit was connected as indicated in Figure 1.

3.3.1.1.1.2 The test conditions are indicated in the test procedure section of this report.

3.3.1.1.1.3 The input clock pulse was set at the values indicated in Section 2.2 as shown in Figure 2.

3.3.1.1.1.4 The output pulse was read at Q and $\bar{Q}$.

3.3.1.1.1.5 The method for measuring the switching times is indicated in Figure 2.

3.3.1.1.2 Output Voltage:

3.3.1.1.2.1 The test circuit was connected as indicated in Figure 3.

3.3.1.1.2.2 The test conditions are indicated in the test procedure section of this report.

3.3.1.1.2.3 To measure the "OFF", or high voltage at output Q, the switch was momentarily shorted at output $\bar{Q}$. $\bar{Q}$ will read low or the "ON" state. Record V_Q and $V_{\bar{Q}}$ in the Q output high state.

3.3.1.1.2.4 To measure the "OFF", or high voltage at output $\bar{Q}$, the switch was momentarily shorted at output Q. Q will read low or the "ON" state. Record V_Q and $V_{\bar{Q}}$ in the $\bar{Q}$ output high state.

3.3.1.1.2.5 The output voltage at Q and $\bar{Q}$ was also measured with a fan-out load of four. The load is indicated in Figure 8. The test method is the same as indicated in paragraphs 3.3.1.1.2.3 and 3.3.1.1.2.4 above.

3.3.1.1.3 Minimum Clock Input Voltage:

3.3.1.1.3.1 The test circuit was connected as indicated in Figure 4.

3.3.1.1.3.2 The test conditions are indicated in the test procedure section of this report.

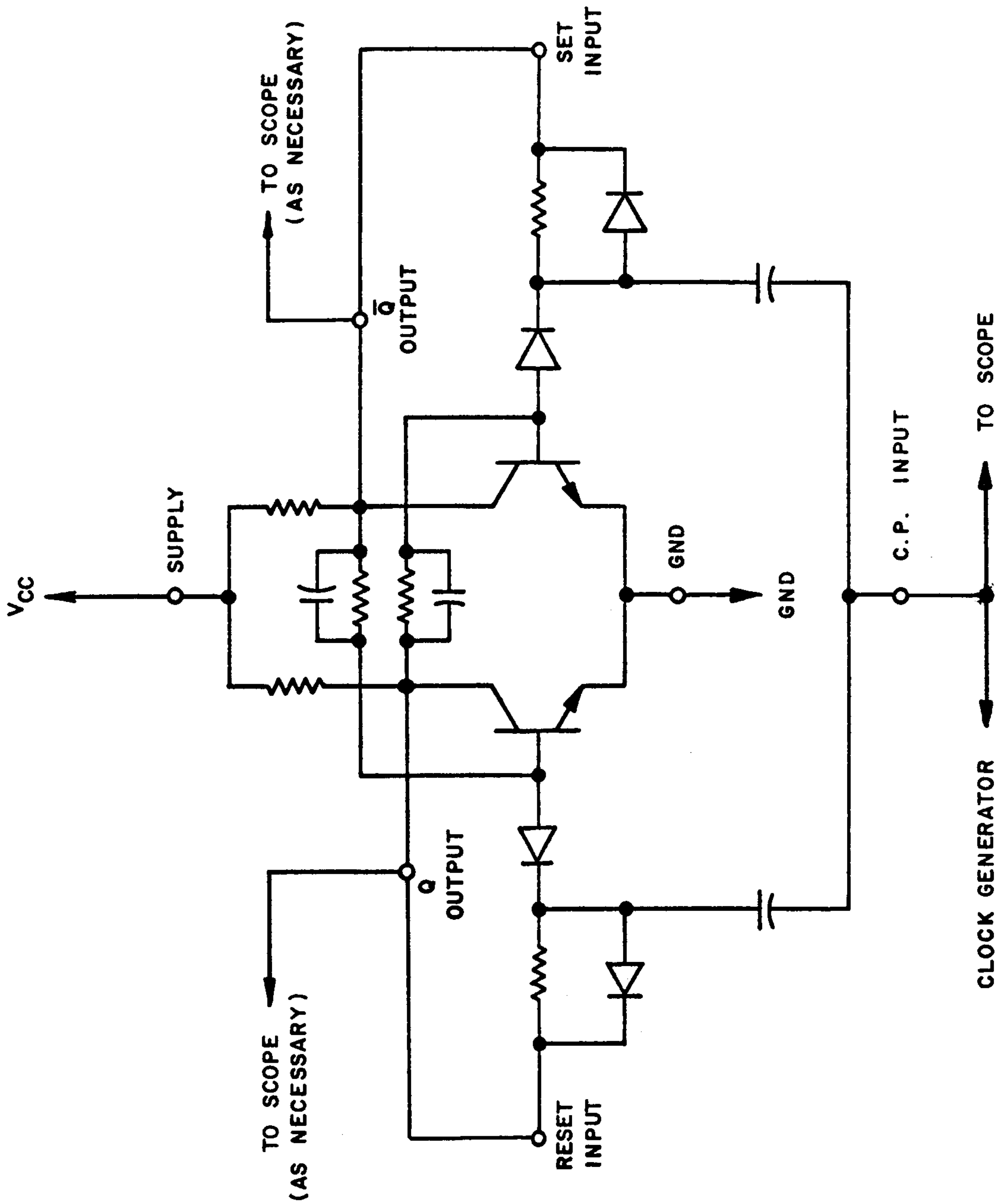
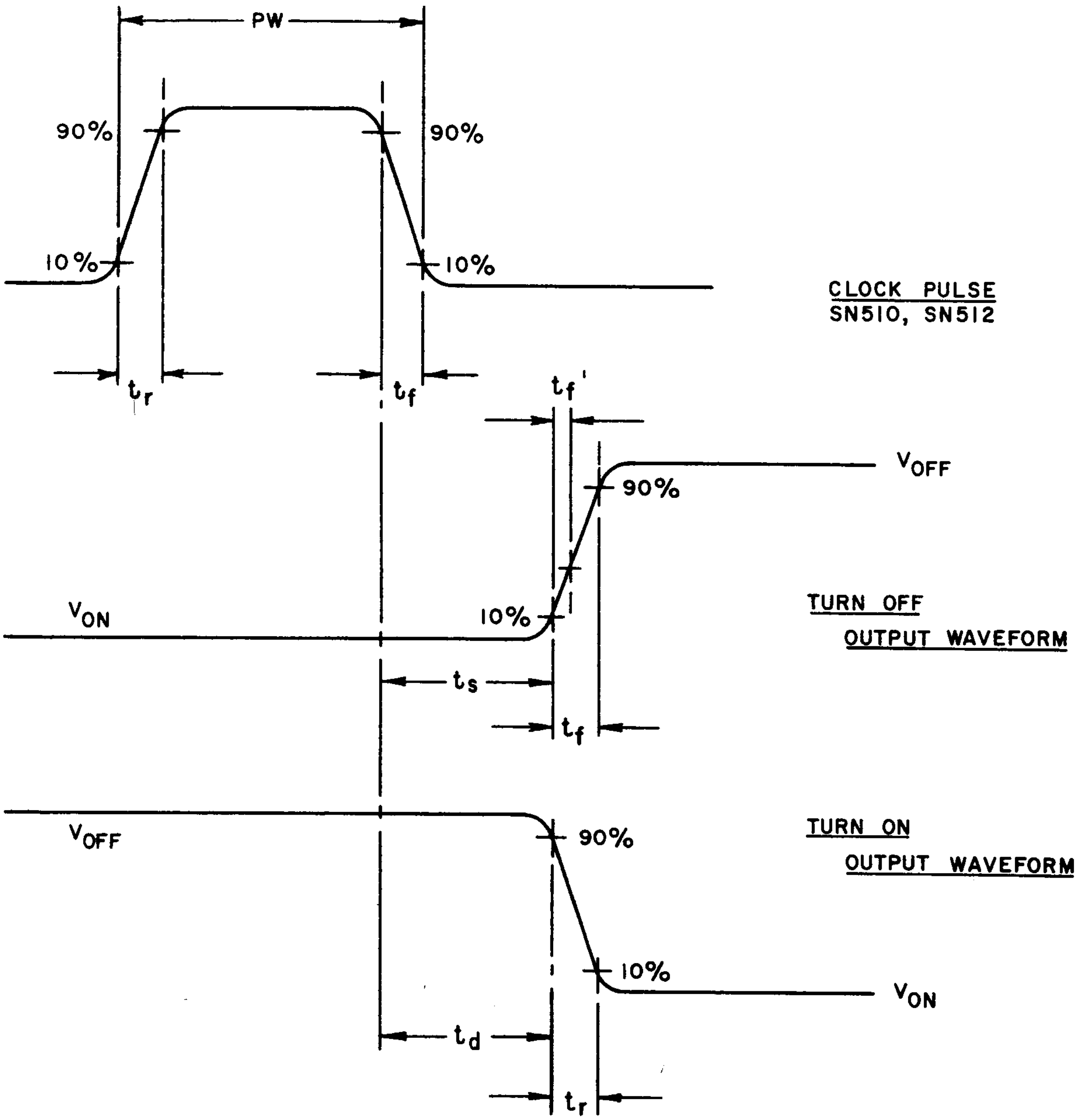


FIGURE 1. TEST CIRCUIT FOR SWITCHING TIME MEASUREMENT, SN510



PROPAGATION DELAY:

$$t_p = \frac{t_d + t_s}{2}$$

FIGURE 2. SWITCHING TIME MEASUREMENT, SN510

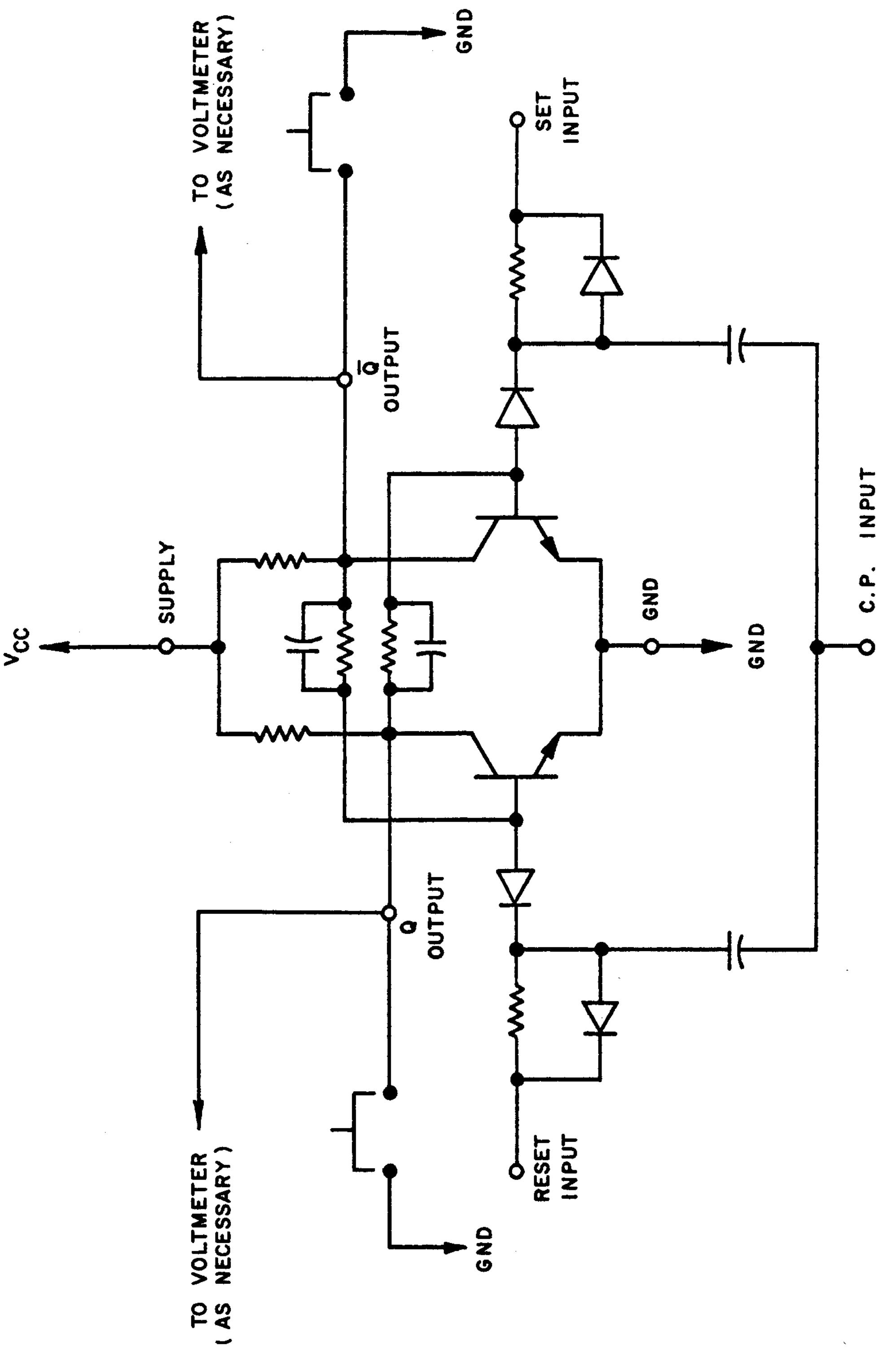


FIGURE 3. TEST CIRCUIT FOR Q & $\overline{Q}$ OUTPUT VOLTAGE, SN510

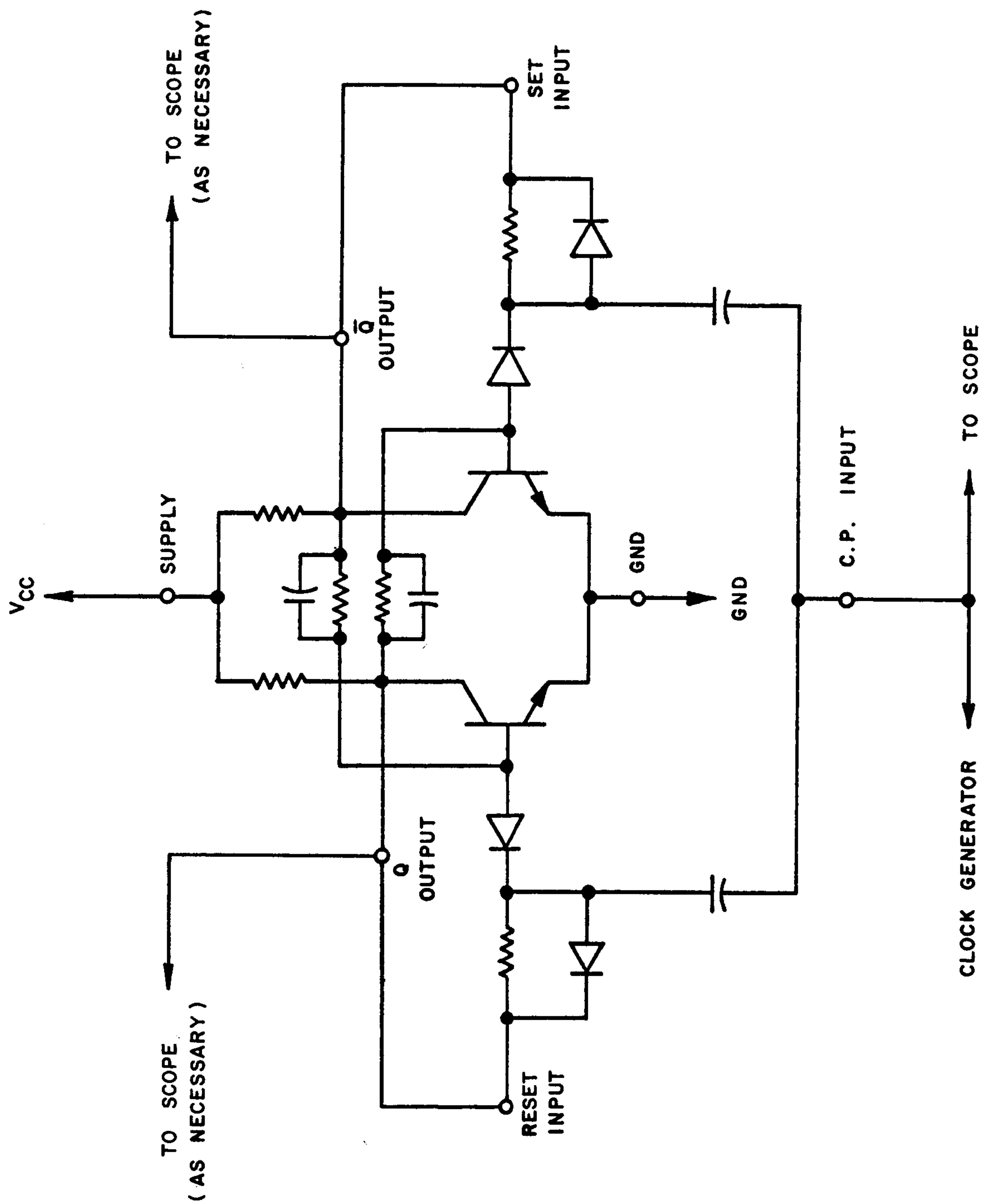


FIGURE 4. TEST CIRCUIT FOR V_{CP-MIN} MINIMUM CLOCK INPUT VOLTAGE, SN510

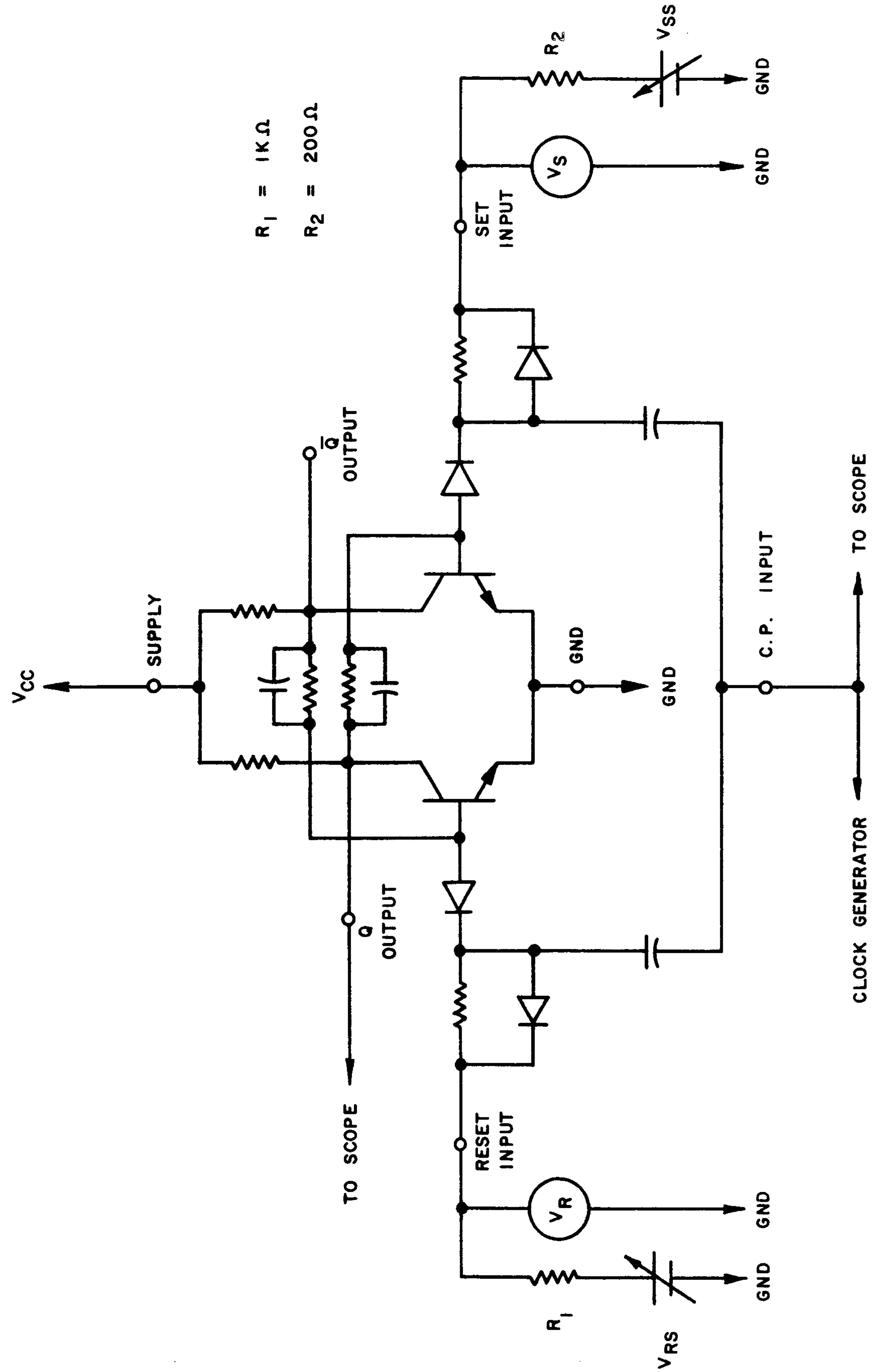


FIGURE 5. TEST CIRCUIT FOR MINIMUM SET & RESET VOLTAGE, SN510

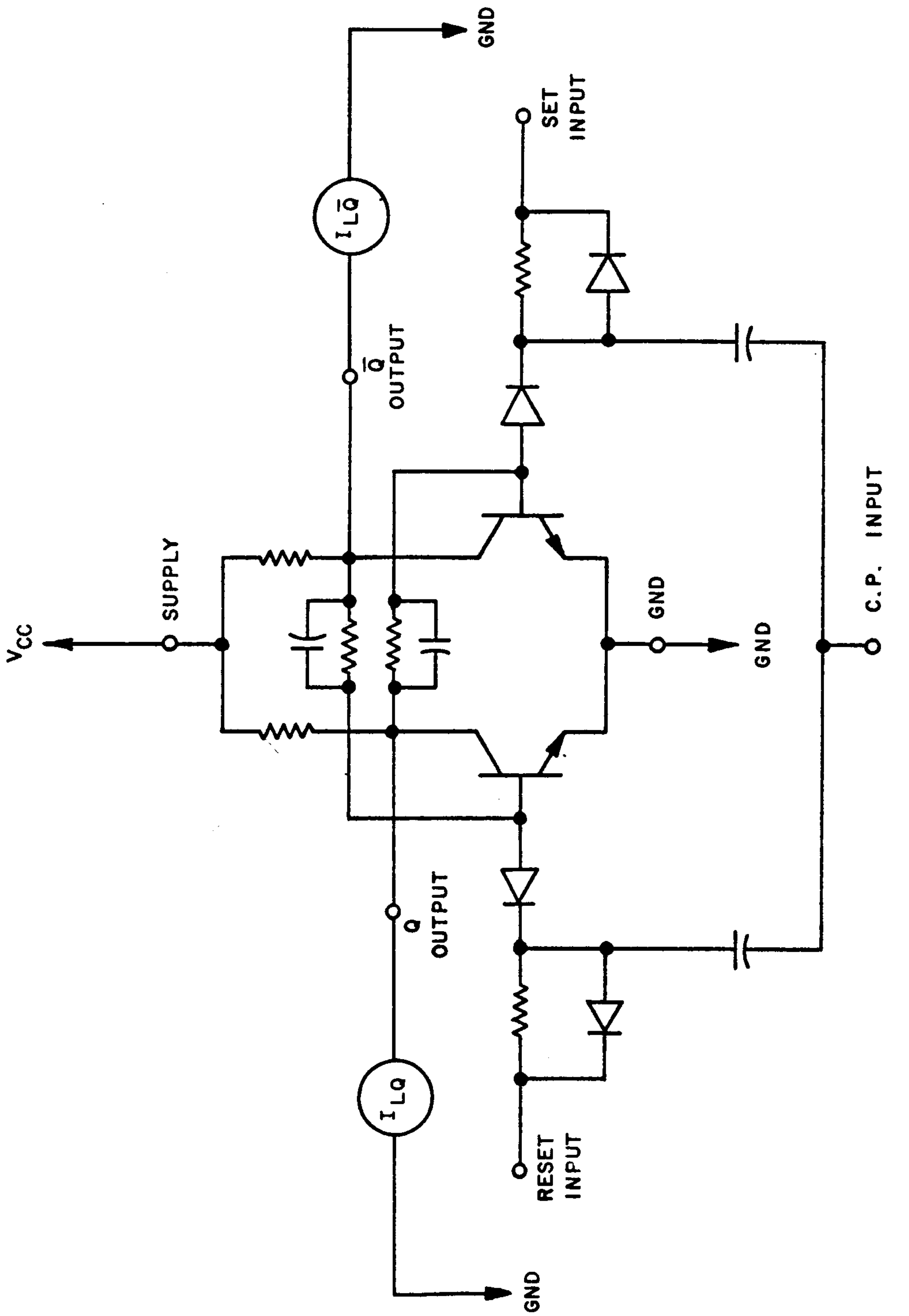


FIGURE 6. TEST CIRCUIT FOR LOAD RESISTANCE R_L MEASUREMENT, SN510

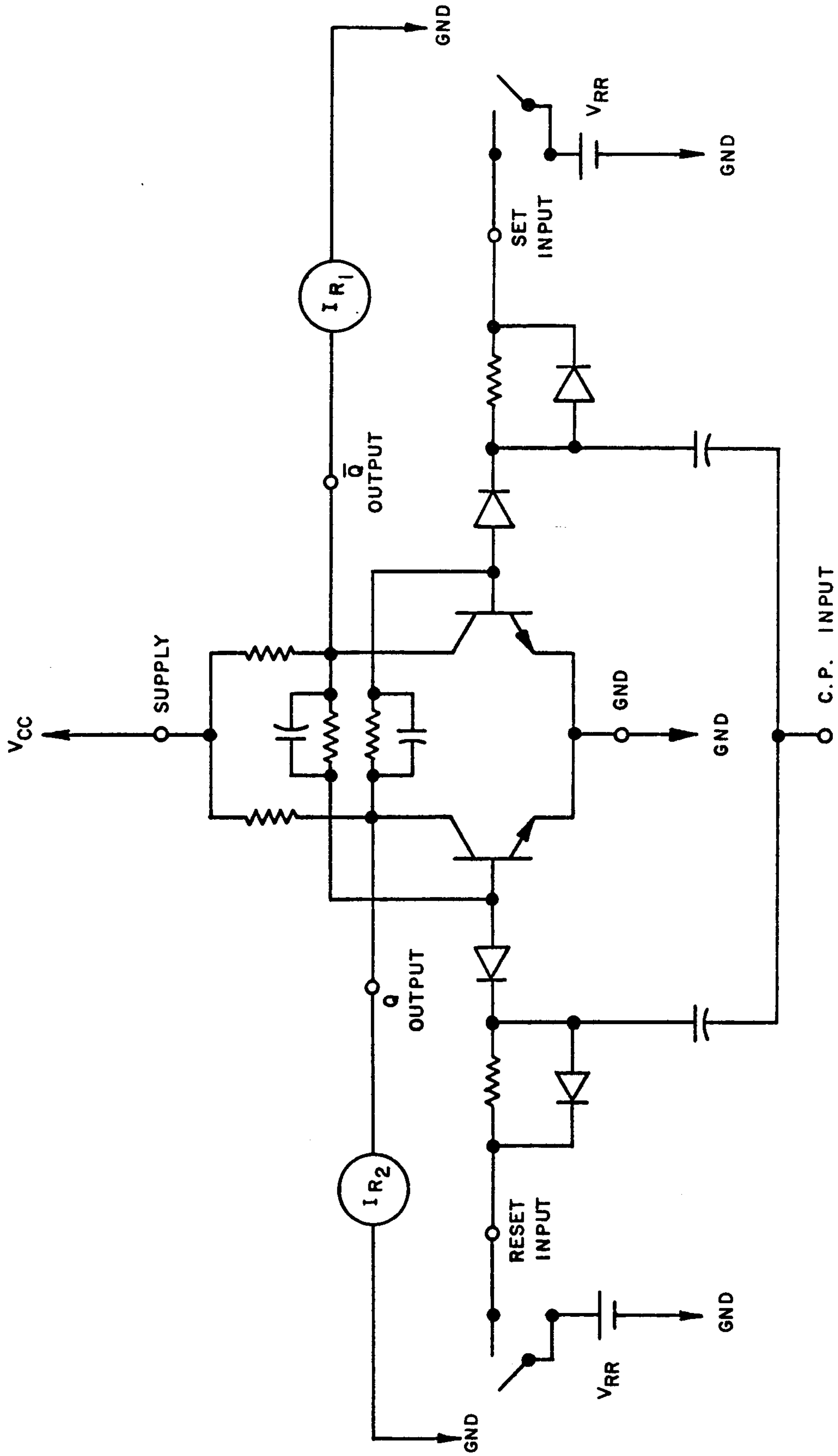
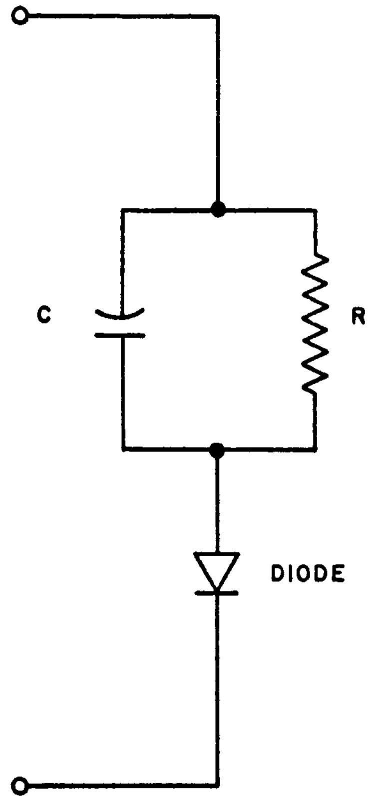


FIGURE 7. TEST CIRCUIT FOR DIODE LEAKAGE I_R MEASUREMENT, SN510



C = 200 pf

R = 5 KΩ

D = IN914

FIGURE 8. LOAD CIRCUIT FOR SN510. N = 4

3.3.1.1.3.3 The clock input pulse was calibrated to the values indicated in paragraph 2.2.

3.3.1.1.3.4 The input clock pulse was increased from zero voltage to a value which indicated the output pulse at Q or $\bar{Q}$ was stable. (The pulse on the oscilloscope was steady). Minimum input clock pulse voltage was recorded with the output stable.

3.3.1.1.4 Minimum Set and Reset Voltage:

3.3.1.1.4.1 The test circuit was connected as indicated in Figure 5.

3.3.1.1.4.2 The test conditions are indicated in the test procedure section of this report.

3.3.1.1.4.3 The input clock pulse conditions were set as indicated in Paragraph 2.3 as shown in Figure 2.

3.3.1.1.4.4 The minimum reset voltage (V_R) was measured by setting V_S at 0.25 volts and increasing V_R from zero until the output voltage at Q was in the "ON" or low voltage state. The reset voltage (V_R) was recorded.

3.3.1.1.4.5 Interchange resistors - R_1 and R_2 (Figure 5).

3.3.1.1.4.6 The minimum set voltage (V_S) was measured by setting V_R at 0.25 volts and increasing V_S from zero until the output voltage at $\bar{Q}$ was in the "ON" or low voltage state. The set voltage (V_S) was recorded.

3.3.1.2 Failure Analysis Parameters:

3.3.1.2.1 Load Resistance R_L:

3.3.1.2.1.1 The test circuit was connected as indicated in Figure 6.

3.3.1.2.1.2 The test conditions are indicated in the test procedure section of this report.

3.3.1.2.1.3 An ammeter was connected to Q output and the current indicated on the meter was recorded. The load resistance (R_{LQ}) is the supply voltage (V_{CC}) divided by the current (I_{LQ}) indicated on the meter, i.e. $V_{CC}/I_{LQ} = R_{LQ}$.

3.3.1.2.1.4 The ammeter was then connected to $\bar{Q}$ output and the current indicated was recorded. The load resistance ($R_{L\bar{Q}}$) is the supply voltage (V_{CC}) divided by the current ($I_{L\bar{Q}}$) indicated on the meter. $V_{CC}/I_{L\bar{Q}} = R_{L\bar{Q}}$.

3.3.1.2.2 Diode Leakage Current I_R:

3.3.1.2.2.1 The test circuit was connected as indicated in Figure 7.

3.3.1.2.2.2 The test conditions are indicated in the test procedure section of this report.

3.3.1.2.2.3 Test voltage V_{RR} was applied to reset input. An ammeter was connected to $\bar{Q}$ and diode leakage I_{R1} (reset input) was measured.

3.3.1.2.2.4 Test voltage V_{RR} was applied to set input. An ammeter was connected to Q and diode leakage I_{R2} (set input) was measured.

3.3.2 Electrical Parameter Test Method SN 512-"NOR"or"NAND"Gate Network:

3.3.2.1 Design Parameters:

3.3.2.1.1 Switching Time Measurements:

3.3.2.1.1.1 The test circuit was connected as indicated in Figure 9.

3.3.2.1.1.2 The test conditions are indicated in the test procedure section of this report.

3.3.2.1.1.3 The clock pulse was set at the values indicated in Paragraph 2.3 as shown in Figure 2.

3.3.2.1.1.4 The output "G" was loaded with the circuit indicated in Figure 16.

3.3.2.1.1.5 Each input "A" through "F"was sequentially tested with all other inputs held at ground. All output readings are made at "G".

3.3.2.1.2 Output Voltage:

3.3.2.1.2.1 The test circuit was connected as indicated in Figure 11.

3.3.2.1.2.2 The test conditions are indicated in the test procedure section of this report.

3.3.2.1.2.3 The input voltage V_{BB} was set to the minimum value specified for "Input Turn-On" in Section 2.3 (Note the "Input Turn-On specified at 125°C was used for measurements at 25°C also). The input voltage (V_B) and the output voltage (V_G) were recorded.

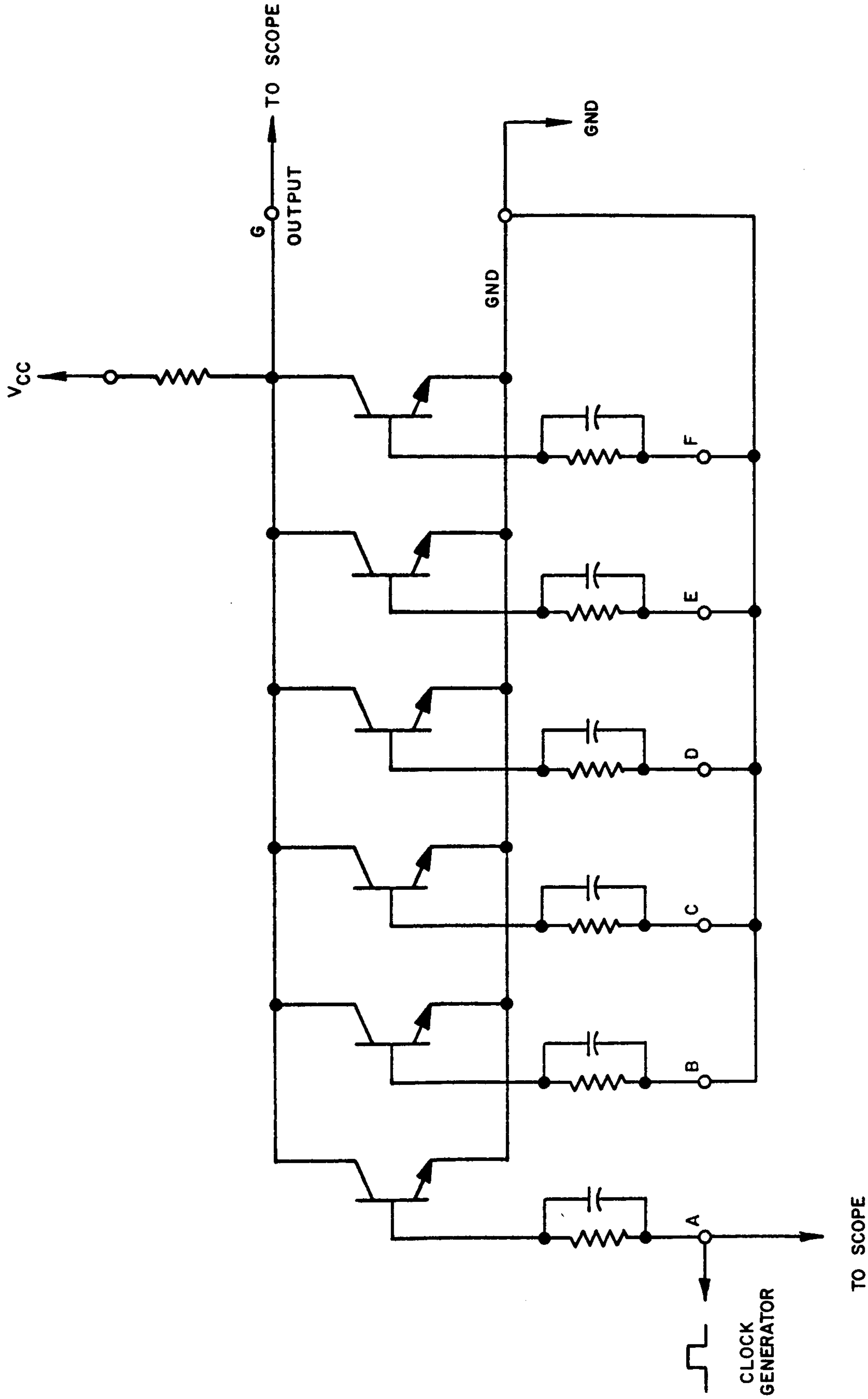


FIGURE 9. TEST CIRCUIT FOR SWITCHING TIME MEASUREMENTS, SN512

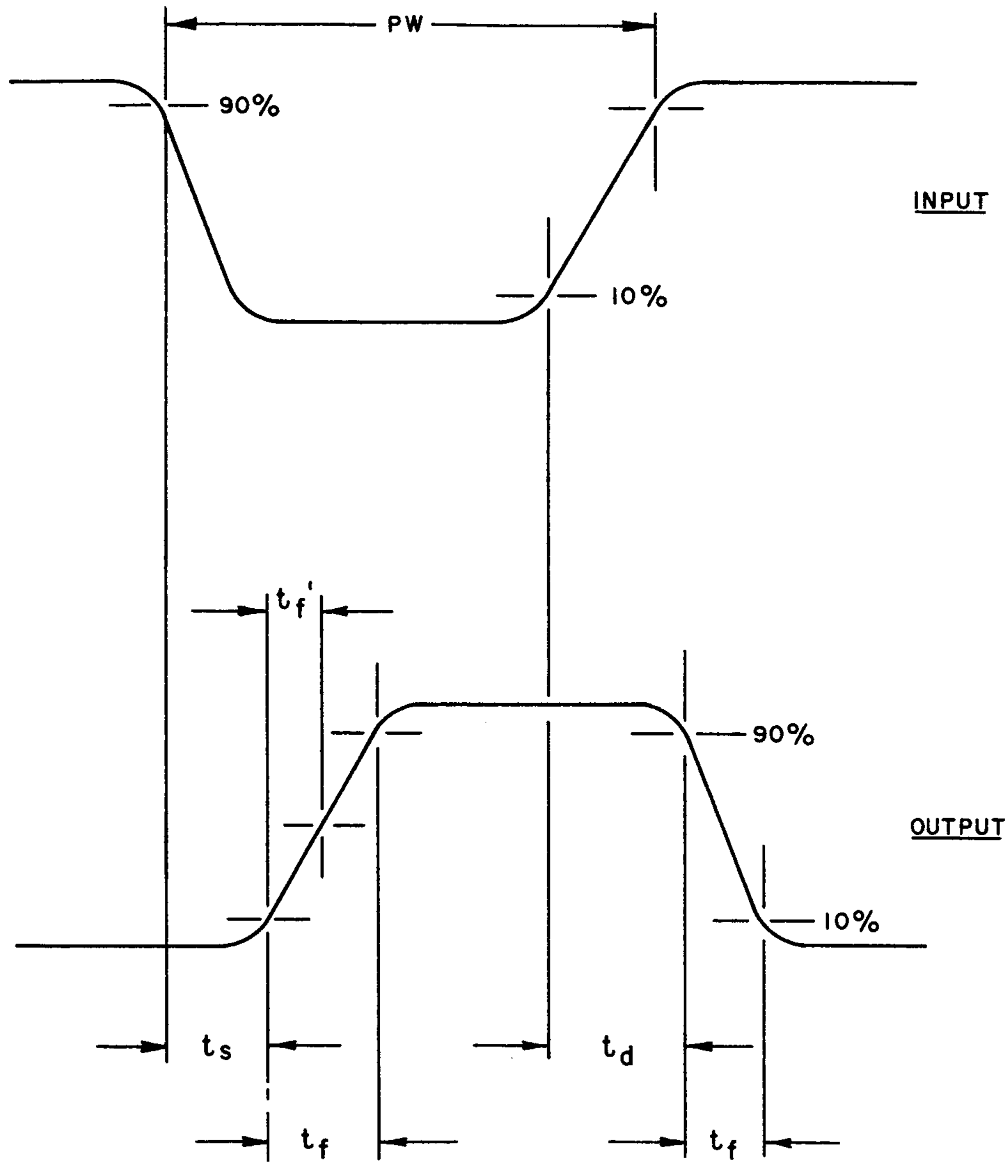


FIGURE 10. SWITCHING TIME MEASUREMENT, SN512

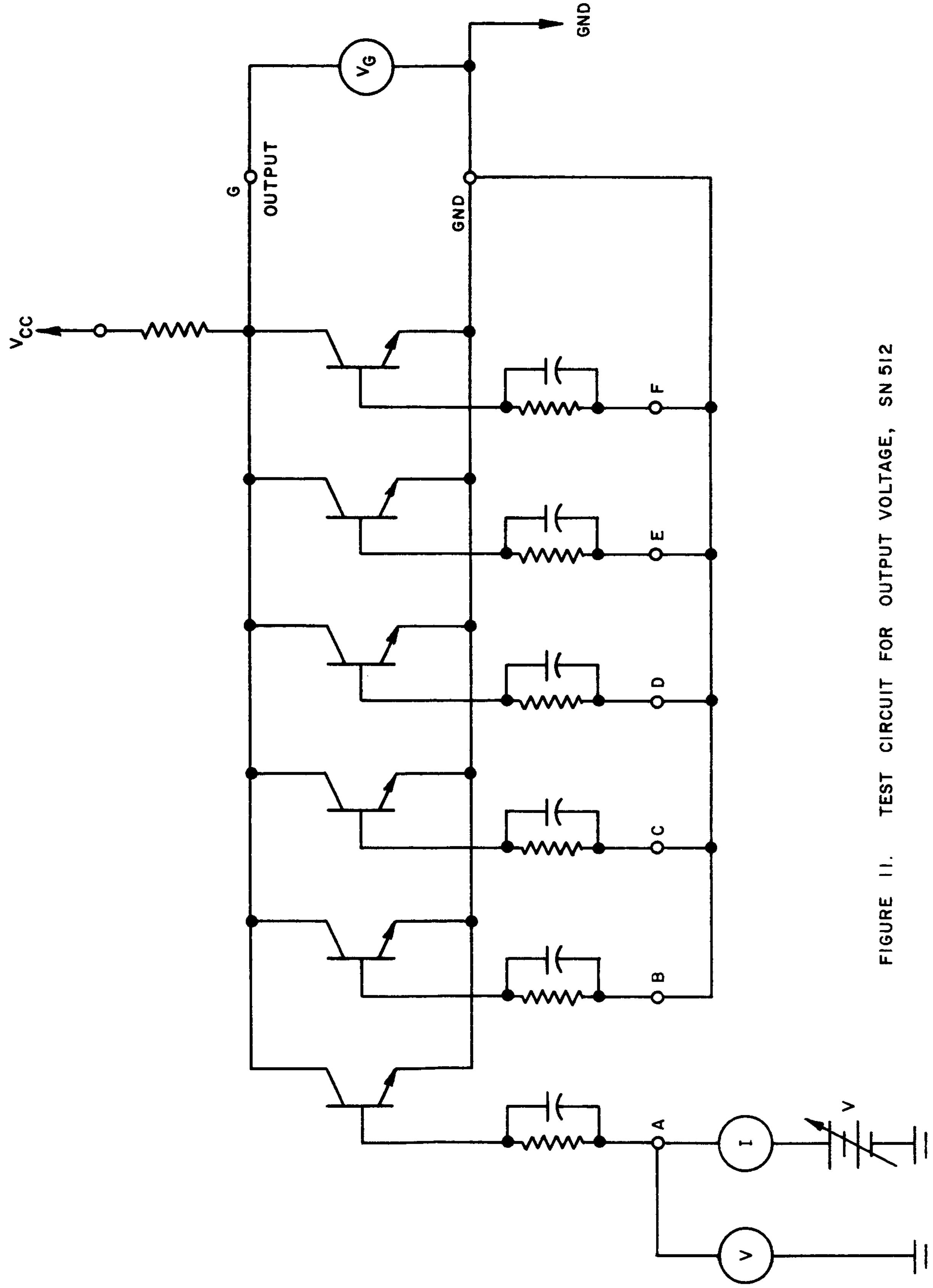


FIGURE 11. TEST CIRCUIT FOR OUTPUT VOLTAGE, SN 512

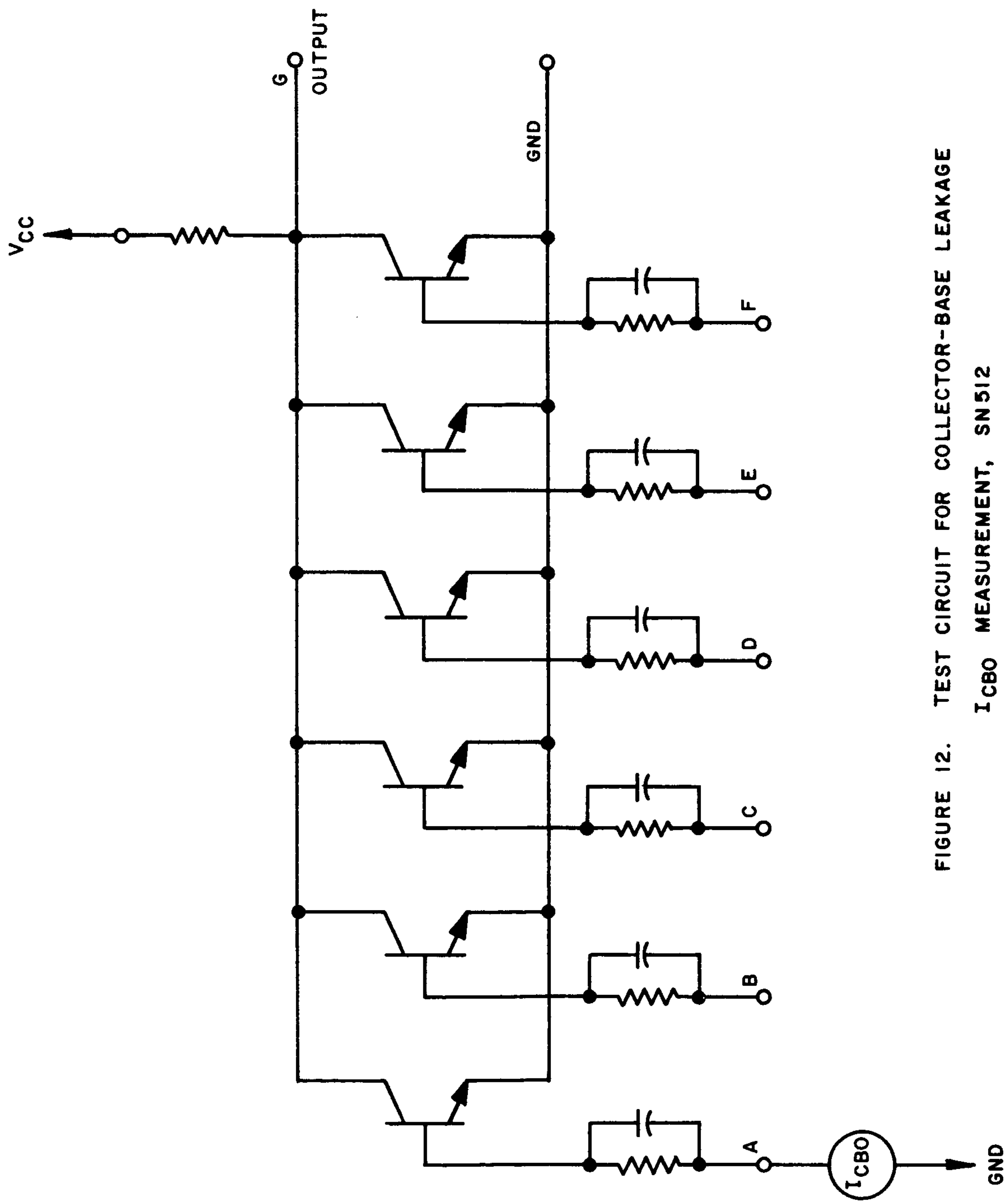


FIGURE 12. TEST CIRCUIT FOR COLLECTOR-BASE LEAKAGE I_{CBO} MEASUREMENT, SN512

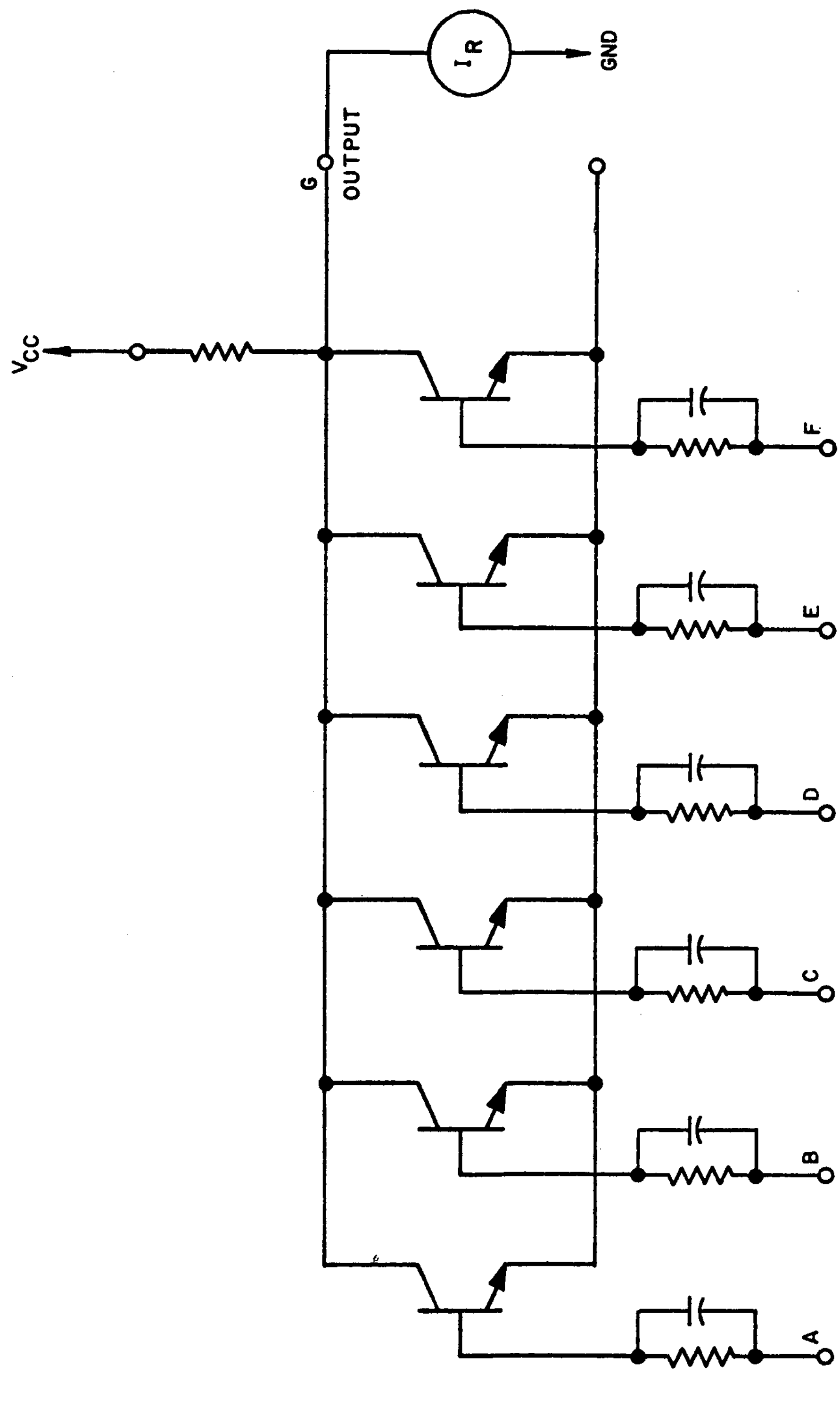


FIGURE 13. TEST CIRCUIT FOR LOAD RESISTANCE R_L MEASUREMENT, SN 512

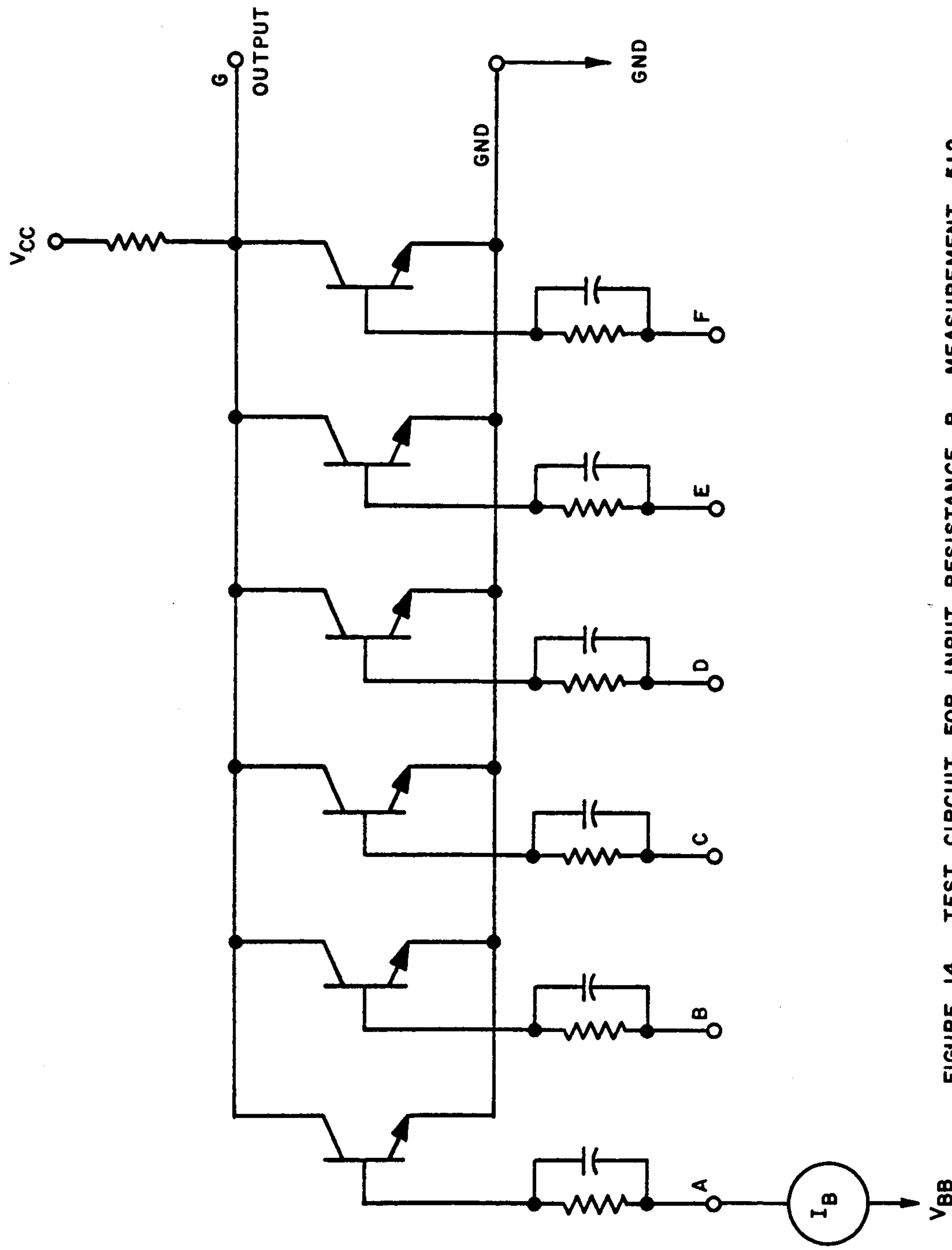


FIGURE 14. TEST CIRCUIT FOR INPUT RESISTANCE R_B MEASUREMENT, 512

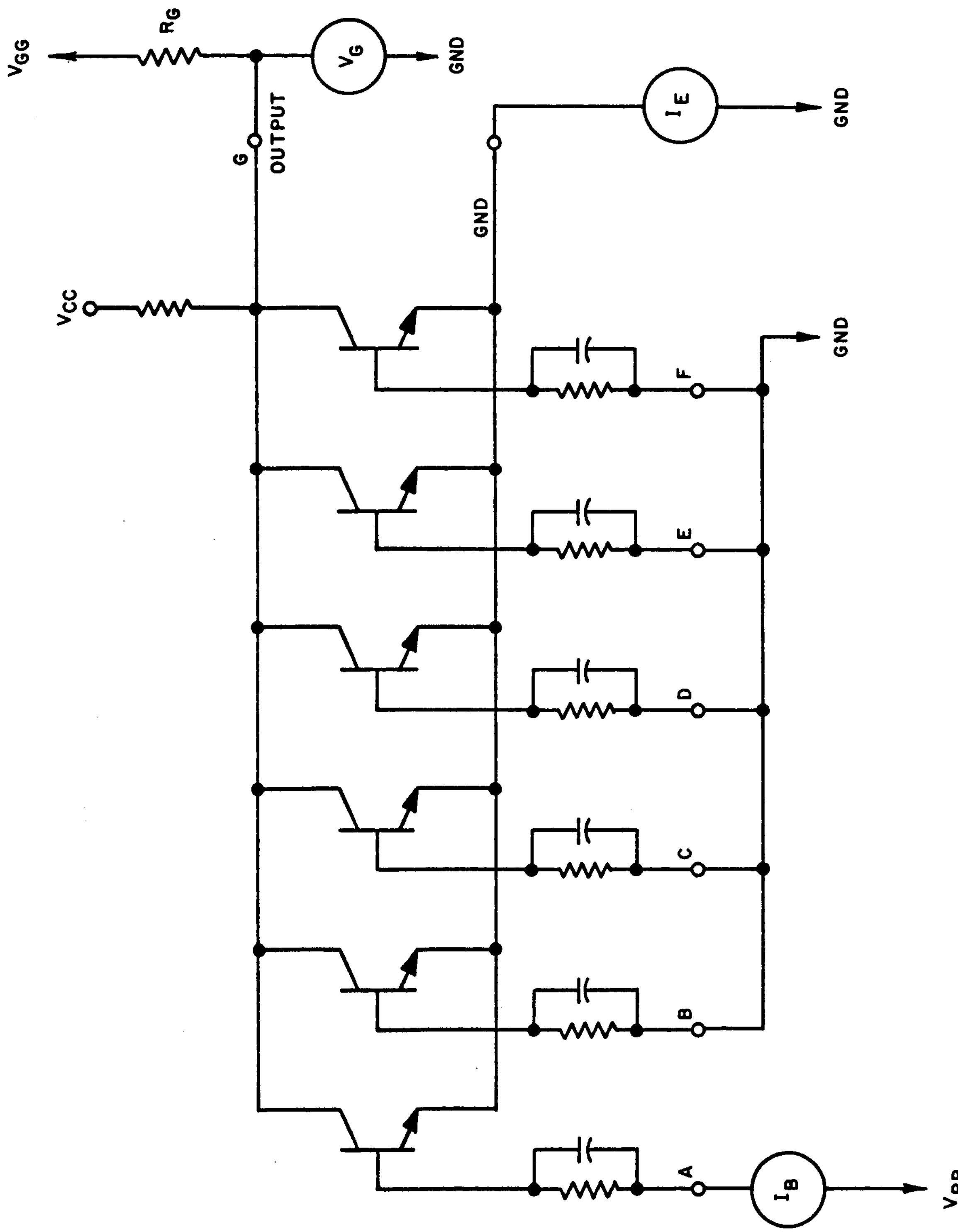
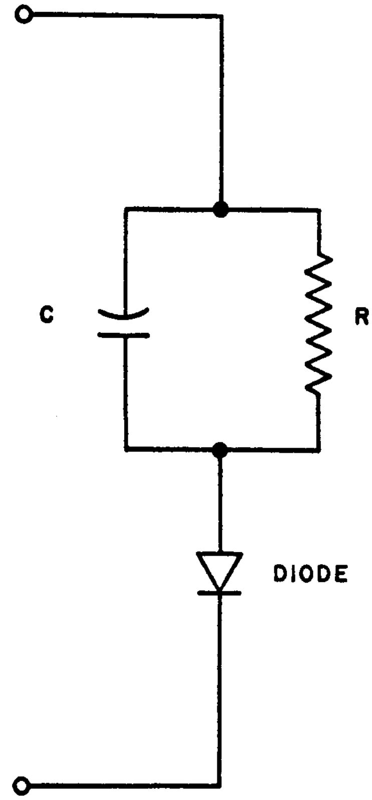


FIGURE 15. TEST CIRCUIT FOR CURRENT GAIN h_{FE} MEASUREMENT, SN 512



C = 250 pf

R = 4KΩ

D = IN914

FIGURE 16. LOAD CIRCUIT FOR SN512. N = 5

3.3.2.1.2.4 All inputs "A" through "F" were sequentially tested in the above manner with all other inputs grounded.

3.3.2.1.2.5 An equivalent load (N=5) as shown in Figure 16 was connected to the output "G" and the tests above in paragraphs 3.3.2.1.2.3 and 3.3.2.1.2.4 were repeated.

3.3.2.2 Failure Analysis Parameters:

3.3.2.2.1 Collector-Base Leakage Current I_{CBO}

3.3.2.2.1.1 The test circuit was connected as indicated in Figure 12.

3.3.2.2.1.2 The test conditions are indicated in the test procedure section of this report.

3.3.2.2.1.3 The reverse current was measured and recorded at each input with other inputs left open.

3.3.2.2.2 Load Resistance R_L:

3.3.2.2.2.1 The test circuit was connected as indicated in Figure 13.

3.3.2.2.2.2 The test conditions are indicated in the test procedure section of this report.

3.3.2.2.2.3 The current at output G was measured and recorded.

3.3.2.2.2.4 The load resistance (R_L) was determined by dividing the supply voltage (V_{CC}) by the current at the output terminal G (I_G), i.e. $R_L = V_{CC}/I_G$.

3.3.2.2.3 Input Resistance R_B:

3.3.2.2.3.1 The test circuit was connected as indicated in Figure 14.

3.3.2.2.3.2 The test conditions are indicated in the test procedure section of this report.

3.3.2.2.3.3 The input voltage (V_{BB}) was set at the value specified in the **test procedure section** and the input current was measured and recorded.

3.3.2.2.3.4 All inputs "A" through "F" were sequentially measured in the above manner.

3.3.2.2.3.5 Each input resistance was determined by dividing the input voltage (V_{BB}) by the input current. (I_B) i.e. , $R_B = V_{BB}/I_B$.

3.3.2.2.4 Current Gain h_{FE}:

3.3.2.2.4.1 The test circuit was connected as indicated in Figure 15.

3.3.2.2.4.2 The test conditions are indicated in the test procedure section of this report.

3.3.2.2.4.3 The supply voltage (V_{GG}) was set as specified in the test section of this report with a load resistor (R_G) of 5 K. The base supply voltage (V_{BB}) was increased until the collector base voltage (V_G) read 1 volt. Base current (I_B) was read and recorded at this point.

3.3.2.2.4.4 Inputs "A" through "F" were sequentially tested per the above procedure with all other inputs grounded.

3.3.2.2.4.5 The DC current gain (h_{FE}) was determined by dividing the emitter current (I_E) by the input current (I_B) for each input i.e., $h_{FE} = I_E/I_B$.

3.3.3 Electrical Parameter Test Method SN 515 -"Exclusive OR" NETWORK:

3.3.3.1 Design Parameters:

3.3.3.1.1 Switching Time Measurements:

3.3.3.1.1.1 The test circuit was connected as indicated in Figure 17.

3.3.3.1.1.2 The test conditions are indicated in the test procedure section of this report.

3.3.3.1.1.3 The input clock pulse was set at the values indicated in Para. 2.4, as shown in Figure 18.

3.3.3.1.1.4 The output connections were loaded as indicated below:

Output	Load
C, E	N=4 (See Figure 23)
D	N=5 (See Figure 23)

3.3.3.1.1.5 Measurements were performed at inputs and outputs sequentially in the order shown below:

Input:	Output:
A	C
B	C
A	D
B	D
A	E
B	E
A	D
B	D

3.3.3.1.2 Output Voltage:

3.3.3.1.2.1 The test circuit was connected as indicated in Figure 19.

3.3.3.1.2.2 The test conditions are indicated in the test procedure section of this report.

3.3.3.1.2.3 The input supply voltage (V_{BB}) to the input under test was set at the minimum "Input Turn-On" as specified in paragraph 2.4 and the voltage reading at the auxiliary output was recorded. (Note: minimum "Input Turn-On" specified at 125°C was used for the 25°C measurements also).

3.3.3.1.2.4 The input supply voltage (V_{BB}) to the input under test was then set at the maximum "Output On" as specified in paragraph 2.4 and the voltage reading at the "Exclusive OR" (D) output was recorded (Note: maximum "Output On" specified at 125°C was used for the 25°C measurement also).

3.3.3.1.2.5 The above measurements (Para. 3.3.3.1.2.3 and 3.3.3.1.2.4) were sequentially done in the order below:

Input:	Output:
A	C
B	C
B	D
A	E
B	E
B	D

3.3.3.1.2.6 The measurements above (Para. 3.3.3.1.2.5) were then repeated with a simulated auxiliary load of N = 4 and an "Exclusive OR" load of N = 5 as shown in Figure 23.

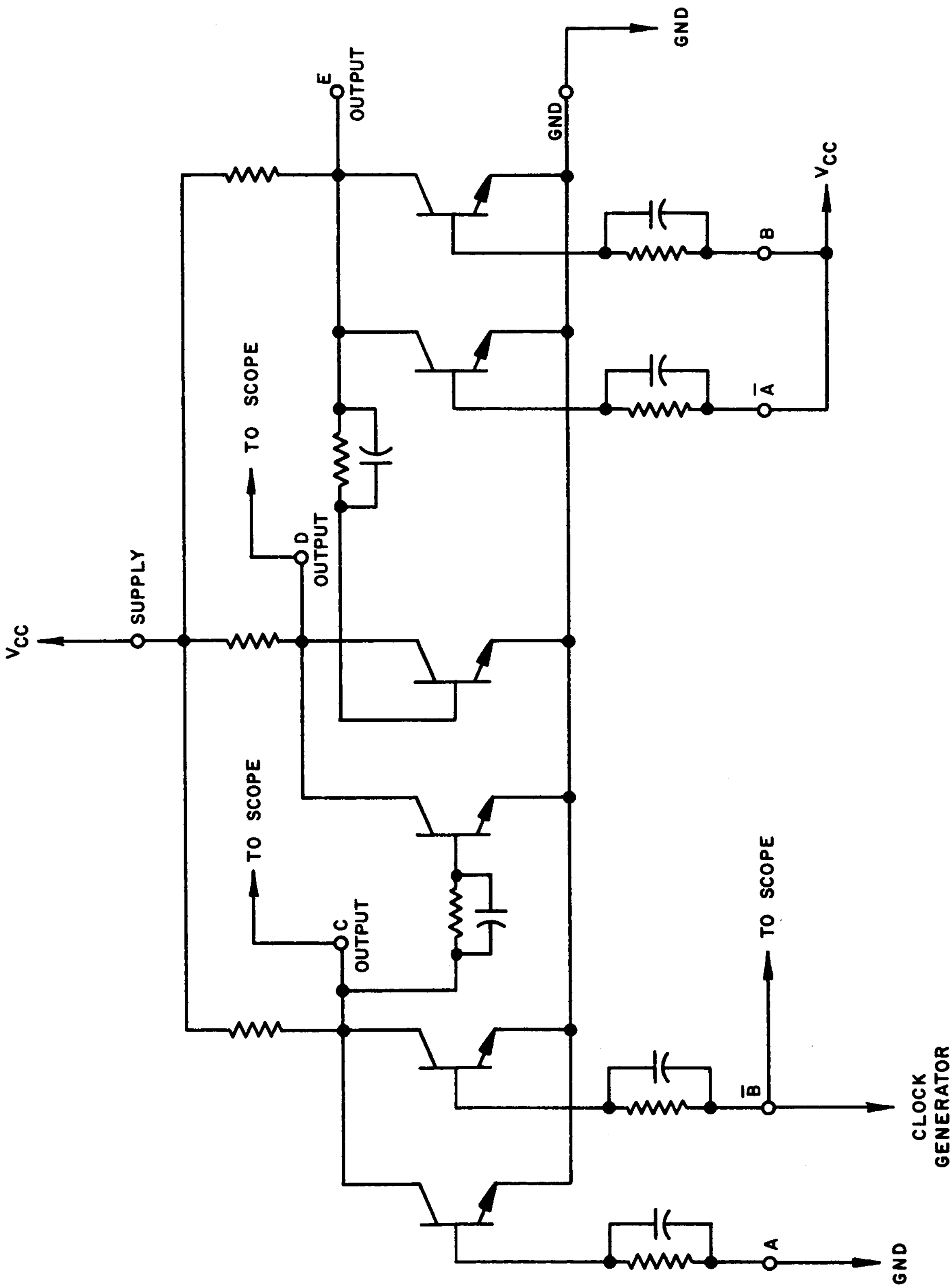


FIGURE 17. TEST CIRCUIT FOR SWITCHING TIME, SN515

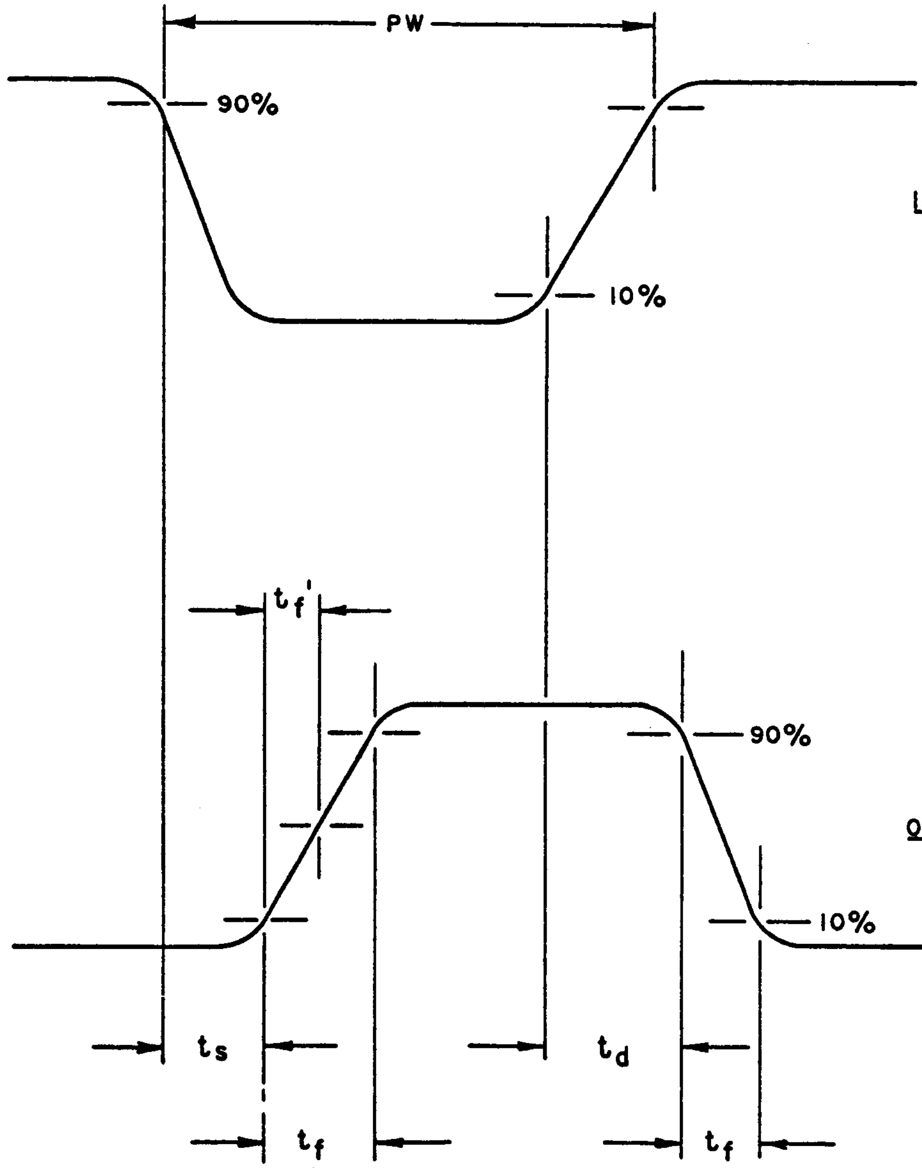


FIGURE 18. SWITCHING TIME MEASUREMENT, SN515

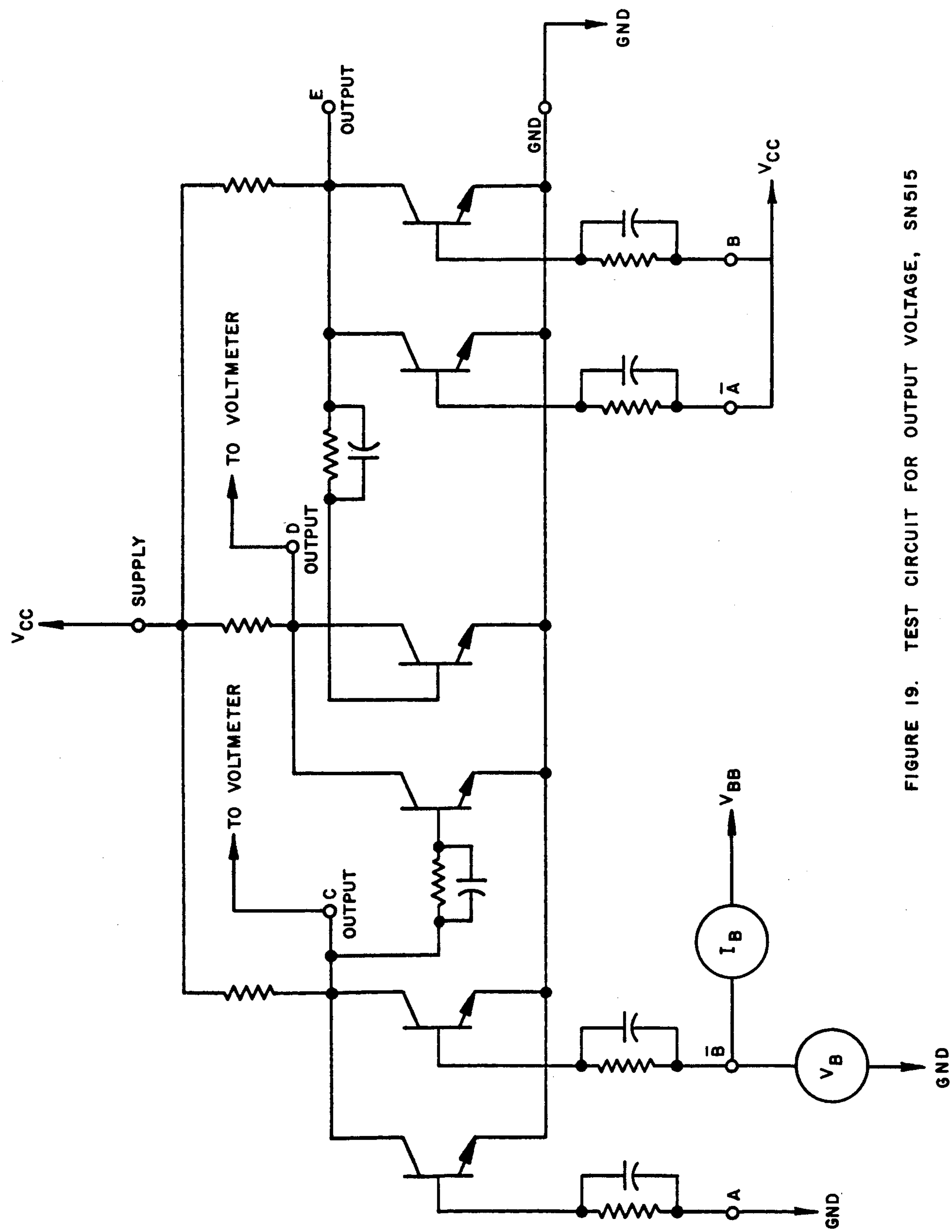


FIGURE 19. TEST CIRCUIT FOR OUTPUT VOLTAGE, SN515

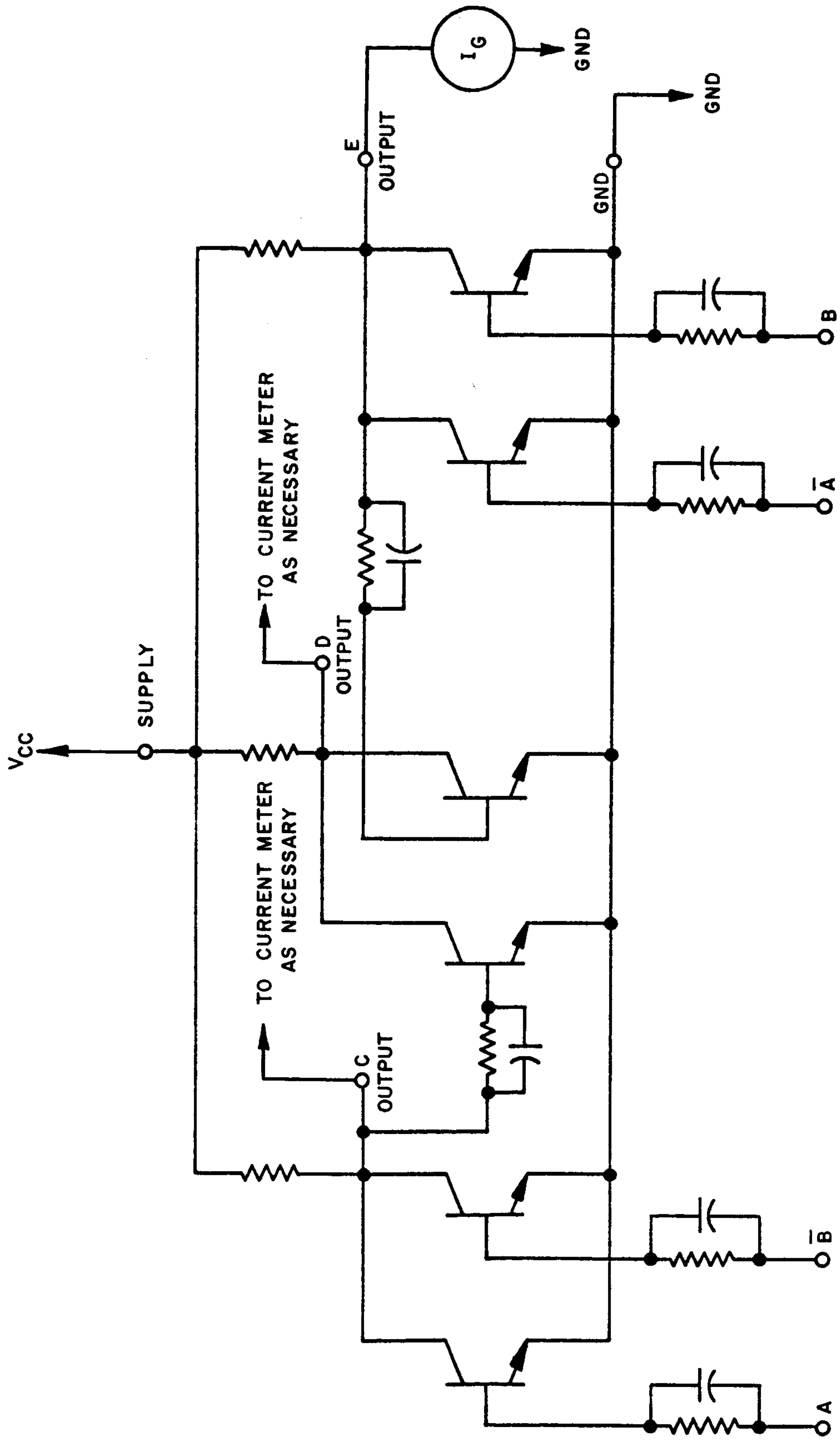


FIGURE 20. TEST CIRCUIT FOR LOAD RESISTANCE R_L MEASUREMENT, SN 515

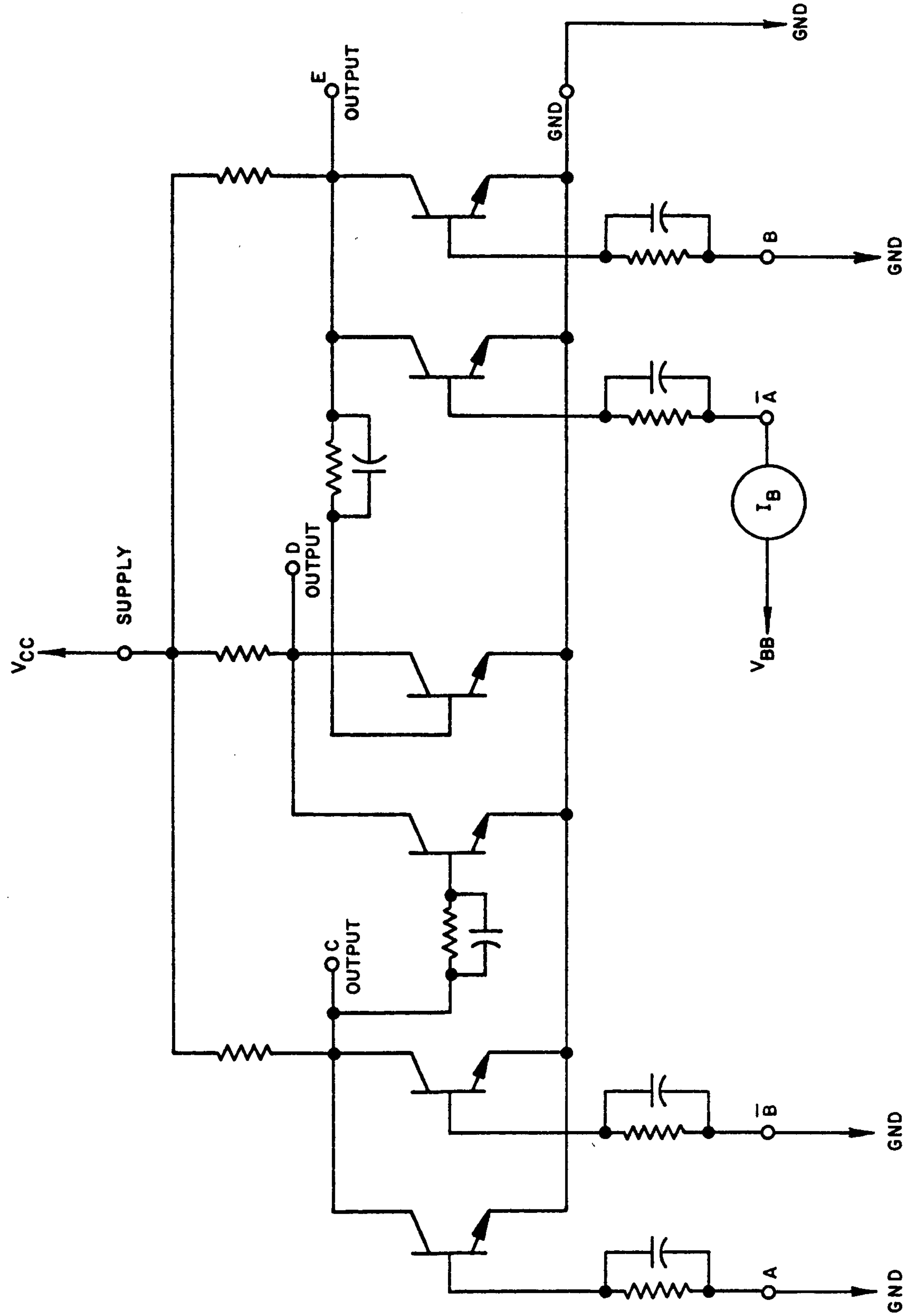


FIGURE 21. TEST CIRCUIT FOR INPUT RESISTANCE R_B MEASUREMENT, SN 515

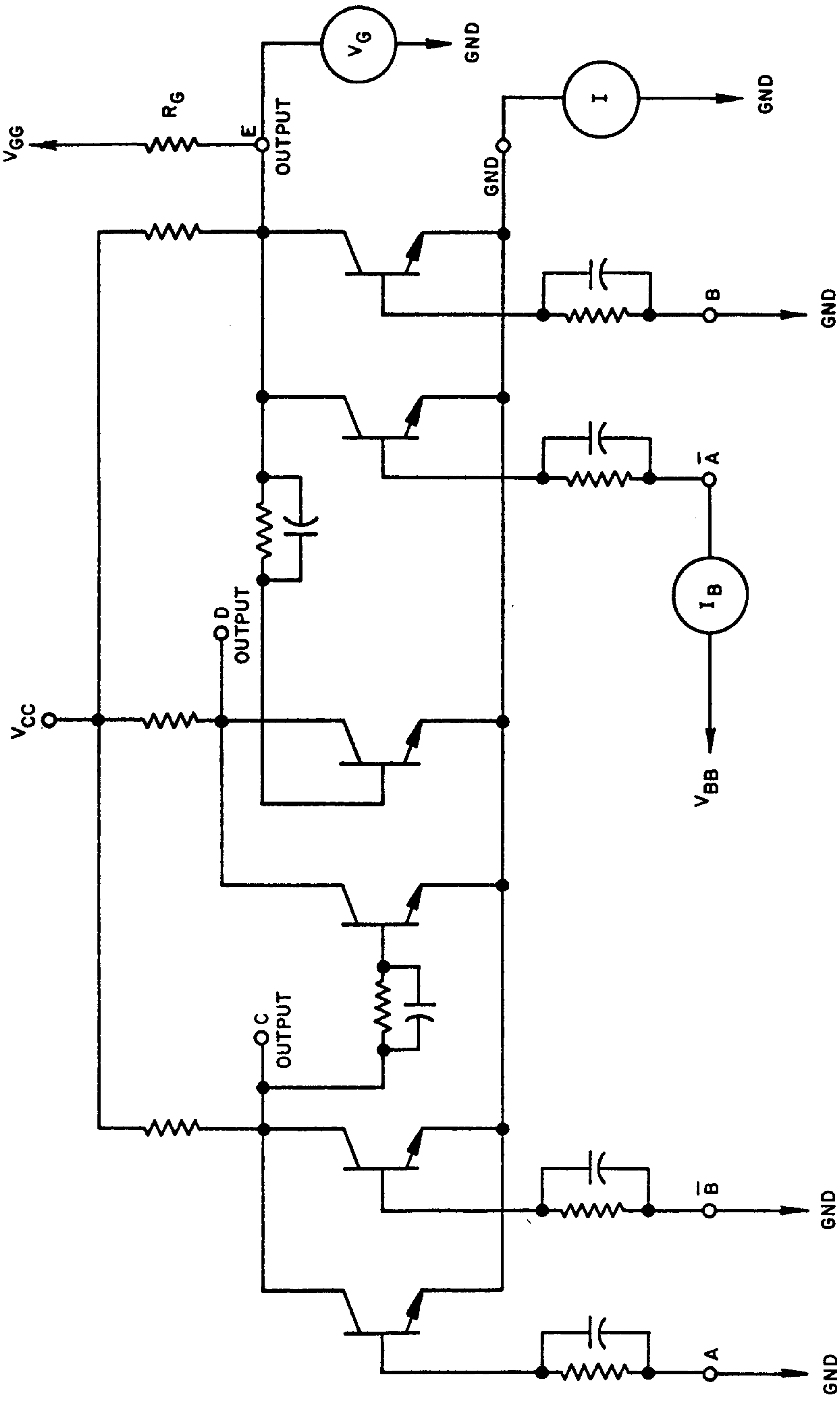
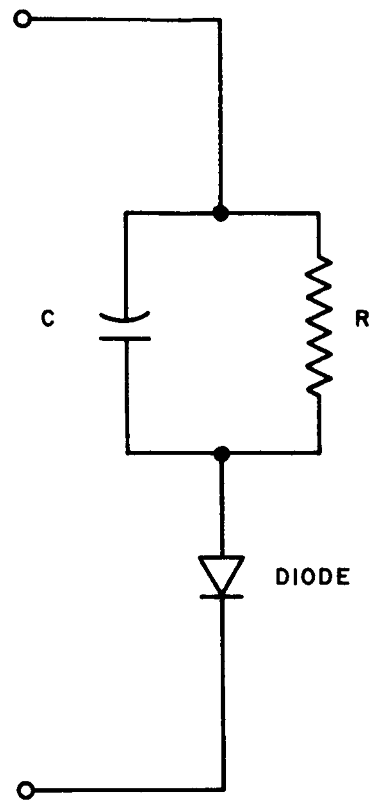


FIGURE 22. TEST CIRCUIT FOR CURRENT GAIN h_{FE} MEASUREMENT, SN 515



C = 200 pf
R = 5 KΩ
D = IN914
N = 4

C = 250 pf
R = 4 KΩ
D = IN914
N = 5

N = FAN-OUT

FIGURE 23. LOAD CIRCUIT FOR SN515

3.3.3.2 Failure Analysis Parameters:

3.3.3.2.1 Collector-Base Reverse Leakage Current I_{CBO}:

The original test circuit planned for this measurement proved unfeasible in usage.. Use of the circuit resulted in the reverse breakdown of base emitter diode of the transistor under test and so the leakage readings were invalidated. No measurements were made of this parameter therefore.

3.3.3.2.2 Load Resistance R_L:

3.3.3.2.2.1 The test circuit was connected as indicated in Figure 20.

3.3.3.2.2.2 The test conditions are indicated in the test procedure section of this report.

3.3.3.2.2.3 The current at each output terminal (I_G) was measured and recorded.

3.3.3.2.2.4 The load resistance (R_L) was determined by dividing the supply voltage (V_{CC}) by the current (I_G) at the output terminals, i.e., $R_L = V_{CC}/I_G$.

3.3.3.2.3 Input Resistance R_B:

3.3.3.2.3.1 The test circuit was connected as indicated in Figure 21.

3.3.3.2.3.2 The test conditions are indicated in the test procedure section of this report.

3.3.3.2.3.3 The input voltage (V_{BB}) was set at the value specified in Para. 2.4 and the input current was measured and recorded.

3.3.3.2.3.4 The test was sequenced in the above manner to obtain measurements of all input resistances.

3.3.3.2.3.5 Each input resistance was determined by dividing the input voltage (V_{BB}) by the input current (I_B), i.e., $R_B = V_{BB}/I_B$.

3.3.3.2.4 Current Gain h_{FE}:

3.3.3.2.4.1 The test circuit was connected as indicated in Figure 22.

3.3.3.2.4.2 The test conditions are indicated in the test procedure section of this report.

3.3.3.2.4.3 The Supply Voltage (V_{GG}) was set at 6 volts with a load resistor (R_G) of 5 K. The base supply voltage (V_{BB}) was increased until the collector-emitter voltage (V_G) was 1 volt. Input Current (I_B) was read and recorded at this point.

3.3.3.2.4.4 The above measurement was performed sequentially at each input.

3.3.3.2.4.5 The DC current gain, (h_{FE}), was determined by dividing the emitter current (I_E) by the input current (I_B) for each input, i.e., $h_{FE} = I_E/I_B$.

3.4 Test Procedures:

3.4.1 Initial Electrical Measurements:

All specimens were subjected to initial visual and mechanical inspection to assure adherence to the manufacturer's physical description and integrity of the test specimen as mounted on the test connector. Units were then numbered in sequence 1 through 20 for each of the specimen types. All units were then measured for the parameters and conditions indicated in the following paragraphs:

3.4.1.1 Unit Type SN 510:

3.4.1.1.1 Switching Times measured per the procedure given in paragraph 3.3.1.1.1 at:

V_{CC} = 3 volts; Temperature = -55°C, 25°C and 125°C

and

V_{CC} = 6 volts; Temperature = -55°C, 25°C and 125°C.

3.4.1.1.2 Output Voltage measured per the procedure given in paragraph 3.3.1.1.2 at;

V_{CC} = 3 volts: Temperature = -55°C, 25°C and 125°C

and

V_{CC} = 6 volts; Temperature = -55°C, 25°C and 125°C

3.4.1.1.3 Minimum Clock Input Voltage measured per the procedure given in paragraph 3.3.1.1.3 at:

V_{CC} = 3 volts; Temperature = 25°C

and

V_{CC} = 6 volts; Temperature = 25°C

3.4.1.1.4 Minimum Set and Reset Voltage measured per the procedure given in paragraph 3.3.1.1.4 at:

V_{CC} = 3 volts; Temperature = 25°C

and

V_{CC} = 6 volts; Temperature = 25°C

3.4.1.1.5 Load Resistance measured per the procedure given in paragraph 3.3.1.2.1 at:

V_{CC} = 6 volts; Temperature = 25°C

3.4.1.1.6 Diode Leakage Current measured per the procedure given in paragraph 3.3.1.2.2 at:

V_{RR} = 6 volts, Temperature = 25°C

3.4.1.2 Unit Type SN 512:

3.4.1.2.1 Switching Times measured per the procedure given in paragraph 3.3.2.1.1 at:

V_{CC} = 3 volts; Temperature = -55°C, 25°C and 125°C

and

V_{CC} = 6 volts; Temperature = -55°C, 25°C and 125°C.

3.4.1.2.2 Output Voltage measured per the procedure given in paragraph 3.3.2.1.2 at:

V_{CC} = 3 volts; Temperature = -55°C, 25°C and 125°C

and

V_{CC} = 6 volts; Temperature = -55°C, 25°C and 125°C

3.4.1.2.3 Input Resistance measured per the procedure given in paragraph 3.3.2.2.3 at:

V_{BB} = 3 volts; Temperature = 25°C

and

V_{BB} = 6 volts; Temperature = 25°C

3.4.1.2.4 Load Resistance measured per the procedure given in paragraph 3.3.2.2.2 at:

V_{CC} = 3 volts; Temperature = 25°C

and

V_{CC} = 6 volts; Temperature = 25°C

3.4.1.2.5 Collector-Base Leakage Current measured per the procedure given in paragraph 3.3.2.2.1 at:

V_{CC} = 3 volts; Temperature = 25°C

and

V_{CC} = 6 volts; Temperature = 25°C

3.4.1.2.6 Current Gain measured per the procedure given in paragraph 3.3.2.2.4 at:

V_{GG} = 3 volts; Temperature = 25°C

and

V_{GG} = 6 volts; Temperature = -55°C and 25°C

3.4.1.3 Unit Type SN 515:

3.4.1.3.1 Switching Times measured per the procedure given in paragraph 3.3.3.1.1 at:

V_{CC} = 3 volts; Temperature = -55°C, 25°C and 125°C

and

V_{CC} = 6 volts; Temperature = -55°C, 25°C and 125°C

3.4.1.3.2 Output Voltage measured per the procedure given in paragraph 3.3.3.1.2 at:

V_{CC} = 3 volts; Temperature = -55°C, 25°C and 125°C

and

V_{CC} = 6 volts; Temperature = -55°C, 25°C and 125°C

3.4.1.3.3 Load Resistance measured per the procedure given in paragraph 3.3.3.2.2 at:

V_{CC} = 6 volts; Temperature = 25°C

3.4.1.3.4 Current Gain measured per the procedure given in paragraph 3.3.3.2.4 at:

V_{GG} = 6 volts; Temperature = -55°C and 25°C

3.4.2.0 Environmental Test Procedures:

3.4.2.1 Thermal Sterilization Test:

3.4.2.1.1 The specified test groups were subjected to three cycles of thermal sterilization. A thermal sterilization cycle consisted of 8 hours of storage at a temperature of 25°C and 42 hours storage at a temperature of 145°C with a transition time of 2 hours between extremes. The thermal sterilization cycle is depicted in Figure 24.

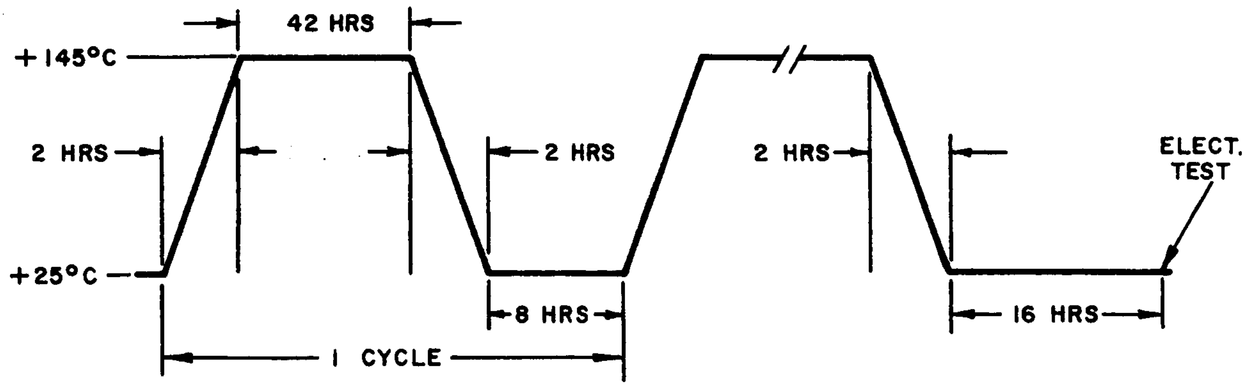


FIGURE 24. THERMAL STERILIZATION CYCLES

3.4.2.1.2 The test units were stabilized at a temperature of 25°C for a period of 8 hours before the following electrical measurements were made.

3.4.2.1.2.1 Unit Type SN 510:

3.4.2.1.2.1.1 Switching Times measured per the procedure given in paragraph 3.3.1.1.1 at:

V_{CC} = 3 volts; Temperature = 25°C

3.4.2.1.2.1.2 Output Voltage measured per the procedure given in paragraph 3.3.1.1.2 at:

V_{CC} = 3 volts; Temperature = -55°C, 25°C and 125°C

and

V_{CC} = 6 volts; Temperature = -55°C, 25°C and 125°C

3.4.2.1.2.1.3 Minimum Clock Input Voltage measured per the procedure given in paragraph 3.3.1.1.3 at:

V_{CC} = 6 volts; Temperature = 25°C

3.4.2.1.2.1.4 Diode Leakage Current measured per the procedure given in paragraph 3.3.1.2.2 at:

V_{RR} = 6 volts; Temperature = 25°C

3.4.2.1.2.2 Unit Type SN 512:

3.4.2.1.2.2.1 Output Voltage measured per the procedure given in paragraph 3.3.2.1.2 at:

V_{CC} = 6 volts; Temperature = 25°C

3.4.2.1.2.2.2 Collector - Base Leakage Current measured per the procedure given in paragraph 3.3.2.2.1 at:

V_{CC} = 6 volts; Temperature = 25°C

3.4.2.1.2.3 Unit Type SN 515:

Output Voltage measured per the procedure given in paragraph 3.3.3.1.2 at:

V_{CC} = 6 volts; Temperature = 25°C

3.4.2.2 Temperature Cycling Test:

3.4.2.2.1 The specified test groups were subjected to 5 cycles of thermal extremes. The thermal cycle consisted of: 25°C for 5 minutes minimum; +125°C for 2 hours minimum; 25°C for 5 minutes minimum; -55°C for 2 hours minimum and return to 25°C for 5 minutes minimum. Transition time between specified temperatures was held to a minimum. Measurements as specified below in paragraph 3.4.2.2.2 were made at the third cycle and the fifth cycle temperature extremes. The thermal cycle is depicted in Figure 25.

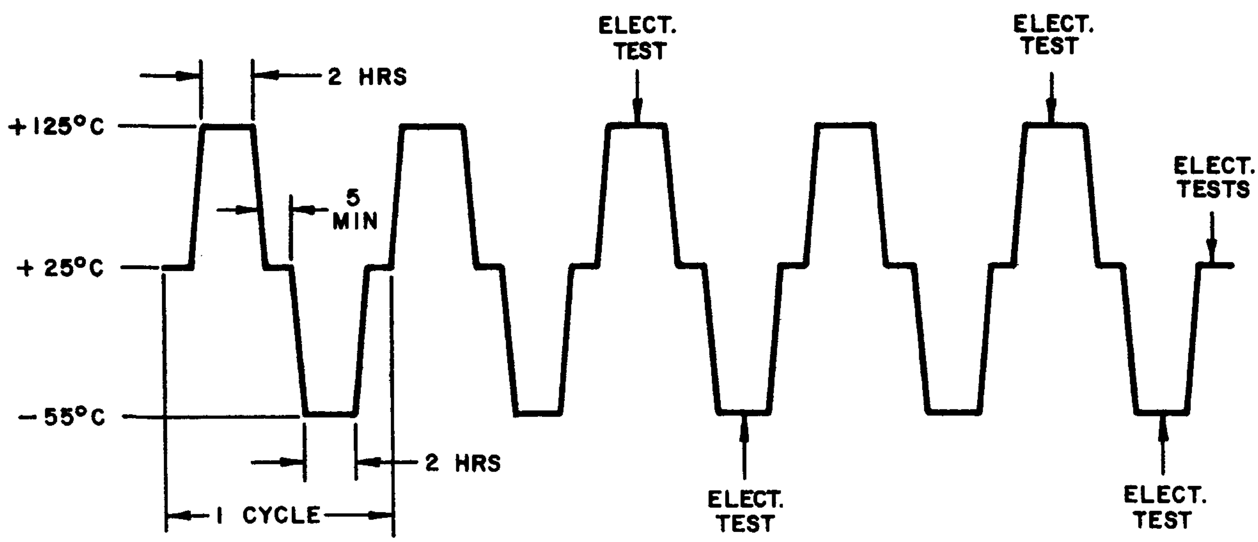


FIGURE 25. THERMAL CYCLES

3.4.2.2.2 The electrical measurements given below were made during the third cycle and the fifth cycle of the temperature cycling test.

3.4.2.2.2.1 Unit Type SN510:

3.4.2.2.2.1.1 Output Voltage measured per the procedures given in paragraph 3.3.1.1.2 at:

V_{CC} = 6 volts; Temperature = -55°C and 125°C

3.4.2.2.2.1.2 Minimum Clock Input Voltage measured per the procedure given in paragraph 3.3.1.1.3 at:

V_{CC} = 6 volts; Temperature = -55°C and 125°C

3.4.2.2.2.1.3 Load Resistance measured per the procedure given in paragraph 3.3.1.2.1 at:

V_{CC} = 6 volts; Temperature = -55°C

3.4.2.2.2.1.4 Diode Leakage Current measured per the procedure given in paragraph 3.3.1.2.2 at:

V_{RR} = 6 volts; Temperature = 125°C

3.4.2.2.2.2 Unit Type SN 512:

3.4.2.2.2.2.1 Output Voltage measured per the procedure given in paragraph 3.3.2.1.2 at:

V_{CC} = 6 volts; Temperature = -55°C and 125°C

3.4.2.2.2.2.2 Collector - Base Leakage current measured per the procedure given in paragraph 3.3.2.2.1 at:

V_{CC} = 6 volts; Temperature = 125°C

3.4.2.2.2.2.3 Input Resistance measured per the procedure given in paragraph 3.3.2.2.3.at:

V_{BB} = 6 volts; Temperature = -55°C

3.4.2.2.2.3 Unit Type SN 515:

Output Voltage measured per the procedure given in paragraph 3.3.3.1.2 at

V_{CC} = 6 volts; Temperature = -55°C and 125°C

3.4.2.2.3 At the completion of the 5 cycles of thermal cycling, the test units were stabilized at a temperature of 25°C for a period of 8 hours before the following measurements were made.

3.4.2.2.3.1 Unit Type SN 510:

3.4.2.2.3.1.1 Switching Time measured per the procedure given in paragraph 3.3.1.1.1 at:

V_{CC} = 3 volts; Temperature = 25°C

3.4.2.2.3.1.2 Output Voltage measured per the procedure given in paragraph 3.3.1.1.2 at:

V_{CC} = 6 volts; Temperature = 25°C

3.4.2.2.3.1.3 Minimum Clock Input Voltage measured per the procedure given in paragraph 3.3.1.1.3 at:

V_{CC} = 6 volts; Temperature = 25°C

3.4.2.2.3.2 Unit Type SN 512:

3.4.2.2.3.2.1 Switching Time measured per the procedure given in paragraph 3.3.2.1.1 at:

V_{CC} = 6 volts; Temperature = 25°C

3.4.2.2.3.2.2 Output Voltage measured per the procedure given in paragraph 3.3.2.1.2 at:

V_{CC} = 6 volts; Temperature = 25°C

3.4.2.2.3.2.3 Input Resistance measured per the procedure given in paragraph 3.3.2.2.3 at:

V_{BB} = 6 volts; Temperature = 25°C

3.4.2.2.3.3. Unit Type SN 515:

3.4.2.2.3.3.1 Switching Time measured per the procedure given in paragraph 3.3.3.1.1 at:

V_{CC} = 6 volts; Temperature = 25°C

3.4.2.2.3.3.2 Output Voltage measured per the procedure given in paragraph 3.3.3.1.2 at:

V_{CC} = 6 volts; Temperature = 25°C

3.4.2.3 Humidity Test:

3.4.2.3.1 The specified test groups were subjected to humidity cycling test per MIL-E-5272C (ASG), procedure I. This test consisted of 10 thermal cycles of storage at a relative humidity of 95%. A thermal cycle started at 25°C. The temperature was gradually raised to 71°C over a 2 hour transition period. The temperature of 71°C was held constant for a period of 6 hours. The temperature was then gradually reduced to 25°C again over a period of 16 hours. The thermal-humidity cyclic test is depicted in Figure 26.

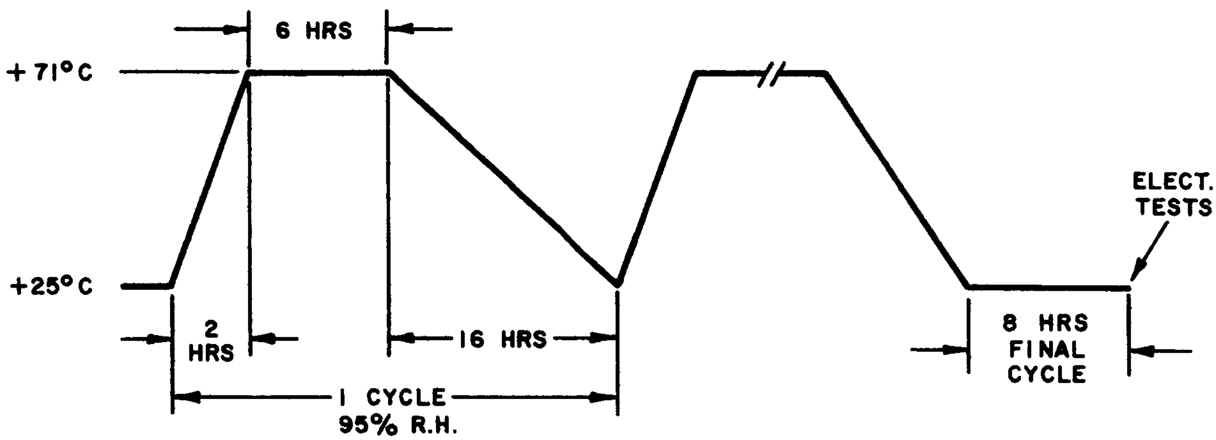


FIGURE 26. THERMAL HUMIDITY CYCLES

3.4.2.3.2 The test units were stabilized at a temperature of 25°C for a period of 8 hours before the following electrical measurements were made.

3.4.2.3.2.1 Unit Type SN 510:

3.4.2.3.2.1.1 Switching Time measured per the procedure given in paragraph 3.3.1.1.1 at:

V_{CC} = 3 volts; Temperature = 25°C

3.4.2.3.2.1.2 Output Voltage measured per the procedure given in paragraph 3.3.1.1.2 at:

V_{CC} = 6 volts; Temperature = 25°C

3.4.2.3.2.1.3 Minimum Clock Input Voltage measured per the procedure given in paragraph 3.3.1.1.3 at:

V_{CC} = 6 volts; Temperature = 25°C

3.4.2.3.2.1.4 Collector-Base Leakage Current measured per the procedure given in paragraph 3.3.1.2.2 at:

V_{CC} = 6 volts; Temperature = 25°C

3.4.2.3.2.2 <u>Unit Type SN 512</u>:

3.4.2.3.2.2.1 Switching Times measured per the procedure given in paragraph 3.3.2.1.1 at:

V_{CC} = 6 volts; Temperature = 25°C

3.4.2.3.2.2.2 Output Voltage measured per the procedure given in paragraph 3.3.2.1.2 at:

V_{CC} = 6 volts; Temperature = 25°C

3.4.2.3.2.2.3 Collector-Base Leakage current measured per the procedure given in paragraph 3.3.2.2.1 at:

V_{CC} = 6 volts; Temperature = 25°C

3.4.2.3.2.3 <u>Unit Type SN 515</u>:

3.4.2.3.2.3.1 Switching Times measured per the procedure given in paragraph 3.3.3.1.1 at:

V_{CC} = 6 volts; Temperature = 25°C

3.4.2.3.2.3.2 Output Voltage measured per the procedure given in paragraph 3.3.3.1.2 at:

V_{CC} = 6 volts; Temperature = 25°C

3.4.3.0 <u>Life Test Procedures</u>:

3.4.3.1 <u>High Temperature Operating Life Test Procedures</u>:

3.4.3.1.1 All test specimens were subjected to a 2000-hour high temperature operating life test. The units were logically interconnected as shown in figures 27-30. The test circuit

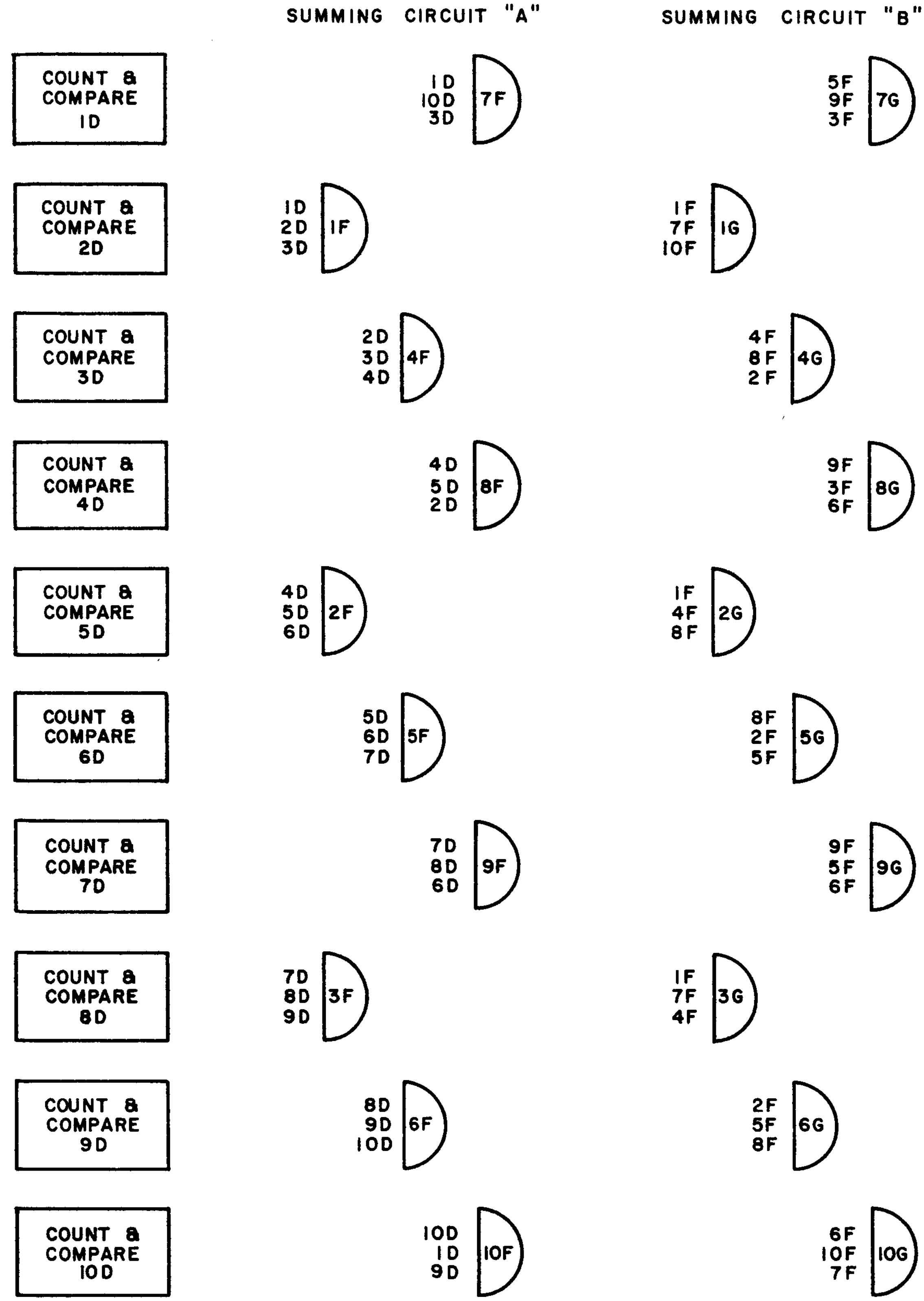


FIGURE 27. OPERATING LIFE TEST CIRCUIT BLOCK DIAGRAM

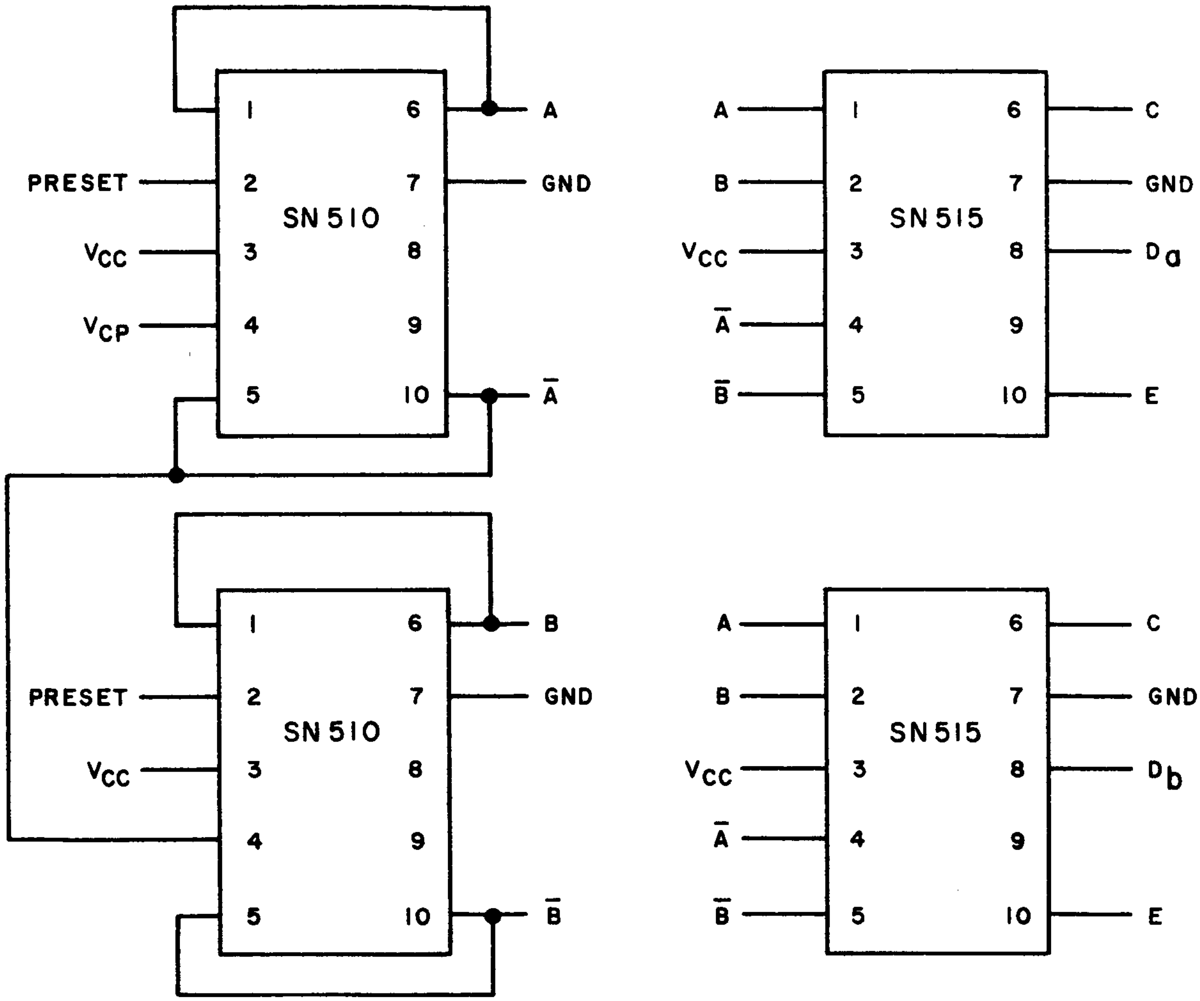


FIGURE 28. OPERATING LIFE TEST CIRCUIT
COUNT AND COMPARE MODULE

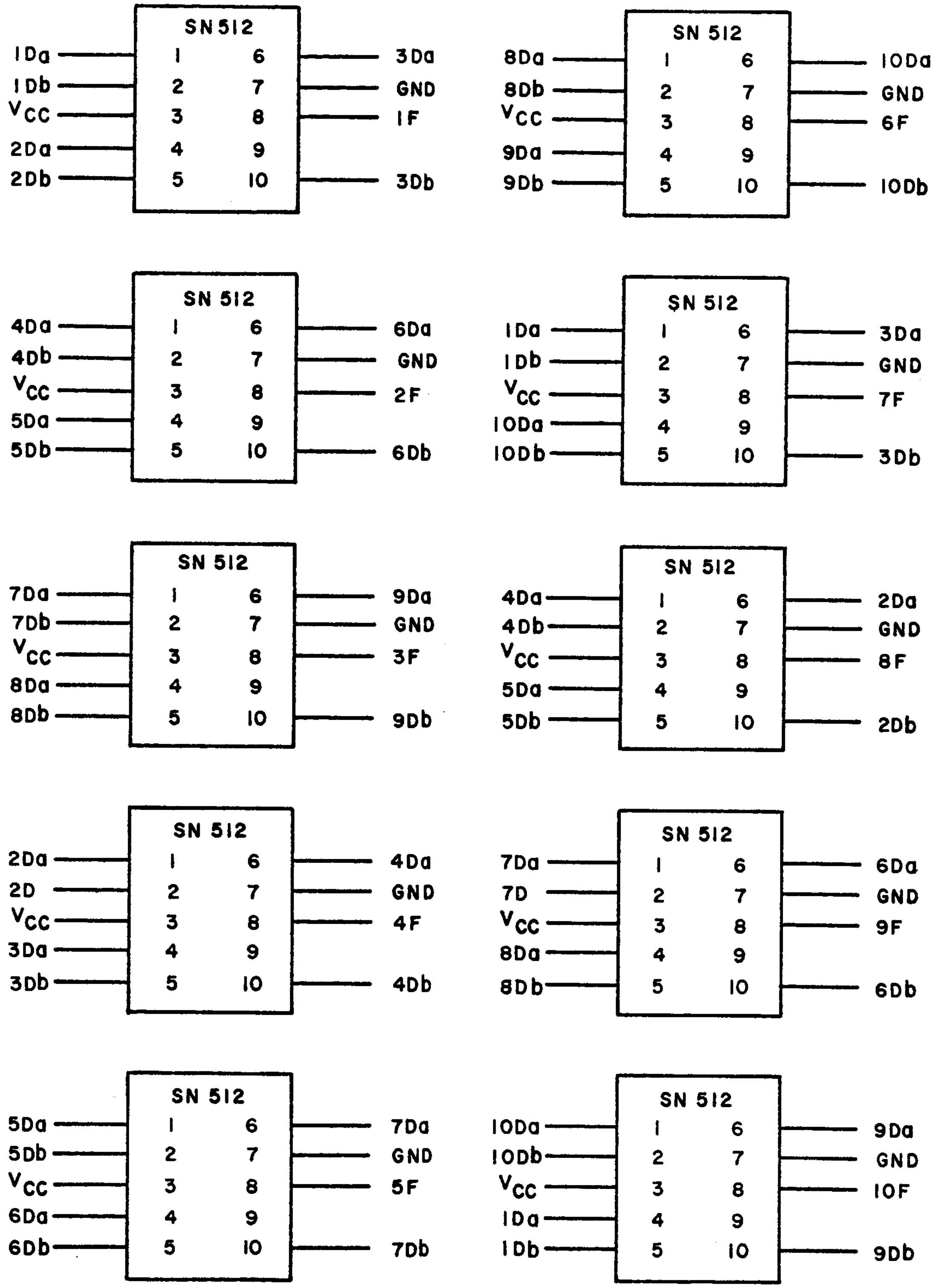


FIGURE 29. LIFE TEST CIRCUIT SUMMING CIRCUIT "A"

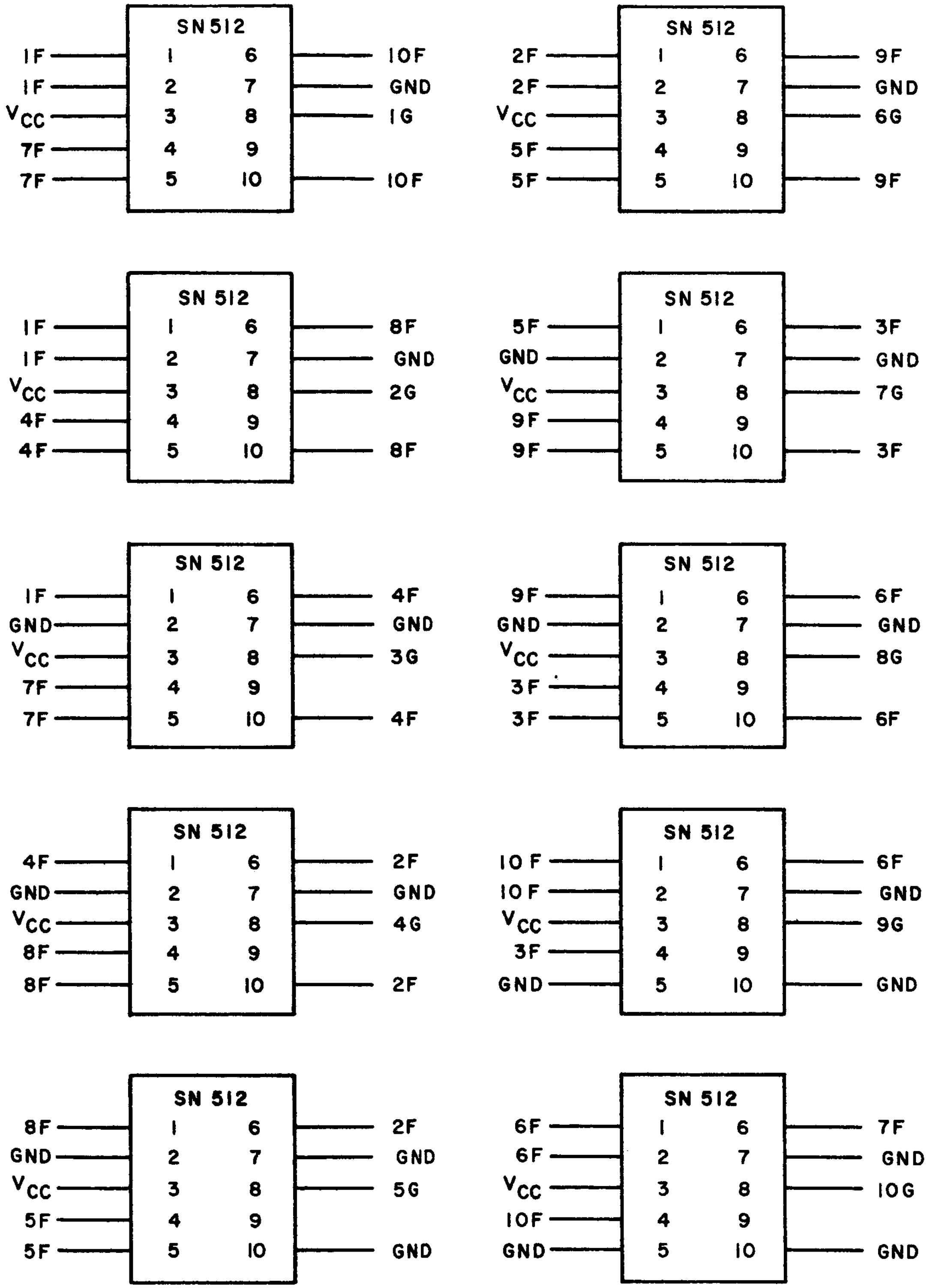


FIGURE 30. LIFE TEST CIRCUIT SUMMING CIRCUIT "B"

was designed to obtain maximum loading on the test units. Equivalent "dummy" loads such as shown in figures 8, 16, and 23 were used to fully load every test unit. The logic design also allowed removal of catastrophic failures without functionally disrupting the remaining circuitry. The load and logic interconnections and the test platform were integrated into a single test fixture to minimize lead capacitance problems.

The high temperature operating life test was made at an ambient test temperature of 100°C. The test units were operated at V_{CC} = 6 volts and a clock input frequency of 100 KC at a clock voltage of 2 volts peak to peak.

3.4.3.1.2 The logic operation was monitored periodically throughout the life test to ensure functional operation and to observe for failures. This was accomplished manually with an oscilloscope probe at output points.

The following measurements were made at 50, 100, 500, 1000 and 2000 hours check points. Test units were allowed to stabilize at a temperature of 25°C for a period of at least 8 hours before measurements were performed.

3.4.3.1.2.1 Unit Type SN 510:

3.4.3.1.2.1.1 Output Voltage measured per the procedure given in paragraph 3.3.1.1.2 at:

V_{CC} = 6 volts; Temperature = 25°C

3.4.3.1.2.1.2 Minimum Clock Input Voltage measured per the procedure given in paragraph 3.3.1.1.3 at:

V_{CC} = 6 volts; Temperature = 25°C

3.4.3.1.2.2 Unit Type SN 512:

3.4.3.1.2.2.1 Output Voltage measured per the procedure given in paragraph 3.3.2.1.2 at:

V_{CC} = 6 volts; Temperature = 25°C

3.4.3.1.2.2.2 Current Gain measured per the procedure given in paragraph 3.3.2.2.4 at:

V_{GG} = 6 volts; Temperature = 25°C

3.4.3.1.2.3 Unit Type SN 515:

3.4.3.1.2.3.1 Output Voltage measured per the procedure given in paragraph 3.3.3.1.2 at:

V_{CC} = 6 volts; Temperature = 25°C

3.4.3.1.2.2.2 Current Gain measured per the procedure given in paragraph 3.3.2.2.4 at:

V_{GG} = 6 volts; Temperature = 25°C

3.4.3.1.2.3 Unit Type SN 515:

3.4.3.1.2.3.1 Output Voltage measured per the procedure given in paragraph 3.3.3.1.2 at:

V_{CC} = 6 volts; Temperature = 25°C

3.4.3.1.2.3.2 Current Gain measured per the procedure given in paragraph 3.3.3.2.4 at:

V_{GG} = 6 volts; Temperature = 25°C

3.4.3.2 High Vacuum Operating Life Test Procedures:

3.4.3.2.1 All test units were subjected to a 500 hour high vacuum operating life test. The test units were operated in the same configuration and input supplies as used in the preceeding test (paragraph 3.4.3.1.1). The vacuum was maintained at a maximum of 10-4 mm Hg.

3.4.3.2.2 Measurements per paragraph 3.4.3.1.2 were performed on all test units at 250 and 500 hours test points.

3.4.4 Mechanical Test Procedures:

3.4.4.1 Shock Test Procedures:

3.4.4.1.1 The specified groups of test units were subjected to 5 impacts of shock of an amplitude of 300 G's and a duration of 3 m sec in each of the 3 mutually perpendicular planes (X, Y, Z). The test units were initially encapsulated in Shell Epon 828 epoxy in a form that could be rigidly secured in the shock fixture.

3.4.4.1.2 All final electrical measurements as specified in paragraph 3.4.5 were initially performed on the mechanical test specimen as a precautionary measure. Measurements per paragraph 3.4.3.1.2 were performed at the conclusion of the encapsulating operation and following the shock tests.

3.4.4.2 Vibration Test Procedures:

3.4.4.1.1 The shock test units were subjected to a sweep vibration test of 35 G's peak acceleration. The frequency sweep was from 30 cps to 3000 cps and back to 30 cps at a logarithmic rate. A sweep cycle duration was 5 minutes with 3 cycles made in each of the 3 mutually perpendicular planes (X,Y,Z).

3.4.4.1.2 Measurements per paragraph 3.4.3.1.2 were made at the conclusion of the test.

3.4.5 Final Electrical Measurements:

At the conclusion of the Life Test all test units were measured per the procedure given for the Initial Electrical Measurements in paragraph 3.4.1.

3.5 Data Recording Procedures:

All measurement and observation data were manually recorded in permanent form on reproducible data sheets. Data records include conditions of test, type of test, identity of specimens tested, equipment used and a description of unusual occurances noted. Data was screened by the cognizant test engineer for failures and data trend assessments. In the event unusual or suspect data was found, measurements were repeated.

3.6 Failure Criteria and Analysis Procedures:

3.6.1 Failure Definitions:

3.6.1.1 Catastrophic Failure:

A catastrophic failure was defined as a degradation of a logic or transfer function to such an extent that the specimen is unable to fully drive a like stage. Included in this definition would be open and short circuits of a specimen element.

3.6.1.2 Degradation Failure:

A degradation failure was defined as a change in a Design Parameter of greater than or equal to ±20% of the initial measured value.

3.6.2 Failure Analysis Procedures:

When a catastrophic failure as defined in paragraph 3.6.1.1 was observed, the cognizant JPL Representative was notified informally of the occurance. Preliminary analysis was conducted at that time to determine the area and mode of failure and the possible causes. In the event the specimen had partial normal functional capability, it was returned to test. If the specimen was wholly disabled, and in any event at the conclusion of the test program, the failure analysis was continued with autopsy of the unit to determine the exact area of failure and probable causes. The findings of these analysis efforts are contained in the Results Section of this report.

4.0 TEST RESULTS:

4.1 Catastrophic Failures:

4.1.1 Mechanical Failures:

4.1.1.1 Test Specimen Lead Breakage:

A severe handling problem was encountered during the test program resulting in considerable test specimen lead breakage. This problem was inherent in the exposed mounting technique used for the test specimens. The problem may also be attributed to the multiplicity of test specimen handling for measurement and test set-up. Lead breakage occurred in the two hi-stress bend areas as shown in Figure 31. Remedial controlled-temperature soldering was sometimes successful if the break occurred in the bend "B" area. This technique was used on some of the test specimens during the test program to prolong their usefulness.

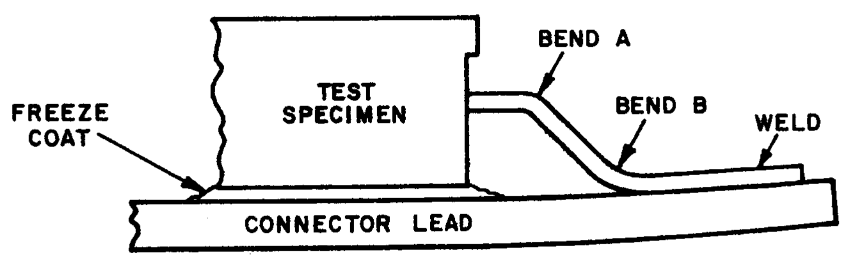


FIGURE 31. TEST SPECIMEN MOUNTING

Listed below are test specimens that experienced lead breakage during the test program.

Type SN510; Unit #5:

Lead #1 (reset input) broken during measurements at the 1037 hour test point of the high temperature operating life test. This broken connection disabled the element operation and necessitated removal from the test.

Type SN510; Unit #6:

Lead #1 (reset input) broken after measurements at the 1037 hour point of the high temperature operating life test. This broken connection disabled the element operation and the test specimen was removed from test.

Type SN 515; Unit #1:

Lead #5 (B input) broken before initial measurements started. The test specimen remained in the test program. This lead then was temporarily repaired at the 537 hour test point during high temperature operating life test and remained operational until the 250 hour test point during high vacuum operating life test. At this time, leads #1 (A input); #2 (B input); #4 (A input) and #6 (C output) were broken. The damage was not repairable and the test specimen was withdrawn from the test program.

Type SN 515; Unit #8:

Lead #1 (A input) broken before the start of the high temperature operating life test. The test specimen remained in the test program operating with reduced functional capability.

Type SN 515; Unit #15:

Lead #4 (A input) was broken during initial measurements. The test specimen remained in the test program operating with reduced functional capability.

4.1.1.2 Test Specimen Mounting Failures:

An error in the mounting process resulted in the failure of two of the test specimens. (type SN 510; Unit #16 and Unit #18). They were mounted on the connector in a reversed-transposed manner which preserved the connector pin arrangement but resulted in shorting the leads #6 through #10 to the metal wafer cover. This shorting of the elements functions caused catastrophic damage to the test specimens.

4.1.1.3 Connector Contact Failures:

Considerable difficulty was encountered during the test program with connector contacts. The test specimens were mounted on prototype samples of the Cannon Micro "D" line. The many insertions and withdrawals to which the connectors were subjected resulted in instances of random contact failure and of two specific cases of continous failure. Examination of the open connector contact problems indicated the spiral-wound multi-wire element "Micropin" would take on a semi-permanent "set" with a contacting surface diameter less than that of the mating "Microsocket". When this occurred an open circuit would result. Random contact failures, when noticed by the technician, would be repeated. In a few instances during the test program, the open contact was not observed or could not be remedied at the time and the recorded data was in error. In two instances, during the test program, the connector failures were permanent. These units are noted below. All other contact failures observed were completely random in nature, occurring on a one time basis only.

Type SN 512; Unit #3:

Pin lead #4 ("D" input) failed during initial measurements by exhibiting an open circuit. The test specimen remained in the test program. During final measurements, Pin lead #10 ("F" input) failed in the same manner.

Type SN 512; Unit #17:

Pin lead #5 ("E" input) failed by opening during initial measurements. Other pin lead contacts also opened and the unit was removed from further testing.

4.1.2 Confirmed Catastrophic Failures:

There was one incidence of a positive catastrophic failure of a test specimen during the test program. Test specimen type SN 510, Unit #19 failed after the thermal sterilization test. Failure was indicated by an open circuit at lead #6 (Q output) and all element parameters deviating significantly. The test specimen was removed from the test program and an internal autopsy was performed.

The autopsy showed the entire silicon wafer had broken loose from the glass mounting case and was suspended in the package by the gold interconnecting leads. Furthermore the gold wire bond from lead #6 (Q output) had come loose at the aluminized silicon surface.

The cause of the failure was attributed to poor manufacturing control in two areas. First in the process of fusing the silicon wafer to the glass case substrate and secondly, in the thermal compression bond of the gold interconnecting wire to the aluminized silicon surface.

4.2 Parametric Failures:

4.2.1 Test Specimen Group Type SN 510:

During the high temperature operating life test at the 537 hour measurement point, measurements of output voltage at V_{CC} = 6 volts; T = 25°C indicated that 14 test specimens had a marked increase (20-25%) in one or more of the "Off" or high voltage parameters. These increases were noted only at this measurement point as the parameters in question returned to approximately the values recorded previous to the 537 hour test point at the 1037 hours measurement point. Further investigation indicated that the observed deviations were "step function increases" of approximately 0.63 volts for the unloaded measurements and 0.77 volts for the loaded measurements. Analysis has indicated that a temporary increase in input voltage (V_{CC}) of about 1 volt would produce a change of this magnitude. The possibility of a drastic temporary parameter change within the test specimens would be highly improbable. It was therefore concluded that an input voltage regulation failure during a portion of the measurements at the 537 hour test point was the cause of these parameter deviations and that they are not failures.

At the final measurements point the output voltage measurements of the "On" or saturation voltage parameter were found to have increased between 20% - 25% over initial readings for the following conditions and test specimens.

At V_{CC} = 3 volts; T = 125°C: 13 test specimens at one or more measurement points.

At V_{CC} = 6 volts; T = 125°C: 2 test specimens at one or more measurement points.

At V_{CC} = 3 volts; T = -55°C: 6 test specimens at one or more measurement points.

At V_{CC} = 3 volts; T = 25°C: 5 test specimens at one or more measurement points.

All parametric failures above occurred in 13 test specimens only, and there was direct correlation between failures at all conditions. All of the parametric failures above were still within the specification given for output "On" voltage in paragraph 2.2.1 and in no case did any of the test specimens fail functionally in the life test circuit.

4.2.2 Test Specimen Group Type SN 512:

No parametric failures were observed during the test program. In certain specific cases, substantial changes were observed in measured parameter values, but all of these were traced to faulty connector contacts as described in paragraph 4.1.1.3.

4.2.3 Test Specimen Group Type SN 515:

Measurements of output "on" voltage at the 3rd cycle test point of the thermal cycling test indicated the following test specimens had parameter increases of 20% - 25% over initial readings; Test Conditions were: V_{CC} = 6 volts; T = -55°C.

Test Specimen # 5: Input A, Output C

Test Specimen # 13: Input A, Output C
: Input B, Output D
: Input B, Output E

Test Specimen # 18: Input B, Output D
: Input B, Output F

Measurements of output "on" voltage at the final measurements point indicated the following additional test specimen had parameter increases of 20% - 25% over initial readings. Test conditions were: V_{CC} = 6 volts; T = -55°C.

Test Specimen # 10: Input A, Output C

The parametric failures above were still within the specified limits given in paragraph 2.4.1 for output "on" voltage and in no case did any of the test specimens fail functionally in the life test circuit.

4.3 Thermal Environmental Test Results:

4.3.1 Test Specimen Group Type SN 510:

No significant design parameter changes were noted on the test specimens as a result of exposure to the three thermally related environments. Measurement difficulties encountered with the design and operation of the Solid State Module Test Set negated the original initial measurements of output voltage and minimum clock input voltage. These measurements were repeated after corrections were made in the test set and procedures at the post thermal sterilization measurement point. This occurrence did degrade the effectiveness of the observational measurements of the effects of thermal sterilization on the test specimens but sufficient information was available to determine that no significant changes had occurred in the test units.

The effect of the thermal environments on the failure analysis parameters measured on the test specimens were not completely positive. Certain trends did appear as explained below but these changes were not confirmed as typical or significant.

4.3.1.1 Output Voltage:

As noted above, the initial measurement of this parameter were voided so that the repeated measurements after thermal sterilization do not indicate the parameter deviational effects of this environment. However, all measurements taken do indicate the parameters were well within the specified limits in paragraph 2.2.1 and were closely grouped near the respective means (See paragraph 4.6.1.1).

The effects of thermal cycling on output voltages were measured at the two operational temperature extremes. An attempt was made to try to differentiate the effects of an increasing number of thermal cycles by making 3rd cycle and 5th cycle measurements. The results were interesting but not significant. Comparison of initial, 3rd cycle and 5th cycle means indicated incremental changes of less than 3%. A 2^n factorial test was performed on the post thermal cycling measurements and the initial measurements. No significance at the 95% confidence level could be found in the observed incremental changes. The effects of the humidity environment on output voltages was not appreciable. Measurements taken after this environment were compared to initial measurements via a 2^n factorial test. No significant incremental parameter changes were noted assuming a confidence limit of 95%.

4.3.1.2 Switching Time Measurements:

Initial Switching time measurements were made as specified in paragraph 2.2.1 in regards to the output load. The test setup was made following the procedures used at Texas Instruments but no calibrating measurement comparisons were made with their equipment. Therefore, a measurement deviational tolerance of 20% could reasonably be put on the measurements when comparing them to a standard limit. Using this tolerance all initial switching time measurements were within their respective specified limits. Distributions of values were quite close to their respective means (see paragraph 4.6.1.2).

Switching time measurements at the post thermal cycling measurement point indicated that the voltage set time values were less than initial readings but the decrease could not be considered significant.

Switching time measurements at the post humidity measurement point again indicated that there were no significant trends in the values.

4.3.1.3 Minimum Clock Input Voltage:

Initial measurements of this parameter were not completed until after the thermal sterilization test was performed as explained above. This happening limited the analysis of the effects of thermal sterilization on this parameter to the observation that the initial data distributions were all well within the specified limits of paragraph 2.2.1 and the values measured were closely grouped about their respective means (see paragraph 4.6.1.3).

Measurements of this parameter were made at the 3rd and 5th cycle test points of the thermal cycling test to attempt to find if there is a significant effect in the number of thermal cycles applied. The results of this experiment were negative. A 2^n factorial test was performed on the measurements made at the post thermal cycling test point and the initial measurement made at the post thermal sterilization test point. No significance at the 95% confidence level could be attached to the incremental changes in the results.

Minimum clock input voltage was measured at the post humidity test point at ambient conditions. A 2^n factorial test comparing this measurement with the previous initial measurement indicated no significance could be attached to the incremental changes at a confidence level of 95%.

4.3.1.4 Load Resistance:

The load resistance was measured at -55°C during the thermal cycling test at the 3rd and 5th cycle test points. The results indicate a definite downward trend in load resistance with increasing thermal cycling. The mean value at the 3rd cycle test point was 3,220 ohms while at the 5th cycle test point it decreased to 3,010 ohms. These results were confirmed by the increase in total input current observed while making -55°C output voltage measurements.

4.3.1.5 Diode Leakage Current:

The initial measurements of diode leakage current indicated a wide range of values some of which would normally be classified as failures. (Note: diode leakage is not specified). Investigation of the measurements indicated the test specimens were very susceptible to external contamination which had a marked influence on these measurements. The measurements were repeated at the post sterilization point with a resultant decrease in most of the individual measurements. There was still a wide dispersion of values however.

Subsequent measurements were made at the 3rd and 5th cycle test points of the thermal cycling test. These measurements were made at 125°C. The results indicated a wide dispersion of values as before. Preliminary investigation of the causes for these readings indicate that the difficulty involved in isolating the input diode junction leakage from other elements effects may be the cause of some of the seemingly inconsistant measurement values recorded.

4.3.2 Test Specimen Group Type SN 512:

No significant design parameter changes were observed on the test specimens as a consequence of exposure to the three thermally-related environments. Some definite shifts were noted in the failure analysis parameter measurements. It is doubtful that the trends could be judged as typical of the unit, however. Individual parameter summations are given below.

4.3.2.1 Output Voltage:

All initial measurements of output voltage were found to be well within the specified limit given in paragraph 2.3.1 and the measurements in general were closely grouped around their respective means. (See paragraph 4.6.2.1).

Output voltage measurements at the post thermal sterilization measurement point indicated no appreciable parameter change from initial measurements.

Measurements made at the 3rd cycle and the 5th cycle test point of the thermal cycling test of output voltage indicated minimum incremental change of the parameters either at the 125°C or the -55°C measurement condition.

Post thermal cycling measurements of output voltage at ambient temperature were checked with 2^n factorial test against previous readings made at the initial measurement point and at the post thermal sterilization test point. No significant interactions or incremental changes were found at a confidence level of 95%.

Output voltage measurements taken at the post humidity test point were also checked via a 2^n factorial test against the previous readings. Again no significant interactions or incremental.changes were found at a confidence level of 95%.

4.3.2.2 Switching Time Measurements:

All switching time measurements were made with maximum loading on the output to obtain an indication of actual propagation delay times to be expected in device usage. Measurements therefore could not be directly compared to those specified in paragraph 2.3.1. Initial measurements in general were quite closely grouped about their respective computed means (see paragraph 4.6.2.2.).

Switching time measurements at the post thermal cycling point indicated an increase in delay time readings and a reduction of rise time, storage time, and fall time readings. These shifts in measurements were not of a sufficient magnitude to indicate they were significant.

Post humidity switching time measurements also indicated the same trends as specified above evident. But again, the parameter shifts could not be judged significant based on the degree of change (approximately 15% higher and 10% lower respectively) and the inherent accuracy of the measurement.

4.3.2.3 Collector-Base Leakage Current:

The initial readings were generally low with only a few scattered readings exceeding 1 ua (at T=25°C; V_{CC} = 6 volts).

At the 3rd cycle and the 5th cycle test points, during the thermal cycling test, the collector-base leakage current was measured to obtain comparative information. Readings were obtained at the 125°C test point and indicated a definite decrease in leakage current between the 3rd and 5th cycle test points. The mean value calculated for the 3rd cycle readings was 3420 na as opposed to the 5th cycle mean of 1520 na. This marked decrease in collector-base leakage current may be due to a reduction of internal surface leakage thru a continuation of the normal passivation techniques applied to these units as activated by the application of heat.

Readings taken at the post humidity measurement point at ambient temperature also indicated a marked reduction of individual values when compared to initial measurements. This would tend to support the theory given above that an internal passivation mechanism was activated by the thermal environments.

4.3.2.4 Input Base Resistance:

Initial measurements of this parameter indicated a reasonably close distribution about the mean values (See paragraph 4.6.2.4).

Input base resistance measurements were made at the 3rd and the 5th cycle test points during the thermal cycling test. The measurements indicated a slight downward shift of the mean resistances. The mean at the 3rd cycle = 17,400 ohms while at the 5th cycle point = 16,900 ohms. This 3% downward shift could not consider to be significant in itself.

4.3.3 Test Specimen Group Type SN 515:

There were no confirmed significant design parameter changes noted on the test specimens as a result of exposure to the three thermally-related environments. Measurement difficulties excluded any current leakage testing on the test specimens during the test. Given below are summaries of individual parameter measurements evaluations.

4.3.3.1 Output Voltage:

All initial readings were within the specification limits given in paragraph 2.4.1 and the value distributions were in general quote closely grouped around their respective means. (See paragraph 4.6.3.1).

Output voltage measurements taken at the post thermal sterilization test point indicated very little change from initial values.

Output voltage measurements were made at the 3rd cycle and 5th cycle test points during the thermal cycling test. Comparison of the values and means at the test temperature of 125°C indicated very little change. Measurements made at the test temperature of -55°C though indicated an upward shift in saturation voltage. The initial measurement mean was 0.151 volts while at the 3rd cycle it was 0.158 volts and at the 5th cycle, it was 0.159 volts. While this upward trend was uniform, it cannot be termed significant.

Output voltage was measured at the post thermal cycling test point. The mean value obtained at this point was 0.163 volts as compared to an initial mean of 0.174 volts. A 2^n Factorial test was performed on this data in comparison to values taken initially and post thermal sterilization. This test indicated no significant interactions or appreciable parameter changes could be detected at a confidence level of 95%.

Output voltage was measured at the post humidity test point. The mean value obtained at this point was 0.175 volts. This mean value was on the same test specimens as used above. This would tend to indicate the previous readings may include instrument error. As far as can be determined, the same instrumentation was used in both measurements, with the same technician attending. The measurements obtained were also subjected to a 2^n factorial test in comparison to data taken initially and post thermal sterilization. No significant interactions or appreciable parameter changes could be detected at a confidence level of 95%.

4.3.3.2 Switching Time Measurements:

All switching time measurements were made with maximum loading in the outputs to obtain an indication of actual propagation delay times to be expected in actual device usage. The measurements, therefore, could not be directly compared to those specified in paragraph 2.4.1. Initial measurements in general were closely grouped about their respective computed mean values (see paragraph 4.6.3.2).

Switching time measurements made at the post thermal cycling test point indicated that voltage set time and fall time values decreased slightly. These changes are not considered significant.

Switching time measurements made at the post humidity test point again indicated that the voltage set time and fall time measurements decreased slightly. The change (approximately 5%) is not judged significant.

4.4 Operating Life Environmental Test Results:

4.4.1 Test Specimen Group Type SN 510:

There were no confirmed significant parameter shifts observed during the coupled-sequential environmental life test of these test specimens. Results of measurement parameter data analysis are presented in the following paragraphs.

4.4.1.1 Output Voltage:

Output voltage measurements were analyzed via the JPL Specification ZPP-2040-GEN A statistical format. The computed results are presented in Appendix B. The analysis was accomplished on a total test sample size of 19, with one replacement sample in the life test logic not exposed to the thermal environment and therefore not in test. The eight possible output variations were analyzed on an individual basis. The analysis indicates very close grouping of both the "Off" voltage and the "On" voltage readings except at certain of the 537 hour high temperature operating life measurements as indicated below.

The analysis of the output "Off" voltages with no external loading is shown in Appendix B, pages 1 and 2. Some of the measurement at the 537 hour point of the high temperature operating life test was found to be substantially in error due to external voltage input (V_{CC}) variation (see paragraph 4.2.1). Thus both the "F" test and the "t" test values for the 537 hour measurements and the 1037 hour measurement, when the measurements returned to control, were statistically significant.

Incremental data changes during the entire life test period were slight in view of the basic sensitivity of the instrumentation and the inherent measurement time-technician variability. The statistical significance indicated, at a confidence of 95%, in the "t" tests at the 117 hour measurement point of the high temperature operating life test and at the 250 hour and 500 hour measurement points of the high vacuum operating life test cannot be considered parametrically significant because of basic measurement tolerances. The general decreasing trend or drift of V off during the life tests, however, it is to be expected in view of the load resistance change noted in initial and final data (see paragraph 4.6)

The analysis of the output "Off" voltages with maximum loading is shown on pages 3 and 4 of Appendix B. A portion of the measurements at the 537 hour point of the high temperature operating life test was found to be grossly in error due to external voltage input (V_{CC}) variation (see paragraph 4.2.1). The abrupt discontinuities in the data caused by this error are indicated by the statistically significant "F" and "t" tests shown for the 537 hour and 1037 hour measurement points. Discounting the basic measurement tolerances imposed by the sensitivity of the instrumentation and the inherent measurement time - technician variability,incremental data changes during the life tests were very small. Therefore, the statistically significant, at a confidence level of 95%, "t" test values calculated for the 117 hour and 2000 hour (V off Q only) measurement points of the high temperature operating life test and the 250 hour and 500 hour measurement points of the high vacuum operating life test cannot be considered parametrically valid.

The analysis of the output "On" voltages, both with no load and maximum external loading is shown in Appendix B, pages 5 through 8. The data is very closely grouped with standard deviations of less than 10 millivolts. All "F" test values of data variability indicated no significance, at a confidence level of 95%. At a confidence level of 95%, all initial and final "t" test values indicated significance data shifts in increasing values of "V on" or saturation voltage. Scattered statistically significant "t" test values were calculated at the intervening measurement points both in the negative and positive directions. These values point out the measurement variability inherent in this data.

It is concluded that a definite parametric increase cannot be predicted based only on the results of these measurements.

4.4.1.2 Minimum Clock Input Voltage:

Minimum clock input voltages measured during the life tests were all well within the tolerances specified in paragraph 2.2.1. Individual incremental changes in measurement values at all points were small. The calculated mean values of the measurement indicated a gradual increase in clock input voltage reaching a peak at the 537 hour high temperature operating life measurement point. The mean value then exhibited a decreasing slope to the final life test measurement. The measure criteria necessary for this particular test involves human judgment of a stability point which increases the total measurement tolerances that must be taken into account in assessing the results of these measurements. The results indicated by this data could not be considered significant because of these limitations.

4.4.2 Test Specimen Group Type SN 512:

There were no confirmed significant parameter shifts observed during the coupled-sequential environmental life tests of these test specimens. Summaries of the analysis of parameter measurements are presented below:

4.4.2.1 Output Voltage:

Output voltage measurements were analyzed via the JPL Specification ZPP-2040-GEN A statistical format. The calculated results are presented in Appendix B, pages 9 through 14. The analysis was accomplished on a total sample size of 19 test specimens. One replacement sample was used in the life tests to complete the logic pattern but was not subjected to the thermal environment and so was not considered a part of the test. One test specimen had a non-operating input (see paragraph 4.1.1.3) which decreased the functional capability of this test specimen and measurement points of the V on (D) parameter by one. The data was grouped for analysis by individual input gates. The analysis results for all 6 input gates indicated the parameter distribution to be very closely grouped about the mean values. Standard deviations of all measurement points were less than eleven millivolts. The "F" statistic test values, at a confidence level of 95% indicated there was no significant spreading of data measurements at any point.

The "t" statistic test values, at a confidence level of 95%, indicated statistically significant incremental data shifts on all initial calculations (at 117 hours, high temperature operating life test); at 537 hours for V on (A), V on (B) and V on (C); at 1037 hours for V on (B), V on (C), and V on (D); at 2000 hours for V on (B). - all values measured during the high temperature life test. Statistical significance was also noted for the V on (E) 250 hour and 500 hour measurement points during the high vacuum operating life test. The shifts could not be termed significant in an engineering sense due to the inherent measurement tolerances that were present. It was concluded that no parameter trends were evident in this data.

4.4.2.2 Current Gain:

D.C. current gain measured during the life tests did not deviate significantly at any point. Calculated mean values exhibited less than 1% shift during the life tests. The data was fairly closely distributed throughout the life tests. No apparent parameter shift was noted at any measurement point.

4.4.3 Test Specimen Group Type SN 515:

There were no confirmed significant parameter shifts observed during the coupled-sequential environment life tests on these test specimens. Summaries of parameter analysis findings are shown below.

4.4.3.1 Output Voltage:

Output voltage measurements were analyzed via the JPL Specification ZPP 2040 GEN A statistical format. The computed results are presented in Appendix B, pages 15 through 18. The analysis was started on a total test sample size of 20, although two test specimens had reduced operational capability (see paragraph 4.1.1.1) which resulted in a reduction of one in the V on ACo and V on $\bar{A}$ Eo parameters sample size at the initial data point. The sample size for the V on B Eo parameter was reduced by one at the 117 hour measurement point of the high temperature operating life test because of external damage (see paragraph 4.1.1.). The total sample size for this group was reduced by one at the final test point because of external damage (see paragraph 4.1.1.). The analysis indicates a very close distribution of saturation voltages throughout the life tests. Standard deviations were less than 5 millivolts at all measurement points. The calculated "F" statistic test values showed no significant data spreading at a confidence level of 95%. There was only a minimum amount of parameter change noted in the resultant data. The "t" statistic test values calculated indicated statistical significance, at a confidence level of 95%, at the 537 hour measurement point on all parameters, at the 1037 hour measurement point for the V on A Co and V on $\bar{B}$ Co parameters; at the 2000 hour measurement point for the V on $\bar{B}$ Co and V on B Eo parameters; and at the 250 hour and 500 hour measurement points for the V on $\bar{B}$ Co parameter. The statistical tests above were of a sensitivity much greater than the measurement tolerance inherent in this test. It is concluded that no detectable parameter shift was visible in these results.

4.4.3.2 Current Gain:

D. C. current gain measured during the life tests did not deviate significantly in any direction. The calculated mean values of the data rose to a maximum at the 117 hour measurement point then shifted downward during the remainder of the life tests. This downward trend was slight and was actually reversed at the final measurement point. Total mean deviations were less than 7% over the complete life tests. It is concluded that no definite parameter shift was found in this test.

4.5 Mechanical Environment Test Results:

4.5.1 Test Specimen Group #9A; Type SN 510:

There were no failures of the test specimens during the two mechanical tests. The original test group #9, because of external and internal failures of test specimens during previous testing, was completed with substitute test specimens, units #9, #10, and #11.

As the primary motive in performing these tests was to examine for mechanical deficiencies which are usually detectable by large parameter shifts or failures, little measurement data analysis was attempted. A survey of the measured data - output voltage and minimum clock input voltage indicated very little change at any of the measurement points. Minimum clock input voltage increased slightly during the tests but the movement was not sufficient to be indicative of any trend.

4.5.2 Test Specimen Group #9A; Type SN 512:

There were no failures of the test specimens during the two mechanical tests. The original test group #9, because of an external failure of a test specimen during previous testing, was completed with the addition of test specimen, unit #9.

As the primary motive in performing these tests was to examine for mechanical deficiencies which are usually detectable by large parameter shifts or catastrophic failures, little measurement data analysis was attempted. A survey of the measured data-output voltage and current gain showed a minimum of parameter shift at all readings.

4.5.3 Test Specimen Group #9A; Type SN 515:

There were no failures of the test specimens during the two mechanical tests. The original test group #9, because of an external failure of a test specimen during previous testing, was completed with the addition of test specimen, unit #9.

As the primary motive in performing these tests was to examine for mechanical deficiencies, which are usually detectable by large parameter shifts or catastrophic failures, little measurement data analysis was attempted. A survey of the measured data-output voltage and current gain showed a minimum of parameter shift at all measurement points.

4.6 Discussion of Initial and Final Measurement Distributions:

Histogram presentations were constructed of all pertinent initial and final data measurements. The mean value and the standard deviation of each data distribution was also calculated and presented with the histograms in Volume III of this report.

4.6.1 Test Specimen Group Type SN510:

4.6.1.1 Output Voltage:

Histograms of the output voltage initial and final measurements are shown on pages 61 to 108 of Volume III. The representations in general were skewed with maximum incremental area at low voltage. Certain instances of supposedly significant parameter and data spread shifts in the following histograms were the result of the extraneous causes indicated below:

1. Page No. 65, (Volume III); open-off, initial histogram; -55°C; 3 volts - the data included a point from failed test specimen #19 which biased the distribution significantly.

2. Page No. 66, (Volume III); open-off; final histogram; -55°C; 3 volts - The data included a point from test specimen #4 which experienced intermittent connector contact problems.

3. Page No. 89, (Volume III); open-off; initial histogram; -55°C; 6 volts - The data included a point from failed test specimen #19 which biased the distribution greatly.

4. Page 91 (Volume III); shut-off; initial histogram; -55°C; 6 volts - The data included two points from test specimen #20 which experienced intermittent connector contact problems.

5. Page No. 108 (Volume III); short-off; final histogram; +125°C; 6 volts - The data included a point from test specimen #1 which experienced intermittent connector contact problems.

With the exclusion of the above parameter readings, the data distributional spreads were considered reasonable. There were specific instances of data range increases between the initial and final measurements which coincide with the analysis results presented elsewhere in this report. (See paragraphs 4.2.1 and 4.4.1.1) Typical ranges for output "on" voltages are from 0.075 volts to 0.105 volts (3 volts, all temperatures, final and initial); for output "off" from approximately 0.25 volts initial to 0.52 volts final. (3 volts, all temperatures). Ranges for the 6 volts operating level are proportionately higher but otherwise do not vary significantly.

4.6.1.2 Switching Time Measurements:

Histograms of the initial and final switching time measurements are shown on pages 1 to 60 of Volume III. The representations were generally approximately normal in character. Through an inadvertent data transmission error, a few of the histogram presentations included measurements of some greatly degraded and/or failed test specimens which biased these presentations. Excluding these values from consideration, all switching time measurement distributions had small range values. An increasing parameter drift was observed on the storage time and fall time measurements at all temperatures and voltages. This drift was not sufficient to be considered significant. In all cases the incremental change in the mean values was less than 15%.

4.6.1.3 Minimum Clock Input Voltage:

Histograms of the initial and final minimum clock input voltage appear on pages 109 to 120 of Volume III. The distribution representations of the data were linear-normal in shape with fairly close spreads indicated for all presentations. Data ranges were approximately 0.01 volts initial to 0.02 volts final (3 volts, all temperatures) and 0.02 volts initial to 0.03 volts final (6 volts, all temperatures). This spreading of the data range between the initial and final readings is not considered significant in view of the initial very close groupings, and inherent data measurement variability.

4.6.1.4 Minimum Set and Reset Voltage:

Histograms of the initial and final minimum set and reset voltages appear on pages 121 to 128 of Volume III. Distribution representations were skewed with maximum area appearing at low voltage with data ranges of 0.5 volts to 0.7 volts (3 volts) and 1.3 volts to 1.6 volts (6 volts). These ranges are quite high considering the values of the mean measurement, 0.35 volts and 0.43 volts respectively. This wide spread in values may account for certain instabilities noted in the operating life tests (see paragraph 5.1) It should also be noted, however, that there was no significant unbalance evident in the calculated evident in the calculated mean values of the V_{m1} and V_{m2}. (Set and Reset) data.

4.6.1.5 Load Resistance:

Histograms of the initial and final load resistance measurements are shown on pages 129 and 130 of Volume III. The representations are normal in shaping with fairly wide data ranges (2700 ohms initial and 2500 ohms-final). The data mean values indicate an increase in total resistance. This is in contrast to the decreasing load resistance measurement noted during thermal cycling (paragraph 4.3.1.4). In both cases however, the amount of data shift was not adequate to definitely confirm the significance. It is held that the results indicate a certain instability in the resistive substrate of these test specimens which is subject to certain aging variations.

4.6.2 Test Specimen Group Type SN512:

4.6.2.1 Output Voltage:

Histograms of the initial and final output voltage measurements appear on pages 191 to 202 of Volume III. Distribution presentations were approximately normal in shapings with voltage ranges of 0.90 volts initial to 0.110 volts final (3 volts; -55°C); 0.122 volts (3 volts; +25°C and +125°C) and 0.17 volts (6 volts -55°C); 0.183 volts (6 volts +25°C and +125°C). The ranges indicated above do not seem excessive and the calculated respective data mean values did not vary significantly.

4.6.2.2 Switching Time Measurements:

Histograms of the initial and final switching time measurements appear on pages 131 to 190 of Volume III. All data distributions appear approximately normal in character with data spreads that were not considered excessive in view of inherent data measurement variations.

Distributional data mean comparisons indicated increasing parametric values of delay time, rise time and fall times and decreasing values of storage times as a result of the environmental testing. The incremental changes of these parameters (at all temperature and voltage measurement points) were not sufficient to attribute engineering significance to the results.

4.6.2.3 Current Gain:

Histograms of the initial and final current gain measurements appear on pages 203 to 206 of Volume III. Distribution representations are skewed in shape with maximum area in the low current gain region. Data ranges are not excessive at any of the measurement points. No incremental mean value changes were discernable between initial and final data.

4.6.2.4 Input Base Resistance:

Histograms of the initial and final input base resistance measurements are shown on pages 207 to 210 of Volume III. Distribution representations are approximately normal in character. Data ranges are about 15,500 ohms initial to 14,500 ohms final. No appreciable data mean value changes were noted as a result of the environmental testing.

4.6.2.5 Load Resistance:

Histograms of the initial and final load resistance measurements appear in pages 211 to 214 of Volume III. Distributional presentations approximated a normal curve in all cases with a range of about 1500 ohms. No incremental mean value change was noted as a result of the testing imposed.

4.6.3 Test Specimen Group Type SN515:

4.6.3.1 Output Voltage:

Histograms of the initial and final output voltage measurements appear on pages 335 to 346 of Volume III. Data presentations approximated a normal curve in shaping with a data spread generally closely grouped. (Approximate range was 0.08 volts). There was a minimum amount of incremental parameter change noted between the initial and final mean values.

4.6.3.2 Switching Time Measurements:

Histograms of the initial and final switching time measurements appear on pages 215 to 234 of Volume III. The data presentations indicated most distributions were approximately normal in character. Data spreads, for the most part, were not excessive. There were little incremental parameter mean value changes indicated. The delay time and rise time measurement mean values of the "C" and "E" (one invertor stage propagation) increased approximately 15% and 20% respectively over the range of temperatures and voltages observed. This change was not considered significant in view of the inherent measurement accuracies involved.

4.6.3.3 Current Gain:

Histograms of the initial and final current gain measurements appear on pages 347 to 350 of Volume III. Presentations indicate the distribution is approximately normal in shaping. Total data spreads are approximately 160 initial to 40 final on the -55°C data indicating a marked tightening of the current gain distribution as the specimens were subjected to the tests. The mean current gain value at -55° decreased 13% from the initial value. Data taken at the 25°C temperature point did not indicate this change, in fact, the spread of values actually increased slightly.

4.6.3.4 Load Resistance:

Histograms of the initial and final load resistance measurements appear on pages 351 and 352 of Volume III.

Data presentations approximate a normal curve with a range of about 1100 ohms. No incremental mean value changes were observed in the data as a result of the environmental testing.

4.7 Reliability Estimates:

Reliability estimates were calculated based on the available environmental life test data. The estimates were based on the assumption of an exponential failure rate distribution. The report: Statistical Techniques in Life Testing, Chapter III, Technical Report #4 under Contract NOUR 2163 (00) (NR-042-018); dated January 15, 1959; by Benjamin Epstein was used for background and equations.

As there were no catastrophic or parametric failures observed during the life tests, the failure rates can be estimated with a one-sided limit only.

Test Specimen	Reliability Estimate (Lower Limit Only) % per 1000 hours	
	50% Confidence	90% Confidence
SN 510, SN 512	1.39	4.61
SN 515	1.46	4.85
SN 5-- Series	0.478	1.59

The estimates presented here are based on a minimum amount of life information (for this type of data reduction) and should be used only as an indicator of device reliability life potential.

4.8 Composite List of All Test Failures:

Catastrophic Failures:

	Type	Unit	Failure
1.	SN510	#5	Lead #1 broken
2.	SN510	#6	Lead #1 broken
3.	SN510	#16	Mounted in a reverse-transposed direction
4.	SN510	#18	Mounted in a reverse-transposed direction
5.	SN510	#19	Silicon wafer dislocated
6.	SN512	#3	Test Connector failed
7.	SN512	#17	Test connector failed
8.	SN515	#1	Leads #1,2,4,5, and 6 broken
9.	SN515	#8	Lead #1 broken
10.	SN515	#15	Lead #4 broken

Parametric Failures:

	Type	Unit	Failure
11.	SN510	#1	At Final Measurements - 3 volts, +125°C- V_{sat} increased.
12.	SN510	#2	At final measurements - 3 volts, +125°C- 3 volts -55°C - V_{sat} increased.
13.	SN510	#3	At 537 hours High Temperature Life- Improper input voltage regulation --At Final Measurements - 3 volts, +125°C- V_{sat} increased.
14.	SN510	#4	At 537 hours High Temperature Life -- Improper input voltage regulation -- At final measurements - 3 volts, +125°C; 6 volts, +125°C; 3 volts, +25°C- V_{sat} increased.

4.8 (Cont.)

Parametric Failures:

Type	Unit	Failure
15. SN510	#5	At 537 hours High Temperature Life - Improper input voltage regulation -- At Final Measurements - 3 volts; +125°C- V_{sat} increased.
16. SN510	#6	At 535 hours High Temperature Life - Improper input voltage regulation.
17. SN510	#7	At 535 hours High Temperature Life - Improper input voltage regulation --- At final measurements - 3 volts, +125°C; 3 volts, -55°C; 3 volts, +25°C - V_{sat} increased.
18. SN510	#8	At 535 hours High Temperature Life -- Improper input voltage regulation--- At final measurements - 3 volts, +125°C; 3 volts, -55°C- V_{sat} increased.
19. SN510	#9	At 535 hours high temperature life - improper input voltage regulation --- at final measurements - 3 volts, +125°C- V_{sat} increased.
20. SN510	#10	At 535 hours High Temperature Life - Improper input voltage regulation.
21. SN510	#11	At 535 hours High Temperature Life - At Final Measurements 3 volts, +125°C - V_{sat} increased.
22. SN510	#12	At final measurements - 3 volts, +125°C- V_{sat} increased.
23. SN510	#13	At 535 hours High Temperature Life - Improper input voltage regulation.
24. SN510	#14	At final measurements - 3 volts, +125°C; 3 volts, -55°C; 3 volts, +25°C - V_{sat} increased.
25. SN510	#15	At 535 hours High Temperature Life - Improper input voltage regulation --- At Final Measurements - 3 volts,+125°C; 6 volts, +125°C; 3 volts, -55°C; 3 volts, +25°C - V_{sat} increased.

4.8 (Cont.)

Parametric Failures:

Type	Unit	Failure
26. SN510	#16A	At 535 hours High Temperature Life - Improper input voltage regulation
27. SN510	#17	At 535 hours High Temperature Life - Improper input voltage regulation.
28. SN510	#20	At 535 hours High Temperature Life - Improper input voltage regulation. At Final Measurements - 3 volts, +125°C; 3 volts, -55°C; 3 volts, +25°C - V_{sat} increased.
29. SN515	#5	At 3rd cycle Thermal Cycling - 6 volts, -55°C - V_{sat} increased.
30. SN515	#10	At Final Measurements - 6 volts, -55°C V_{sat} increased.
31. SN515	#13	At 3rd cycle Thermal Cycling - 6 volts, -55°C - V_{sat} increased.
32. SN515	#18	At 3rd cycle Thermal Cycling - 6 volts, -55°C - V_{sat} increased.

5.0 GENERAL DISCUSSION OF TEST RESULTS:

5.1 Test Results:

The overall test program was judged as successful in accomplishing the objectives as called for in the original test design. Secondary problem areas were found, however, that must be solved before the devices may be said to be fully qualified for usage.

The thermal environmental tests, in general, successfully proved the test specimens physically able to withstand these environments. No significant change could be detected in the applied measurements after any thermal environment that would prove indicative of a serious problem area.

There were no parametric measurement shifts noted during the thermal sterilization tests that could be attributed to intrinsic device instabilitities. It is concluded that there should be no device degradation expected when subjected to a similar thermal sterilization process in practical usage.

There were no significant design parameter changes noted during the thermal cycling tests, although three test specimens did fail parametrically as defined in paragraph 3.6.1.2. In this occurrence, and in the case of the parametric failures at the final measurement point, the "failed" units operated functionally with no noticable degradation.

It was concluded from these and other test findings, that the parametric failure criteria as initially stated for this test (see paragraph 3.6.1.2) is not adequately adaptable for use in evaluating these test specimens. This insufficiency of comprehensive parametric failure criteria should be corrected as an adjunct to any purchasing specification control document. This would be necessary to sufficiently define acceptance and inspection procedures.

The significant failure analysis test parameter deviations noted during the thermal cycling test, i.e., load resistance reduction in the type SN510 and collector-base leakage current in the type SN512, should be considered to be individual characteristics of the particular test specimens and should not, at this time, be considered to be indicative of any major manufacturing control problem. Also tending to decrease the significance of these findings is the fact that there was no provable correlation of these changes with device functional changes.

There were no apparent changes in the test specimens when subjected to the humidity environment. It was concluded from the test results that there was no container seal problem. It should be noted, however, that Texas Instrument has changed to an all welded package for this Series 51 line since these test specimens were manufactured. (The test specimens were mounted in a depressed rectangular glass bowl containing the hermetically sealed-in-glass lead tabs and was enclosed with a solder sealed metal cover). The present manufacturing method uses metal covers with a hermetically sealed glass ring enclosing the lead tabs. The introduction of a new packaging arrangement opens the question on the device container seal effectiveness again.

There was an insignificant amount of measurement parameter deviations noted during the sequentially-coupled operating life tests. But a basic problem was found in the area of functionally evaluating the test specimens by simple measurements of D. C. parameter changes. The life test logic was actively switched at a basic clock frequency of 100KC. Device monitoring facilities were provided for but no self-detecting circuitry was available to investigate the intermittent malfunctions that occurred during the life test. These errors, which consisted of missed counts, could be observed in the final staging areas but tracing to the initial source could not be accomplished. Intermittent errors were observed throughout the life testing program but tracing efforts to locate the exact causes of these malfunctions were unsuccessful. Extraneous influences on the life test, such as a result of conducted or radiated signals were reduced to a minimum within the confines of the test criteria. Attempts to definitely link the intermittent malfunctions noted in the life test with any measured test specimen parameter has in general, proved fruitless. One possible clue may be the degree of unbalance measured between individual minimum "set" and "reset" voltages on the SN510 test specimens. Mean values of the measurements have indicated little incremental change or imbalance during the course of the test. A mean value of the degree of unbalance is 0.148 volts (6 volts, 25°C, final) which is 37% of the data mean value. More information is necessary to prove that this unbalance was related to the observed intermittent failures. This unsolved problem area should be investigated before the devices can be fully accepted for usage.

There were no significant problems observed as a result of the mechanical environmental testing. It must be noted however, that a new package arrangement is now being used by the manufacturer, which to an extent, negates the results of this series of tests.

5.2 General Conclusions:

When this testing program was past the preliminary stages of development and fulfillment, it was realized by all concerned, that the project could be defined most accurately as a test developmental program, that would, along with the basic evaluation requirements, seek to find some answers to allied problems as discovered.

Early in the test, many problems were noted with the mounting configuration used for this test. It was necessary, due to the requirements of a humidity test, to mount the test specimens free of any encapsulating medium. The mounting method used resulted in two problems.

The open mounting method invited lead tab breakage during handling of units for measurement set-ups. The other problem was an external one of using a mounting connector, which was unproven at that time and which resulted in connector contact problems. As a result, it is concluded that in future testing of these devices, mechanical test design is of paramount interest and necessity. Encapsulation of the unit, which would be the normal usage mounting technique should be used in testing whenever possible.

Especially noticable in the operating life test portion of the program was the uncertain correlation between the specified D. C. measurement parameters and the functionally active digital usage to which these devices will be subjected. The untraced intermittent malfunctions observed then resulted essentially in an unsolved problem area. It is believed that selected D. C. measurements plus certain switching time measurements would present the most complete evaluation picture of these test specimens. Listed below are what are considered to be, at first inspection, some of the more important measurement parameters.

1. Output "OFF" voltage
2. Selected Output "ON" voltages
3. Minimum Set and Reset voltages
4. Minimum Clock voltage
5. Propagation time
6. Fall Time
7. Rise Time

6.0 RECOMMENDATIONS:

The test devices - Texas Instrument Series 51 integrated networks have qualified to the test environments and by the measurements specified in this report. However, certain problem areas remain and so the following additional tests are recommended:

6.1 High temperature operating life incorporating self-detection circuitry for possible intermittent failure detection. Testing should be evaluated based on active circuits measurements and operation.

6.2 High pressure leak tests (Joy Bomb) to determine integrity of the redesigned container seals.

6.3 Vibration and shock tests to determine adequacy of the redesigned container.

6.4 Further definition of evaluation measurement techniques to obtain the most desirable and adequate device purchase and acceptance specifications.

APPENDIX A

DESCRIPTION OF

SOLID STATE MODULE

TEST SET

GENERAL NOTES:

1. The test set front panel selector switches shall be designated by number as indicated below, for clarity and efficiency:

S1 - SN512 and SN515 Test Selector
S2 - SN512 and SN515 Gate Selector
S3 - SN510 Test Selector
S6 - Unit Selector

2. Auxiliary Test Equipment

a) VM1
VM2 John Fluke Model 803 or equivalent
VM3

b) IM1 - Hewlett Packard Micro Volt-ammeter Model 425A or equivalent

IM2 - Same as IM1

c) IM3 - Westinghouse type PX-14 or equivalent

d) Clock Pulse (C.P.) - Rutherford B-7 or equivalent

e) DC Voltage Inputs - Hewlett Packard, Model 721A or equivalent

3. The following test for the SN series devices are described employing 6V DC. These tests may be done at 3V DC by providing data sheet or predetermined Logic Levels corresponding to V_{CC} = 3V DC as the inputs.

4. CAUTION:

All switches, R1 and R2 while not being used for unit under test, must be in the "OFF" or in the extreme left position!

5. No calibration is required for this Test Set.

I Micro Electronic "NOR" or "NAND" Gate SN512 Electrical Measurements.

A. Transistor Leakage Current, I_{CBO}

1. Connect meters and power, and position the SN512 Test Control switches as indicated below.

   A. Connect an ammeter to jacks indicated as Iml.

   B. Position S1 to "I_{CBO}".

   C. Position S2 to "A".

   D. Position S6 to "SN512".

   E. Position the SN512 "LOAD SELECTOR" switch to "N = O".

   F. Position all other switches to "OFF" or to the extreme left.

   G. Apply 6 or 3 VDC ± .1% to the front panel jacks designated as + DC input.

2. Read and record Iml.

3. Repeat A.2 with S2 in positions "B" through "F".

B. Circuit Load Resistance Measurement R_L;

1. Position S1 to "RL".

2. Position S2 to "A" only.

3. Connect a voltmeter to jacks indicated as Vml.

4. All other switches, meters, and power as for Test I.A.

5. Read and record Vml and Iml.

C. Transistor Base Resistance Measurement RB.

1. Position S1 to "RB".

2. Position S2 to "A".

3. All other switches, meters, and power as for Test I.A.

4. Read and record Vm1 and Im1.

5. Repeat C.4 with S2 in positions "B" through "F".

D. Transistor Gain Measurement, Beta.

1. Position S1 to Beta.

2. Position S2 to "A".

3. All other switches, meters, and power as for Test I.A.

4. Adjust R2 until 1VDC ± .1% is indicated on Vm1.

5. Read and record Im1 and Vm1.

6. Repeat D.4 and D.5 with S2 in positions "B" through "F".

E. On-Off Voltage Level Measurements.

1. Position S1 to "On-Off Level".

2. Position S2 to "A".

3. Connect a voltmeter to jacks indicated as Vm2.

4. All other switches, meters, and power as for Test I.A.

5. Adjust R2 until a minimum voltage is observed on Vm1.

6. Read and record Vm1 and Vm2.

7. Adjust R2 until a maximum voltage is observed on Vm1.

8. Read and record Vm1 and Vm2.

9. Position the SN512 "LOAD SELECTOR" switch to "N-5" and repeat steps E.5 through E.8.

10. Repeat E.5 through E.9 with S2 in positions "B" through "F".

"NOR" or "NAND" GATE SN512 DATA SHEET

Table 1

Transistor Leakage Current I_{cbo}

Temperature ____________

Vcc = ____________

S2 - GATE	$Iml = I_{cbo}$
A	________
B	________
C	________
D	________
E	________
F	________

Table 2

Circuit Load Resistance R_L

Vml = ________ Temperature ________

Iml = ________ Vcc = ________

R_L = Vml/Iml ________

Table 3

Transistor Base Resistance R_B

Temperature ________

Vcc = ________

S2 - GATE	Iml	Vml	RB = Vml/Iml
A	_____	_____	________
B	_____	_____	________
C	_____	_____	________
D	_____	_____	________
E	_____	_____	________
F	_____	_____	________

Table 4

Transistor Gain, B

Temperature________

Vcc = ____________

S2 - GATE	Iml	Vml	$B = 10^{-3}/Iml$
A	______	______	______
B	______	______	______
C	______	______	______
D	______	______	______
E	______	______	______
F	______	______	______

Table 5

ON-OFF Voltage Levels

Temperature________

Vcc = ____________

		S2 - GATE	A	B	C	D	E	F
N=0	ON	Vm1	____	____	____	____	____	____
		Vm2	____	____	____	____	____	____
	OFF	Vm1	____	____	____	____	____	____
		Vm2	____	____	____	____	____	____
N = 5	ON	Vm1	____	____	____	____	____	____
		Vm2	____	____	____	____	____	____
	OFF	Vm1	____	____	____	____	____	____
		Vm2	____	____	____	____	____	____

II MICROELECTRONIC "EXCLUSIVE OR" NETWORK SN515 ELECTRICAL MEASUREMENTS:

A. Transistor Leakage Current, I_{CBO}

1. Connect meters and power, and position the SN515 test control switches as indicated below.

   a. Connect an ammeter to jacks designated as "Iml".

   b. Position S1 to "I_{CBO}".

   c. Position S2 to "A".

   d. Position S6 to "SN515".

   e. Position the SN515 "LOAD SELECTOR" switch to "N = 0".

   f. Position all other switches to "OFF" or to the extreme left.

2. Read and record Iml.

3. Repeat A.2 with S2 in positions "B" through "D".

B. Circuit Load Resistance Measurement, R_L

1. Position S1 to "R_L"

2. Position the SN515 "OUTPUT SELECTOR" switch to "C".

3. Connect a voltmeter to jacks designated as Vml.

4. All other switches, meters, and power as for test I.A.

5. Read and record, Vml and Iml.

6. Repeat B.5 with the SN515 "OUTPUT SELECTOR" switch in positions "D" and "E".

C. Transistor Base Resistance Measurement, R_B

1. Position S1 to "R_B"

2. Position S2 to "A".

3. Connect a voltmeter to jacks designated as Vml.

4. All other switches, meters, and power as for test I.A.

5. Read and record Vml and Iml.

6. Repeat C.5 with S2 in positions "B" through "D".

D. Transistor Gain Measurement, Beta

1. Position S1 to Beta.

2. Position S2 to "A".

3. Connect a voltmeter to jacks designated as Vm1.

4. All other switches, meters, and power as for test I.A.

5. Adjust R2 until 1 VDC $\pm$ .1% is indicated on Vm1.

6. Read and record Im1 and Vm1.

7. Repeat D.5 and D.6 with S2 in positions "B" through "D".

E. ON-OFF Voltage Level Measurements.

1. Position S1 to "ON-OFF LEVEL".

2. Position S2 to "A".

3. Position the SN515 "OUTPUT SELECTOR" switch to "C".

4. Connect voltmeters to jacks designated as Vm1 and Vm2.

5. All other switches, meters and power as for test II.A.

6. Adjust R2 until a minimum voltage is observed on Vm1.

7. Read and record Vm1 and Vm2.

8. Adjust R2 until a maximum voltage is observed on Vm1.

9. Read and record Vm1 and Vm2.

10. Position the SN515 "LOAD SELECTOR" switch to "N=4" and repeat steps E.6 through E.9.

11. Position S2 to "B" and repeat E.6 through E.10

12. Position the SN515 "OUTPUT SELECTOR" switch to "D" and the SN515 "LOAD SELECTOR" switch to "N=0" and repeat E.6 through E.9.

13. Position the SN515 "LOAD SELECTOR" switch to "N=5" and repeat E.6 through E.9.

14. Position S2 to "C" and the SN515 "OUTPUT SELECTOR" switch to "E" and repeat E.6 through E.10.

15. Position S2 to "D" and repeat E.6 through E.10.

16. Repeat E.12 and E.13

17. See Table 10 for clarity.

Table 6
Transistor Leakage Current, I_{cbo}

Temperature _______

S2	GATE	$Iml = I_{cbo}$
A	1	_______
B	2	_______
C	4	_______
D	5	_______

Table 7
Circuit Load Resistance, R_L

Temperature _______

OUTPUT SELECTOR	Vml	Iml	$R_L = Vml/Iml$
C	_______	_______	_______
D	_______	_______	_______
E	_______	_______	_______

Table 8
Transistor Base Resistance, R_B

Temperature _______

S2	GATE	Iml	Vml	$R_B = Vml/Iml$
A	1	_______	_______	_______
B	2	_______	_______	_______
C	4	_______	_______	_______
D	5	_______	_______	_______

Table 9
Transistor Gain, Beta

Temperature________

S2	GATE	Iml	Vml	$B = 10^{-3}/Iml$
A	1			
B	2			
C	4			
D	5			

Table 10
E, ON-OFF Voltage Levels

Temperature________

S2	GATE			ON		OFF	
S2	Gate	OUTPUT	LOAD	Vml	Vm2	Vml	Vm2
A	1	C	N=0				
			N=4				
B	2	C	N=0				
			N=4				
B	2	D	N=0				
			N=5				
C	4	E	N=0				
			N=4				
D	5	E	N=0				
			N=4				
D	5	D	N=0				
			N=5				

III Flip-Flop Network SN510
Electrical Measurements

A. Diode Leakage Current, I_{co}

1. Connect meters and power, and position the SN510 Test Control Switches as indicated below.

   a. Connect an ammeter to jacks indicated as Iml.

   b. Position S3 to "ICO Diode".

   c. Position S6 to "SN510".

   d. Position the SN510 "OUTPUT" switch to "Q".

   e. Position the SN510 "OUTPUT SELECTOR" switch to "1".

   f. Position all other switches to the "OFF" position or to the extreme left.

   g. Apply 6 or 3VDC ± .1% to the front panel "s" and repeat A.2

B. Circuit Load Resistance, RL.

1. Position S3 to "RL" and the SN510 "OUTPUT SELECTOR" switch to "1".

2. All other switches, meters and power as for test III.A.

3. Read and record Iml, and +DC input.

4. Position the "OUTPUT SELECTOR" switch to "2" and repeat B.3.

C. On-Off Voltage Level Measurements.

1. Position S3 to "ON-OFF" level.

2. Connect a voltmeter to jacks designated as Vml.

3. Connect a voltmeter to jacks designated as Vm2.

4. Place a voltmeter (Vm3 from + to "GND" on the "Flip-Flop output" jacks.

5. Apply a +6 VDC through a current meter (im3) to jacks designated as +DC input.

6. Apply -15VDC ± 10% to jacks designated as -DC input.

7. Position -DC input switch to 6 or 3V depending on + DC input being used.

8. Adjust R1 and R2 until 2.5 VDC is observed on Vm1 and Vm2.

9. Activate and hold the "PRESS TO SET" switch and read and record Vm3 and the power input current Im3.

10. Position the SN510 "OUTPUT" switch to "$\bar{Q}$" and again activate the "PRESS TO SET" switch and read and record Vm3.

11. Activate and hold the "PRESS TO RESET" switch and read and record Vm3 and Im3.

12. Position the "OUTPUT" switch to "Q" and again activate the "PRESS TO RESET" switch and read and record Vm3.

13. Place a shorting lead from "+" to "-" on the panel jacks indicated as "FLIP-FLOP OUTPUT" and repeat E.7 through E.10.

14. (Leave setup for following tests).

D. Minimum Clock Pulse Input.

1. Position S3 to the counter position.

2. Adjust R2 until 0.35 VDC is observed on Vm2.

3. Set the clock pulse generator (counter pos.) to provide the following output:

a) 100 K cps.
b) 100N sec. rise time.
c) 0.5n sec. pulse width.
d) Positive pulse.

4. Record the clock pulse amplitude.

E. Minimum set and reset voltages (VS).

1. Position S3 to "ON-OFF LEVEL".

2. Apply a 2 VP clock pulse, Vcc = 3 Volt, apply a 4 VP clock pulse, Vcc = 6 Volts, as described in F.5.

3. Adjust R2 until 0.25 volts is observed on Vm2.

4. Position the SN "OUTPUT" switch to "Q".

5. Activate the "PRESS TO SET" switch.

6. Adjust R1 until Q "sets high", this will be indicated on the scope by a step from a low to a high voltage.

7. Read, and record Vm1.

8. Adjust R1 until 0.25 volts is observed on Vm1.

9. Activate the "PRESS TO RESET" switch and note that the scope indicates a high voltage.

10. Adjust R2 until Q "sets low", i.e., the scope indicates a low voltage.

11. Read and record the voltage indicated on Vm2.

Table 11

Diode Leakage Current, I_{co}

Temperature________

Vcc_______________

OUTPUT SELECTOR	$Iml = I_{co}$
1	_______
2	_______

Table 12
Circuit Load Resistance, R_L

Temperature________

Vcc_______________

OUTPUT SELECTOR	+DC INPUT	Iml	R2 = +DC/Iml
1	_______	_______	_______
2	_______	_______	_______

Table 13
Base and Base to Collector Coupling Resistor, R_B

Temperature________

Vcc_______________

OUTPUT SELECTOR	+DC INPUT	Iml	R_B = +DC/Iml
1 (Q to $\overline{Q}$)	_______	_______	_______
2 ($\overline{Q}$ to Q)	_______	_______	_______
3. (Base of preset)	_______	_______	_______

Table 15

On-Off Voltage Levels

+ and - FLIP FLOP JACKS	OUTPUT SWITCH	DEVICE CONDITION	(Im3) PWR. SUPP CURRENT	Vm3
OPEN	Q	SET		
		RESET		
	$\bar{Q}$	SET		
		RESET		
SHORTED	Q	SET		
		RESET		
	$\bar{Q}$	SET		
		RESET		

Table 17

Minimum Clock Pulse Input

Temperature ____________

Vcp min. = ________________ Vcc ________________

Table 18

Minimum Set (V_S) and Reset (V_{rs}) Voltages

Temperature ____________

Vcc ________________

Part

H.7 V_s = Vm1 = ________________

H.11 V_{rs} = Vm2 = ________________

 7-0024

APPENDIX B

JPL Specification
ZPP2040 - GEN A
Statistical Format
Calculations for
Environmental Life Tests
Measurement Data

JPL TEST NUMBER: 7-0024 VENDOR: TEXAS INSTRUMENTS PART NUMBER: SN 510 PARAMETER: VoffQo
MULTIPLIER: 1 UNIT: Volts NOMINAL VALUE: None LOWER LIMIT: 4.1 UPPER LIMIT: None

Min.	Mean	Max.	StD.	F	MinD.	MeanD.	MaxD.	StdD.	P.C.	t	No.	NU	NL	NC
Oper. Life Hrs. = 83 (5-13-63)														
4.8200	4.9884	5.2100	.02422								19	0	0	0
Oper. Life Hrs. = 117 (5-16-63)														
4.7900	4.9616	5.1900	.02428	1.005	-.04000	-.02684	-.01000	.00154	-.54100	-17.436	19	0	0	0
Oper. Life Hrs. = 537 (6-4-63)														
4.8000	5.2632	5.8100	.09604	15.650	.00000	.30158	.64000	.07395	5.7300	4.078	19	0	0	0
Oper. Life Hrs. = 1037 (6-28-63)														
4.8000	4.9626	5.1900	.02421	15.741	-.77000	-.30053	.14000	.07808	-6.0558	-3.849	19	0	0	0
Oper. Life Hrs. = 2000 (8-13-63)														
4.7800	4.9610	5.1800	.02326	1.083	-.16000	-.00158	.12000	.01202	-.03183	-.131	19	0	0	0
Vacuum Life Hrs. = 250 (9-23-63)														
4.8100	4.9753	5.2000	.02439	1.100	-.04000	.01421	.04000	.00569	.28562	2.499	19	0	0	0
Vacuum Life Hrs. = 500 (10-10-63)														
4.8000	4.9516	5.1700	.02299	1.125	-.04000	-.02368	-.01000	.00267	-.47832	-8.863	19	0	0	0

JPL TEST NUMBER: 7-0024 VENDOR: TEXAS INSTRUMENTS PART NUMBER: SN 510 PARAMETER: VoffQo

MULTIPLIER: 1 UNIT: Volts NOMINAL VALUE: None LOWER LIMIT: 4.1 UPPER LIMIT: None

Min.	Mean	Max.	StD.	F	MinD.	MeanD.	MaxD.	StdD.	P.C.	t	No.	NU	NL	NC
						Oper. Life Hrs. = 83 (5-13-63)								
4.7800	4.9779	5.5300	.03721								19	0	0	0
						Oper. Life Hrs. = 117 (5-16-63)								
4.7600	4.9516	5.5000	.03700	1.011	-.04000	-.02632	-.02000	.00137	-.53146	-19.206	19	0	0	0
						Oper. Life Hrs. = 537 (6-4-63)								
4.7500	5.1405	5.9000	.09275	6.283	-.01000	.18895	.63000	.06549	3.6756	2.885	19	0	0	0
						Oper. Life Hrs. = 1037 (6-28-63)								
4.7600	4.9526	5.5100	.03727	6.193	-.83000	-.18789	.19000	.07243	-3.7938	-2.594	19	0	0	0
						Oper. Life Hrs. = 2000 (8-13-63)								
4.7900	4.9458	5.5100	.03640	1.049	-.22000	-.00684	.17000	.01558	-.13835	-.439	19	0	0	0
						Vacuum Life Hrs. = 250 (9-23-63)								
4.7600	4.9653	5.5200	.03742	1.057	-.03000	.01947	.04000	.00480	.39219	4.053	19	0	0	0
						Vacuum Life Hrs. = 500 (10-10-63)								
4.7400	4.9442	5.5100	.03695	1.025	-.04000	-.02105	.03000	.00397	-.42580	-5.308	19	0	0	0

JPL TEST NUMBER: 7-0024 VENDOR: TEXAS INSTRUMENTS PART NUMBER: SN 510 PARAMETER: VoffQs
MULTIPLIER: 1 UNIT: Volts NOMINAL VALUE: None LOWER LIMIT: 2.0 UPPER LIMIT: None

Min.	Mean	Max.	StD.	F	MinD.	MeanD.	MaxD.	StdD.	P.C.	t	No.	NU	NL	NC
Oper. Life Hrs. = 83 (5-13-63)														
2.7900	3.0595	3.3100	.02912								19	0	0	0
Oper. Life Hrs. = 117 (5-16-63)														
2.7700	3.0489	3.3200	.03023	1.077	-.02000	-.01053	.01000	.00162	-.34524	-6.508	19	0	0	0
Oper. Life Hrs. = 537 (6-4-63)														
2.8000	3.5889	3.9900	.10802	12.771	.01000	.54000	.81000	.08352	15.046	6.465	19	0	0	0
Oper. Life Hrs. = 1037 (6-28-63)														
2.7900	3.0584	3.3200	.02897	13.904	-.84000	-.53053	.00000	.08448	-17.346	-6.280	19	0	0	0
Oper. Life Hrs. = 2000 (8-13-63)														
2.7900	3.0505	3.3100	.02846	1.036	-.07000	-.00789	.05000	.00505	-.25880	-1.564	19	0	0	0
Vacuum Life Hrs. = 250 (9-23-63)														
2.8000	3.0637	3.3300	.02915	1.049	-.01000	.01316	.03000	.00217	.42947	6.063	19	0	0	0
Vacuum Life Hrs. = 500 (10-10-63)														
2.7900	3.0463	3.3000	.02892	1.016	-.04000	-.01737	.00000	.00314	-.57014	-5.534	19	0	0	0

JPL TEST NUMBER: 7-0024 VENDOR: TEXAS INSTRUMENTS PART NUMBER: SN 510 PARAMETER: VoffQs

MULTIPLIER: 1 UNIT: Volts NOMINAL VALUE: None LOWER LIMIT: 2.0 UPPER LIMIT: None

Min.	Mean	Max.	StD.	F	MinD.	MeanD.	MaxD.	StdD.	P.C.	t	No.	NU	NL	NC
Oper. Life Hrs. = 83 (5-13-63)														
2.8000	3.0458	3.2700	.02784								19	0	0	0
Oper. Life Hrs. = 117 (5-16-63)														
2.7700	3.0342	3.2600	.02808	1.017	-.03000	-.01158	.00000	.00158	-.38161	-7.333	19	0	0	0
Oper. Life Hrs. = 537 (6-4-63)														
2.8000	3.5326	3.9800	.11136	15.730	.01000	.49842	.80000	.08675	14.109	5.746	19	0	0	0
Oper. Life Hrs. = 1037 (6-28-63)														
2.7900	3.0411	3.2600	.02797	15.853	-.79000	-.49158	-.01000	.08677	-16.165	-5.666	19	0	0	0
Oper. Life Hrs. = 2000 (8-13-63)														
2.7900	3.0358	3.2500	.02637	1.124	-.03000	-.00526	.02000	.00290	-.17337	-1.816	19	0	0	0
Vacuum Life Hrs. = 250 (9-23-63)														
2.8000	3.0495	3.2700	.02794	1.122	-.02000	.01368	.03000	.00288	.44873	4.747	19	0	0	0
Vacuum Life Hrs. = 500 (10-10-63)														
2.7900	3.0337	3.2400	.02780	1.010	-.03000	-.01579	.00000	.00257	-.52047	-6.138	19	0	0	0

JPL TEST NUMBER: 7-0024 VENDOR: TEXAS INSTRUMENTS PART NUMBER: SN 510 PARAMETER: VonQo
MULTIPLIER: 1 UNIT: Volts NOMINAL VALUE: None LOWER LIMIT: None UPPER LIMIT: .5

Min.	Mean	Max.	StD.	F	MinD.	MeanD.	MaxD.	StdD.	P.C.	t	No.	NU	NL	NC
					Oper. Life Hrs. = 83 (5-13-63)									
.11400	.15126	.26500	.00863								19	0	0	0
					Oper. Life Hrs. = 117 (5-16-63)									
.11500	.15984	.26900	.00947	1.205	.00100	.00858	.03000	.00208	5.3671	4.134	19	0	0	0
					Oper. Life Hrs. = 537 (6-4-63)									
.11500	.16032	.27200	.00958	1.C23	-.00100	.00047	.00900	.00052	.29547	.920	19	0	0	0
					Oper. Life Hrs. = 1037 (6-28-63)									
.11400	.15337	.26300	.00836	1.313	-.03200	-.00695	.04700	.00403	-4.5299	-1.724	19	0	0	0
					Oper. Life Hrs. = 2000 (8-13-63)									
.11500	.15058	.26300	.00849	1.C31	-.05300	-.00279	.02000	.00318	-1.8525	-.876	19	0	0	0
					Vacuum Life Hrs. = 250 (9-23-63)									
.11400	.15074	.26400	.00858	1.021	-.00100	.00016	.00100	.00014	.10475	1.143	19	0	0	0
					Vacuum Life Hrs. = 500 (10-10-63)									
.11500	.15947	.28100	.00985	1.317	-.00100	.00874	.03200	.00213	5.4785	4.096	19	0	0	0

JPL TEST NUMBER: 7-0024					VENDOR: TEXAS INSTRUMENTS					PART NUMBER: SN 510		PARAMETER: VonQo			
MULTIPLIER: 1		UNIT: Volts			NOMINAL VALUE: None					LOWER LIMIT: None		UPPER LIMIT: .5			
Min.	Mean	Max.	StD.	F	MinD.	MeanD.	MaxD.	StdD.	P.C.	t		No.	NU	NL	NC
					Oper. Life Hrs. = 83 (5-13-63)										
.11700	.14795	.22300	.00661									19	0	0	0
					Oper. Life Hrs. = 117 (5-16-63)										
.12500	.15653	.23600	.00712	1.159	.00000	.00858	.02700	.00155	5.4808	5.552		19	0	0	0
					Oper. Life Hrs. = 537 (6-4-63)										
.12300	.15521	.23600	.00722	1.030	-.00500	-.00132	.00500	.00048	-.84774	-2.753		19	0	0	0
					Oper. Life Hrs. = 1037 (6-28-63)										
.11700	.14747	.22400	.00663	1.186	-.02300	-.00774	.00200	.00133	-5.2463	-5.814		19	0	0	0
					Oper. Life Hrs. = 2000 (8-13-63)										
.11700	.14721	.22400	.00665	1.006	-.01000	-.00026	.00900	.00073	-.17876	-.359		19	0	0	0
					Vacuum Life Hrs. = 250 (9-23-63)										
.11700	.14747	.22500	.00668	1.007	.00000	.00026	.00100	.00010	.17844	2.535		19	0	0	0
					Vacuum Life Hrs. = 500 (10-10-63)										
.12400	.15642	.24600	.00761	1.300	.00000	.00895	.02500	.00150	5.7200	5.952		19	0	0	0

JPL TEST NUMBER: 7-0024 VENDOR: TEXAS INSTRUMENTS PART NUMBER: SN 510 PARAMETER: VonQs

MULTIPLIER: 1 UNIT: Volts NOMINAL VALUE: None LOWER LIMIT: None UPPER LIMIT: .5

Min.	Mean	Max.	StD.	F	MinD.	MeanD.	MaxD.	StdD.	P.C.	t	No.	NU	NL	NC
					Oper. Life Hrs. = 83 (5-13-63)									
.11400	.15121	.26400	.00859								19	0	0	0
					Oper. Life Hrs. = 117 (5-16-63)									
.11500	.16047	.26800	.00945	1.211	.00100	.00926	.03100	.00206	5.7724	4.493	19	0	0	0
					Oper. Life Hrs. = 537 (6-4-63)									
.11500	.16016	.27100	.00956	1.022	-.00100	-.00032	.00300	.00022	-.19718	-1.455	19	0	0	0
					Oper. Life Hrs. = 1037 (6-28-63)									
.11400	.15063	.26300	.00854	1.252	-.03200	-.00953	.01800	.00263	-6.3243	-3.620	19	0	0	0
					Oper. Life Hrs. = 2000 (8-13-63)									
.11400	.15047	.26300	.00850	1.009	-.02000	-.00016	.01900	.00150	-.10494	-.105	19	0	0	0
					Vacuum Life Hrs. = 250 (9-23-63)									
.11300	.15053	.26300	.00854	1.009	-.00100	.00005	.00100	.00012	.03496	.438	19	0	0	0
					Vacuum Life Hrs. = 500 (10-10-63)									
.11500	.15921	.28000	.00986	1.333	.00000	.00868	.03200	.00218	5.4545	3.983	19	0	0	0

JPL TEST NUMBER: 7-0024 VENDOR: TEXAS INSTRUMENTS PART NUMBER: SN 510 PARAMETER: VonQs

MULTIPLIER: 1 UNIT: Volts NOMINAL VALUE: None LOWER LIMIT: None UPPER LIMIT: .5

Min.	Mean	Max.	StD.	F	MinD.	MeanD.	MaxD.	StdD.	P.C.	t	No.	NU	NL	NC
Oper. Life Hrs. = 83 (5-13-63)														
.11700	.14763	.22500	.00675								19	0	0	0
Oper. Life Hrs. = 117 (5-16-63)														
.12500	.15653	.23600	.00715	1.122	.00000	.00889	.02700	.00163	5.6826	5.472	19	0	0	0
Oper. Life Hrs. = 537 (6-4-63)														
.12300	.15516	.23600	.00724	1.023	-.00500	-.00137	.00400	.00044	-.88195	-3.105	19	0	0	0
Oper. Life Hrs. = 1037 (6-28-63)														
.11700	.14753	.22500	.00667	1.178	-.02300	-.00763	.00200	.00133	-5.1730	-5.750	19	0	0	0
Oper. Life Hrs. = 2000 (8-13-63)														
.11700	.14721	.22400	.00665	1.004	-.01000	-.00032	.00900	.00073	-.21452	-.430	19	0	0	0
Vacuum Life Hrs. = 250 (9-23-63)														
.11700	.14737	.22500	.00670	1.014	.00000	.00016	.00100	.00009	.10714	1.837	19	0	0	0
Vacuum Life Hrs. = 500 (10-10-63)														
.12400	.15637	.24600	.00764	1.299	.00100	.00900	.02500	.00148	5.7556	6.061	19	0	0	0

JPL TEST NUMBER: 7-0024 VENDOR: TEXAS INSTRUMENTS PART NUMBER: SN 512 PARAMETER: Vón(A)

MULTIPLIER: 1 UNIT: Volts NOMINAL VALUE: None LOWER LIMIT: None UPPER LIMIT: .5

Min.	Mean	Max.	StD.	F	MinD.	MeanD.	MaxD.	StdD.	P.C.	t	No.	NU	NL	NC
					Oper. Life Hrs. = 83 (5-13-63)									
.14500	.20416	.27700	.01029								19	0	0	0
					Oper. Life Hrs. = 117 (5-16-63)									
.15100	.20921	.28300	.01047	1.035	.00100	.00505	.00700	.00030	2.4151	16.796	19	0	0	0
					Oper. Life Hrs. = 537 (6-4-63)									
.15100	.20963	.28300	.01043	1.008	.00000	.00042	.00200	.00014	-.20085	3.024	19	0	0	0
					Oper. Life Hrs. = 1037 (6-28-63)									
.15000	.20937	.28400	.01050	1.015	-.00300	-.00026	.00200	.00026	-.12570	-1.000	19	0	0	0
					Oper. Life Hrs. = 2000 (8-13-63)									
.15000	.20926	.28300	.01047	1.006	-.00200	-.00011	.00300	.00024	-.05030	-.438	19	0	0	0
					Vacuum Life Hrs. = 250 (9-23-63)									
.15000	.20984	.28300	.01039	1.016	-.00100	.00058	.01000	.00054	.27589	1.067	19	0	0	0
					Vacuum Life Hrs. = 500 (10-10-63)									
.15100	.20968	.28300	.01049	1.020	-.00900	-.00016	.00100	.00050	-.07530	-.314	19	0	0	0

JPL TEST NUMBER: 7-0024 VENDOR: TEXAS INSTRUMENTS PART NUMBER: SN 512 PARAMETER: Von(B)

MULTIPLIER: 1 UNIT: Volts NOMINAL VALUE: None LOWER LIMIT: None UPPER LIMIT: .5

Min.	Mean	Max.	StD.	F	MinD.	MeanD.	MaxD.	StdD.	P.C.	t	No.	NU	NL	NC
Oper. Life Hrs. = 83 (5-13-63)														
.11000	.20068	.28000	.01164								19	0	0	0
Oper. Life Hrs. = 117 (5-16-63)														
.11100	.20553	.28700	.01181	1.029	-.00300	.00484	.00700	.00053	2.3559	9.210	19	0	0	0
Oper. Life Hrs. = 537 (6-4-63)														
.11100	.20595	.28600	.01176	1.009	-.00100	.00042	.00200	.00018	.20444	2.388	19	0	0	0
Oper. Life Hrs. = 1037 (6-28-63)														
.11000	.20537	.28600	.01185	1.015	-.00200	-.00058	.00000	.00016	-.28191	-3.644	19	0	0	0
Oper. Life Hrs. = 2000 (8-13-63)														
.11100	.20568	.28600	.01181	1.006	-.00100	.00032	.00200	.00015	.15353	2.051	19	0	0	0
Vacuum Life Hrs. = 250 (9-23-63)														
.11100	.20558	.28700	.01181	1.000	-.00200	-.00011	.00100	.00013	-.05120	-.809	19	0	0	0
Vacuum Life Hrs. = 500 (10-10-63)														
.11100	.20579	.28700	.01181	1.000	-.00100	.00021	.00100	.00012	.10230	1.714	19	0	0	0

JPL TEST NUMBER: 7-0024 VENDOR: TEXAS INSTRUMENTS PART NUMBER: SN 512 PARAMETER: Vón(C)

MULTIPLIER: 1 UNIT: Volts NOMINAL VALUE: None LOWER LIMIT: None UPPER LIMIT: .5

Min.	Mean	Max.	StD.	F	MinD.	MeanD.	MaxD.	StdD.	P.C.	t	No.	NU	NL	NC
					Oper. Life Hrs. = 83 (5-13-63)									
.14700	.20726	.27900	.01049								19	0	0	0
					Oper. Life Hrs. = 117 (5-16-63)									
.15200	.21247	.28600	.01066	1.031	-.00300	.00521	.00700	.00051	2.4523	10.205	19	0	0	0
					Oper. Life Hrs. = 537 (6-4-63)									
.15200	.21295	.28600	.01062	1.006	-.00100	.00047	.00200	.00016	.22243	2.964	19	0	0	0
					Oper. Life Hrs. = 1037 (6-28-63)									
.15100	.21242	.28500	.01069	1.012	-.00200	-.00053	.00100	.00016	-.24777	-3.293	19	0	0	0
					Oper. Life Hrs. = 2000 (8-13-63)									
.15200	.21242	.28500	.01063	1.010	-.00100	-.00000	.00100	.00013	-.00000	-.000	19	0	0	0
					Vacuum Life Hrs. = 250 (9-23-63)									
.15200	.21263	.28700	.01067	1.008	-.00100	.00021	.00200	.00014	.09901	1.455	19	0	0	0
					Vacuum Life Hrs. = 500 (10-10-63)									
.15200	.21258	.28600	.01061	1.011	-.00200	-.00005	.00100	.00018	-.02476	-.294	19	0	0	0

JPL TEST NUMBER: 7-0024 VENDOR: TEXAS INSTRUMENTS PART NUMBER: SN 512 PARAMETER: Von(D)
MULTIPLIER: 1 UNIT: Volts NOMINAL VALUE: None LOWER LIMIT: None UPPER LIMIT: .5

Min.	Mean	Max.	StD.	F	MinD.	MeanD.	MaxD.	StdD.	P.C.	t	No.	NU	NL	NC
					Oper. Life Hrs. = 83 (5-13-63)									
.13500	.20917	.27200	.01008								18	0	0	0
					Oper. Life Hrs. = 117 (5-16-63)									
.14100	.21422	.27500	.01015	1.014	-.00500	.00506	.00700	.00064	2.3599	7.912	18	0	0	0
					Oper. Life Hrs. = 537 (6-4-63)									
.14100	.21444	.27600	.01012	1.006	-.00100	.00022	.00100	.00015	.10363	1.458	18	0	0	0
					Oper. Life Hrs. = 1037 (6-28-63)									
.14000	.21400	.27600	.01016	1.009	-.00100	-.00044	.00000	.00012	-.20769	-3.688	18	0	0	0
					Oper. Life Hrs. = 2000 (8-13-63)									
.14100	.21411	.27500	.01016	1.000	-.00100	.00011	.00100	.00016	.05189	.697	18	0	0	0
					Vacuum Life Hrs. = 250 (9-23-63)									
.14000	.21417	.27600	.01020	1.008	-.00100	.00006	.00100	.00017	.02594	.325	18	0	0	0
					Vacuum Life Hrs. = 500 (10-10-63)									
.14100	.21411	.27600	.01015	1.010	-.00100	-.00006	.00100	.00010	-.02595	-.566	18	0	0	0

JPL TEST NUMBER: 7-0024 VENDOR: TEXAS INSTRUMENTS PART NUMBER: SN 512 PARAMETER: Von(E)
MULTIPLIER: 1 UNIT: Volts NOMINAL VALUE: None LOWER LIMIT: None UPPER LIMIT: .5

Min.	Mean	Max.	StD.	F	MinD.	MeanD.	MaxD.	StdD.	P.C.	t	No.	NU	NL	NC
Oper. Life Hrs. = 83 (5-13-63)														
.15200	.21268	.28500	.00985								19	0	0	0
Oper. Life Hrs. = 117 (5-16-63)														
.15300	.21726	.28900	.01000	1.030	.00100	.00458	.00700	.00032	2.1075	14.389	19	0	0	0
Oper. Life Hrs. = 537 (6-4-63)														
.15300	.21742	.29000	.01000	1.001	-.00100	.00016	.00200	.00014	.07262	1.143	19	0	0	0
Oper. Life Hrs. = 1037 (6-28-63)														
.15400	.21747	.29000	.01006	1.011	-.00200	.00005	.00200	.00021	.02420	.252	19	0	0	0
Oper. Life Hrs. = 2000 (8-13-63)														
.15300	.21742	.29000	.01002	1.009	-.00300	-.00005	.00200	.00027	-.02421	-.195	19	0	0	0
Vacuum Life Hrs. = 250 (9-23-63)														
.15300	.21705	.29100	.01002	1.001	-.00200	-.00037	.00100	.00021	-.16974	-1.794	19	0	0	0
Vacuum Life Hrs. = 500 (10-10-63)														
.15300	.21742	.29100	.01004	1.004	.00000	.00037	.00100	.00011	.16944	3.240	19	0	0	0

JPL TEST NUMBER: 7-0024 VENDOR: TEXAS INSTRUMENTS PART NUMBER: SN 512 PARAMETER: Von(F)

MULTIPLIER: 1 UNIT: Volts NOMINAL VALUE: None LOWER LIMIT: None UPPER LIMIT: .5

Min.	Mean	Max.	StD.	F	MinD.	MeanD.	MaxD.	StdD.	P.C.	t	No.	NU	NL	NC
					Oper. Life Hrs. = 83 (5-13-63)									
.15000	.21216	.28500	.01037								19	0	0	0
					Oper. Life Hrs. = 117 (5-16-63)									
.15500	.21747	.28900	.01050	1.025	.00300	.00532	.00700	.00028	2.4443	19.241	19	0	0	0
					Oper. Life Hrs. = 537 (6-4-63)									
.15500	.21758	.28900	.01049	1.001	-.00100	.00011	.00100	.00013	.04838	.809	19	0	0	0
					Oper. Life Hrs. = 1037 (6-28-63)									
.15500	.21737	.28900	.01049	1.000	-.00100	-.00021	.00100	.00012	-.09685	-1.714	19	0	0	0
					Oper. Life Hrs. = 2000 (8-13-63)									
.15500	.21726	.28900	.01048	1.002	-.00100	-.00011	.00100	.00013	-.04845	-.809	19	0	0	0
					Vacuum Life Hrs. = 250 (9-23-63)									
.15600	.21747	.28900	.01049	1.001	-.00100	.00021	.00100	.00012	.09680	1.714	19	0	0	0
					Vacuum Life Hrs. = 500 (10-10-63)									
.15200	.21747	.29000	.01060	1.022	-.00500	-.00000	.00100	.00031	-.00000	-.000	19	0	0	0

JPL TEST NUMBER: 7-0024 VENDOR: TEXAS INSTRUMENTS PART NUMBER: SN 515 PARAMETER: VonACo
MULTIPLIER: 1 UNIT: Volts NOMINAL VALUE: None LOWER LIMIT: None UPPER LIMIT: None

Min.	Mean	Max.	StD.	F	MinD.	MeanD.	MaxD.	StdD.	P.C.	t	No.	NU	NL	NC
					Oper. Life Hrs. = 83 (5-13-63)									
.15100	.17432	.21000	.00301								19	0	0	0
					Oper. Life Hrs. = 117 (5-16-63)									
.15100	.17458	.20900	.00300	1.008	-.00100	.00026	.00400	.00025	.15073	1.045	19	0	0	0
					Oper. Life Hrs. = 537 (6-4-63)									
.15000	.17353	.20900	.00300	1.005	-.00500	-.00105	.00000	.00039	-.60661	-2.727	19	0	0	0
					Oper. Life Hrs. = 1037 (6-28-63)									
.15100	.17395	.21000	.00301	1.002	-.00100	.00042	.00200	.00018	.24205	2.388	19	0	0	0
					Oper. Life Hrs. = 2000 (8-13-63)									
.15100	.17374	.21000	.00302	1.008	-.00200	-.00021	.00100	.00020	-.12118	-1.073	19	0	0	0
					Vacuum Life Hrs. = 250 (9-23-63)									
.15100	.17374	.21000	.00300	1.016	-.00100	.00000	.00100	.00015	.00000	.000	19	0	0	0
					Vacuum Life Hrs. = 500 (10-21-63)									
.15000	.17306	.20800	.00312	1.029	-.01600	.00133	.05700	.00363	.77045	.368	18	0	0	0

JPL TEST NUMBER: 7-0024 VENDOR: TEXAS INSTRUMENTS PART NUMBER: SN 515 PARAMETER: VonBCo

MULTIPLIER: 1 UNIT: Volts NOMINAL VALUE: None LOWER LIMIT: None UPPER LIMIT: None

Min.	Mean	Max.	StD.	F	MinD.	MeanD.	MaxD.	StdD.	P.C.	t	No.	NU	NL	NC
Oper. Life Hrs. = 83 (5-13-63)														
.12400	.16805	.19900	.00395								20	0	0	0
Oper. Life Hrs. = 117 (5-16-63)														
.12300	.16810	.19500	.00394	1.002	-.00400	.00005	.00500	.00039	.02974	.129	20	0	0	0
Oper. Life Hrs. = 537 (6-4-63)														
.12400	.16720	.19400	.00387	1.039	-.00500	-.00090	.00100	.00038	-.53828	-2.349	20	0	0	0
Oper. Life Hrs. = 1037 (6-28-63)														
.12400	.16760	.19400	.00383	1.017	-.00100	.00040	.00100	.00013	.23866	2.990	20	0	0	0
Oper. Life Hrs. = 2000 (8-13-63)														
.12400	.16700	.19400	.00386	1.016	-.00200	-.00060	.00000	.00013	-.35928	-4.485	20	0	0	0
Vacuum Life Hrs. = 250 (9-23-63)														
.12400	.16720	.19400	.00383	1.017	.00000	.00020	.00100	.00009	.11961	2.179	20	0	0	0
Vacuum Life Hrs. = 500 (10-21-63)														
.12400	.16616	.19300	.00397	1.020	-.00100	-.00042	.00100	.00014	-.25340	-3.024	19	0	0	0

JPL TEST NUMBER: 7-0024 VENDOR: TEXAS INSTRUMENTS PART NUMBER: SN 515 PARAMETER: VonĀEo

MULTIPLIER: 1 UNIT: Volts NOMINAL VALUE: None LOWER LIMIT: None UPPER LIMIT: None

Min.	Mean	Max.	StD.	F	MinD.	MeanD.	MaxD.	StdD.	P.C.	t	No.	NU	NL	NC
Oper. Life Hrs. = 83 (5-13-63)														
.12700	.17153	.19900	.00428								19	0	0	0
Oper. Life Hrs. = 117 (5-16-63)														
.14800	.17632	.21300	.00407	1.103	-.00100	.00479	.08600	.00452	2.7164	1.060	19	0	0	0
Oper. Life Hrs. = 537 (6-4-63)														
.14800	.17537	.21300	.00412	1.024	-.00500	-.00095	.00000	.00034	-.54022	-2.807	19	0	0	0
Oper. Life Hrs. = 1037 (6-28-63)														
.14800	.17558	.21200	.00403	1.044	-.00100	.00021	.00100	.00018	.11990	1.165	19	0	0	0
Oper. Life Hrs. = 2000 (8-13-63)														
.14800	.17537	.21200	.00409	1.026	-.00100	-.00021	.00100	.00014	-.12005	-1.455	19	0	0	0
Vacuum Life Hrs. = 250 (9-23-63)														
.14800	.17532	.21200	.00412	1.019	-.00100	-.00005	.00100	.00012	-.03002	-.438	19	0	0	0
Vacuum Life Hrs. = 500 (10-21-63)														
.14800	.17522	.21100	.00427	1.014	-.00100	-.00000	.00100	.00020	-.00001	-.000	18	0	0	0

JPL TEST NUMBER: 7-0024 VENDOR: TEXAS INSTRUMENTS PART NUMBER: SN 515 PARAMETER: VonBEo

MULTIPLIER: 1 UNIT: Volts NOMINAL VALUE: None LOWER LIMIT: None UPPER LIMIT: None

Min.	Mean	Max.	StD.	F	MinD.	MeanD.	MaxD.	StdD.	P.C.	t	No.	NU	NL	NC
Oper. Life Hrs. = 83 (5-13-63)														
.13000	.16965	.21300	.00472								20	0	0	0
Oper. Life Hrs. = 117 (5-16-63)														
.13000	.16947	.20700	.00481	1.017	-.00600	.00032	.00400	.00044	.18633	.718	19	0	0	0
Oper. Life Hrs. = 537 (6-4-63)														
.13000	.16847	.20800	.00485	1.019	-.00500	-.00100	.00100	.00037	-.59357	-2.727	19	0	0	0
Oper. Life Hrs. = 1037 (6-28-63)														
.13000	.16858	.20800	.00481	1.018	-.00100	.00011	.00100	.00015	.06244	.697	19	0	0	0
Oper. Life Hrs. = 2000 (8-13-63)														
.13000	.16821	.20700	.00482	1.006	-.00100	-.00037	.00100	.00016	-.21903	-2.348	19	0	0	0
Vacuum Life Hrs. = 250 (9-23-63)														
.13000	.16832	.20700	.00482	1.001	-.00100	.00011	.00100	.00013	.06253	.809	19	0	0	0
Vacuum Life Hrs. = 500 (10-21-63)														
.13000	.16837	.20600	.00476	1.024	-.00200	.00005	.00100	.00022	.03125	.236	19	0	0	0