**OAK RIDGE NATIONAL LABORATORY**
operated by
**UNION CARBIDE CORPORATION**
NUCLEAR DIVISION
for the
**U.S. ATOMIC ENERGY COMMISSION**

ORNL - TM - 1638, Part 21

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# NUCLEAR INSTRUMENT MODULE MAINTENANCE MANUAL

## PART 21

## +10 VOLT AND -10 VOLT VOLTAGE REGULATORS, ORNL MODEL Q-2621

W. E. Lingar

ABSTRACT

The +10 Volt and -10 Volt Voltage Regulator module is for use in providing regulated voltages for nuclear reactor instrumentation. The input to the +10 v regulator circuit is a dc voltage in the range of +28 to +36 v. The input to the -10 v regulator circuit is in the range of -28 to -36 v.

The regulators are packaged in a standard plug-in module of the ORNL Modular Reactor Instrumentation Series.

This report describes the circuits, applications, maintenance procedures, and acceptance test for the regulators.

CONTENTS

# 1. DESCRIPTION

## 1.1 General

The +10 Volt and -10 Volt Voltage Regulator module is for use in providing regulated voltages for nuclear reactor instrumentation. The input to the +10 v regulator circuit is a dc voltage in the range of +28 to +36 v. The input to the -10 v regulator circuit is in the range of -28 to -36 v. The regulator outputs have a common electrical ground.

## 1.2 Construction

The +10 Volt and -10 Volt Voltage Regulators are constructed in a single module 5.63 in. wide, 4.72 in. high, and 11.90 in. deep. It is a standard "4 unit" plug-in module of the ORNL Modular Reactor Instrumentation series depicted on ORNL drawings Q-2600-1 through Q-2600-5.

Each regulator circuit is constructed on a printed circuit board mounted within the module and is unshielded.

## 1.3 Application

The +10 Volt and -10 Volt Voltage Regulators are used to provide sources of well-regulated voltage to any instrument requiring either +10 v dc or -10 v dc within the current rating of the regulators. The input to the regulators is normally a bank of 32-v batteries. The battery bank terminal voltage can vary from 28 to 36 v, however, depending on the charge condition of the battery bank.

## 1.4 Specifications

### 1.4.1 +10 Volt Voltage Regulator

| | | |
|---|---|---|
| 1. | Input voltage: | +28 to +36 v dc. |
| 2. | Output voltage: | +10 v dc. |
| 3. | Maximum output current: | 0.5 amp. |
| 4. | Ambient temperature range: | 10 to 55°C. |
| 5. | Load regulation: | 0.01%. |
| 6. | Line regulation: | 0.01%. |
| 7. | Maximum temperature coefficient: | 0.003%/°C. |
| 8. | Long-term stability: | 0.01%/24 hours. |

### 1.4.2 -10 Volt Voltage Regulator

| | | |
|---|---|---|
| 1. | Input voltage: | -28 to -36 v dc. |
| 2. | Output voltage: | -10 v dc. |
| 3. | Maximum output current: | 0.5 amp. |
| 4. | Ambient temperature range: | 10 to 55°C. |
| 5. | Line regulation: | 0.01%. |
| 6. | Load regulation: | 0.01%. |
| 7. | Maximum temperature coefficient: | 0.003%/°C. |
| 8. | Long-term stability: | 0.01%/24 hours. |

## 1.5 Applicable Drawings

The following list gives the drawing numbers (ORNL Instrumentation and Controls Division drawing numbers) and subtitles and the fabrication specification number for the +10 Volt and the -10 Volt Voltage Regulators:

| | | |
|---|---|---|
| 1. | Q-2621-1 | Circuit. |
| 2. | Q-2621-2 | Details. |
| 3. | Q-2621-3 | Metalphoto Panel. |
| 4. | Q-2621-4 | Printed Circuit Board. |
| 5. | Q-2621-5 | Assembly. |
| 6. | Q-2621-6 | Parts List. |
| 7. | SF-251 | Fabrication Specification. |

The following list gives the drawing numbers and subtitles for the Plug-In Chassis System:

| | | |
|---|---|---|
| 1. | Q-2600-1 | Assembly. |
| 2. | Q-2600-2 | Details. |
| 3. | Q-2600-3 | Details. |
| 4. | Q-2600-4 | Details. |
| 5. | Q-2600-5 | Details. |

# 2. THEORY OF OPERATION

## 2.1 General

The +10 Volt and the -10 Volt Voltage Regulators are transistorized series-voltage regulators. These regulators are essentially high-gain feedback amplifiers. Each regulator provides a stable output voltage when either the input voltage or the output current is varied over the range for which each was designed.

## 2.2 Circuit Description

This circuit description applies to the +10 Volt Voltage Regulator and the -10 Volt Voltage Regulator.

Figure 1, a block diagram of the regulator circuits, is included as an illustration to supplement this circuit description. The complete circuit diagram is shown in Fig. 2.

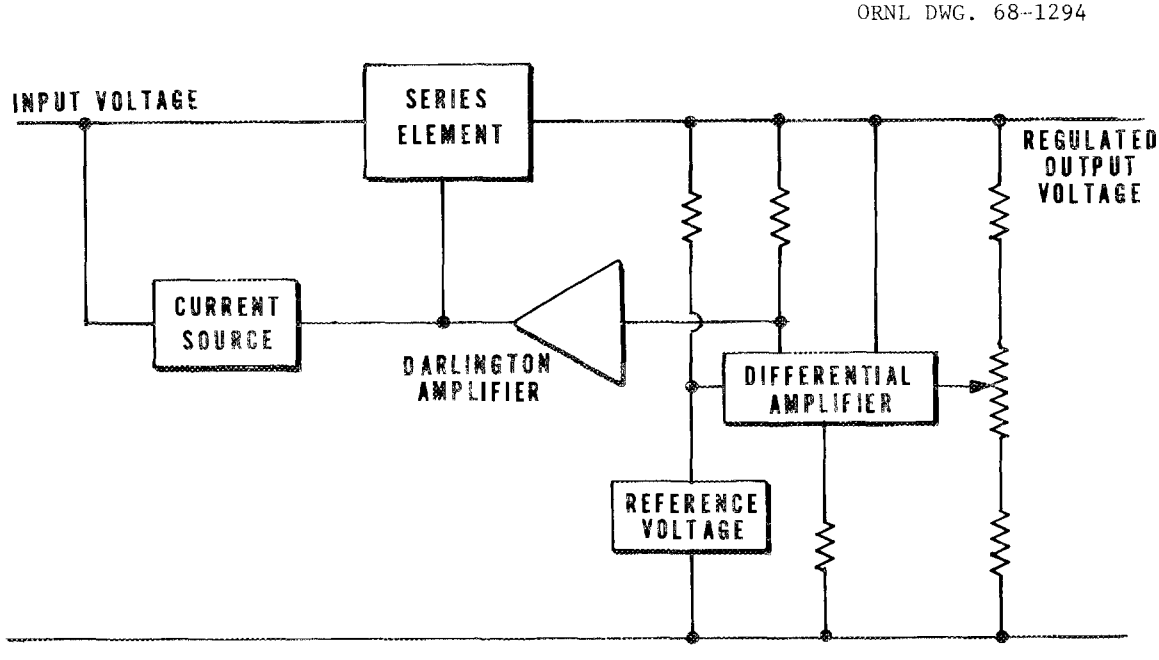
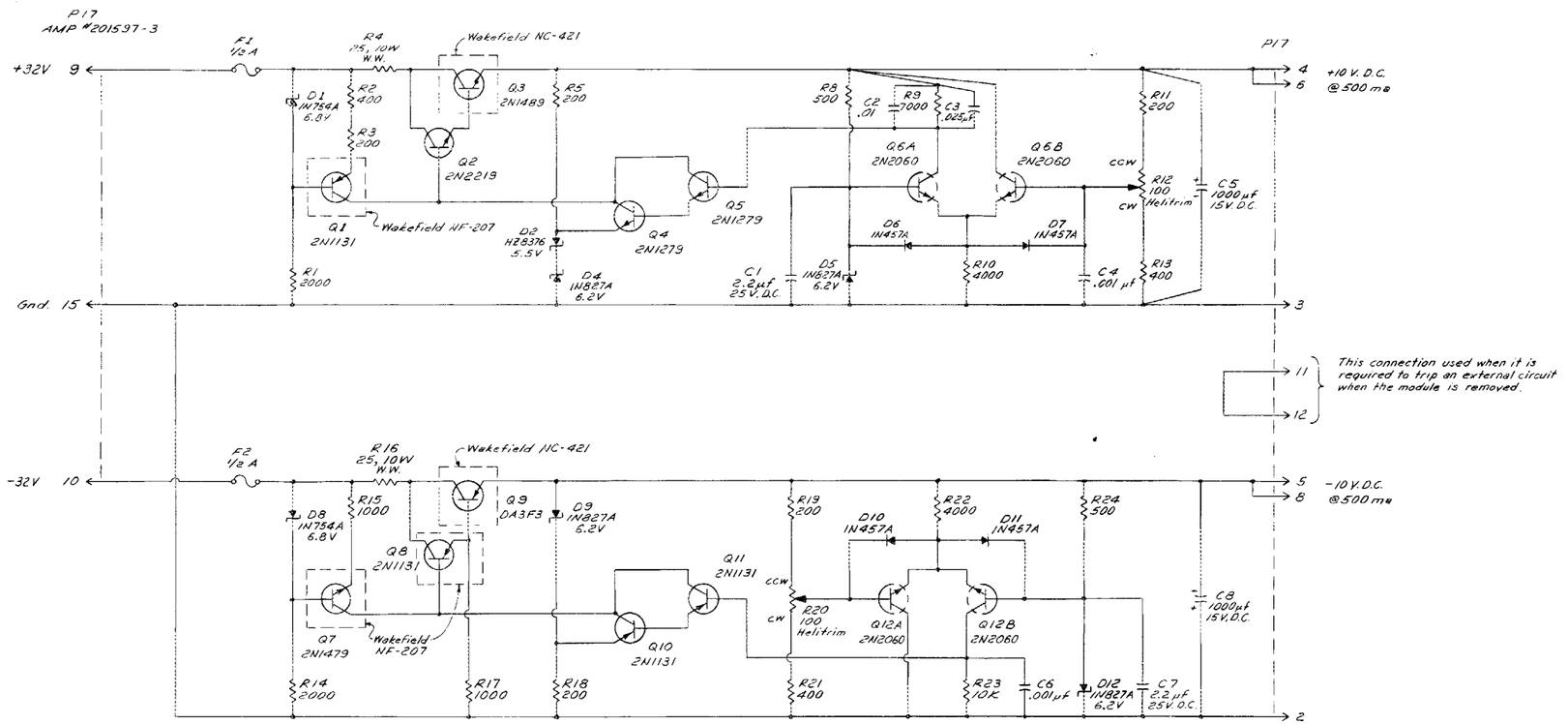



Fig. 1. Diagram of +10 Volt and -10 Volt Regulator Circuits.




NOTE

All resistors are Dawen wirewound, 3/4 W, 1/2% except as noted.


SEMICONDUCTOR BASE DIAGRAMS
BOTTOM VIEWS

| NO. | REVISIONS | DATE | APPD | APPD |
|---|---|---|---|---|
| DRAWN C.E.WAGGONER | DATE 6-27-63 | SUBMITTED J.L. Anderson | DATE 10-2-63 | APPROVED S.H. Hanauer | DATE 10-2-63 |
| DESIGNED W.E.LINGAR | DATE | APPROVED | DATE | APPROVED | DATE |
| CHECKED | DATE | APPROVED | DATE | APPROVED | DATE |

8-2065 O Q-2621-1 DTI
5-14-65 O UNITED NUCLEAR JLA
10-2-63 O KC13-17-1 JLA
10-2-63 O KC11-17-1 JLA

2621-1

| PARTS LIST | Q-2621-6 |
|---|---|
| ASSEMBLY | Q-2621-5 |
| PRINTED CKT. BD. | Q-2621-4 |
| METALPHOTO PANEL | Q-2621-3 |
| DETAILS | Q-2621-2 |
| REFERENCE DRAWINGS | DWG. NO. |

DESIGN RESPONSIBILITY J.L. ANDERSON

MODULAR REACTOR INSTRUMENTATION

+10 VOLT & -10 VOLT VOLTAGE REGULATORS CIRCUIT

INSTRUMENTATION AND CONTROLS DIVISION
OAK RIDGE NATIONAL LABORATORY
OPERATED BY
UNION CARBIDE NUCLEAR COMPANY

| SUBMITTED | ACCEPTED | DATE | APPROVED | DATE |
|---|---|---|---|---|
| | | | | Q-2621-1 RO |

Fig. 2. Circuit of +10 Volt and -10 Volt Voltage Regulators.

Each regulator has a single-ended differential amplifier which samples the output voltage and compares it with the voltage drop across a temperature-compensated reference diode. This amplifier produces an output voltage proportional to the difference between the change in the reference voltage and the change in the sampled output voltage when a change occurs in the output voltage. The two differential-amplifier transistors in each regulator are packaged in a single TO-5 case. These transistors are Q12A and Q12B in the -10 v regulator, and Q6A and Q6B in the +10 v regulator. The two transistors in each package are closely matched in their $V_{BE}$ and $h_{FE}$ characteristics.

The output voltage of the differential amplifier is fed into a Darlington-pair amplifier which produces a large voltage gain from the differential amplifier to the series-regulating element. The collectors of the Darlington pair are connected to a node that joins a current source and the series-regulating element.

The series-regulating element in each regulator is a Darlington-pair amplifier which provides a large current gain from the node to the regulator output. The series-regulating element is connected in series with the regulator input and the regulator output. The output of the series element is varied when either the input voltage or the output current is changed so that constant output voltage is maintained.

## 3. OPERATING INSTRUCTIONS

### 3.1 Installation

The +10 v and -10 v Voltage Regulator module is a module of the ORNL Modular Reactor Instrumentation series. Like the other modules in this series, it has standard connectors and dimensions and has a pin- and hole-code on the rear plate so that the module will not be inserted in a wrong location in the drawer. The module is installed by placing it in its proper location, inserting the module firmly, and tightening the thumb screw. The module may be plugged in with power on without damage.

### 3.2 Operating Controls

There are no operating controls on the module.

### 3.3 Connections

All connections are made through the rear connector P17 when the module is inserted.

# 4. MAINTENANCE INSTRUCTIONS

## 4.1 General

This module is designed to operate continuously with a minimum of maintenance and no adjustments. Should a failure occur, any part listed in the Replaceable Parts List, Sect. 5, may be replaced.

## 4.2 Periodic Maintenance

There is no specific periodic maintenance procedure.

## 4.3 Calibration

Potentiometer R12 on the +10 v voltage regulator card can be adjusted to bring the output voltage to +10 v, and potentiometer R20 on the -10 v voltage regulator card can be adjusted to bring the output voltage to -10 v. For both potentiometers, clockwise rotation of adjustment screw increases the output voltage, and counterclockwise rotation decreases the output voltage.

## 4.4 Trouble Shooting

The most likely source of trouble is an open fuse in the input circuit. The input fuse in the +10 v regulator is F1, and the input fuse in the -10 v regulator is F2. In addition, any of the transistor or diode junctions could become faulty under certain load conditions.

## 4.5 Transistor Voltage Chart

The voltages of all transistors are listed in Table 1.

# 5. REPLACEABLE PARTS LIST

A description and an ORNL stores number for all replaceable parts are given in Table 2.

Table 1. Transistor Voltage Chart[1]

| Transistor | Emitter | Base | Collector |
|---|---|---|---|
| Q1 | +25.83 | +25.28 | +11.15 |
| Q2 | +10.57 | +11.15 | +31.17 |
| Q3 | +10.00 | +10.57 | +31.17 |
| Q4 | + 7.28 | + 8.02 | +11.15 |
| Q5 | + 8.02 | +8.59 | +11.15 |
| Q6A | + 5.82 | +6.46 | +10.01 |
| Q6B | + 5.82 | +6.42 | + 8.59 |
| Q7 | -25.74 | -25.16 | -10.72 |
| Q8 | -10.08 | -10.72 | -30.91 |
| Q9 | -10.00 | -10.08 | -30.92 |
| Q10 | - 3.57 | - 4.23 | -10.72 |
| Q11 | - 4.23 | - 4.81 | -10.72 |
| Q12A | - 7.06 | - 6.45 | 0.00 |
| Q12B | - 7.06 | - 6.43 | - 4.80 |

[1]All voltages were measured with respect to ground with a Cubic V-85 digital voltmeter. The input voltage to the +10 v dc regulator was +32 v dc and the input voltage to the -10 v regulator was -32 v dc. The output of each regulator was unloaded.

Table 2. Replaceable Parts List

| Part No. | ORNL Stores No. | Description |
|---|---|---|
| C5, C8 | | Capacitor, 1000 mf, -10 +100%, 15 v dc w, -10° to +85°C operating temperature, 0.750 in. by 2.0 in. long, type PSD, Callins Industries, Inc. |
| C1, C7 | 06-802-0091 | Capacitor, 2.2 mf, ±20%, 25 v dc w, ceramic, monolithic, Sprague No. 5C15. |
| C2 | 06-802-0084 | Capacitor, 0.01 mf, ±20%, 25 v dc w, ceramic, monolithic, Sprague No. 3C3. |
| C3 | 06-802-0430 | Capacitor, 0.025 mf, ±20%, 500 v dc w, ceramic, disc, formulation C23, Sprague No. 55C30A. |
| C4, C6 | 06-802-0390 | Capacitor, 0.001 mf, ±10%, 1000 v dc w, ceramic, disc, formulation C28, Sprague No. 29C151A1. |
| R12, R20 | 06-930-8202 | Potentiometer, trimmer, 100 ohms, ±10%, 1-1/2 w, conductive glass resistance element, "Helitrim" series 53 with printed circuit pins, Helipot Div. |
| R4, R16 | 06-936-1940 | Resistor, 25 ohms, ±5%, 10 w, ww, vitreous enamel coating, P.R. Mallory No. RW29G-250. |
| R3, R5, R11 R18, R19 | 06-936-0665 | Resistor, 200 ohms, ±1/2%, 3/4 w at 125°C, ww, noninductive, temp coeff not to exceed 20 ppm/°C, Daven type 1252. |
| R2, R13, R21 | 06-936-0670 | Resistor, 400 ohms, ±1/2%, 3/4 w at 125°C, ww, noninductive, temp coeff not to exceed 20 ppm/°C, Daven type 1252. |
| R8, R24 | 06-936-0672 | Resistor, 500 ohms, ±1/2%, 3/4 w at 125°C, ww, noninductive, temp coeff not to exceed 20 ppm/°C, Daven type 1252. |
| R15, R17 | 06-936-0680 | Resistor, 1000 ohms, ±1/2%, 3/4 w at 125°C, ww, noninductive, temp coeff not to exceed 20 ppm/°C, Daven type 1252. |
| R1, R14 | 06-936-0685 | Resistor, 2000 ohms, ±1/2%, 3/4 w at 125°C, ww, noninductive, temp coeff not to exceed 20 ppm/°C, Daven type 1252. |

Table 2. Continued

| Part No. | ORNL Stores No. | Description |
|---|---|---|
| R10, R22 | 06-936-0690 | Resistor, 4000 ohms, ±1/2%, 3/4 w at 125°C, ww, noninductive, temp coeff not to exceed 20 ppm/°C, Daven type 1252. |
| R9 | 06-936-0695 | Resistor, 7000 ohms, ±1/2%, 3/4 w at 125°C, ww, noninductive, temp coeff not to exceed 20 ppm/°C, Daven type 1252. |
| R23 | 06-936-0700 | Resistor, 10 kilohms, ±1/2%, 3/4 w at 125°C, ww, noninductive, temp coeff not to exceed 20 ppm/°C, Daven type 1252. |
| Q1, Q8, Q10, Q11 | 06-996-1710 | Transistor, PNP, silicon, type 2N1131, Texas Instr. |
| Q4, Q5 | 06-996-1880 | Transistor, NPN, silicon, type 2N1279, G.E. |
| Q3 | 06-996-1986 | Transistor, NPN, silicon, type 2N1489, Silicon Transistor Corp. |
| Q7 | 06-996-1985 | Transistor, NPN, silicon, type 2N1479, RCA. |
| Q2 | 06-996-1998 | Transistor, NPN, type 2N2219, Motorola. |
| Q9 | 06-996-2050 | Transistor, PNP, type DA3F3, Honeywell. |
| Q6, Q12 | 06-996-1994 | Transistor, dual NPN, type 2N2060, Fairchild. |
| D1, D8 | 06-995-6244 | Diode, zener, 6.8 v ±5%, 400 mw, type 1N754A, Motorola. |
| D6, D7, D10, D11 | 06-995-5820 | Diode, silicon, type 1N457A, Electrical Ind. Assoc. |
| D2 | 06-995-7870 | Diode, zener, 5.5 v ±5%, 250 mw, type HZ-8376, Hughes Aircraft Co. |
| D4, D5, D9, D12 | | Diode, zener, 6.2 v, temperature compensated, type 1N827A, Motorola. |

# 6. ACCEPTANCE TESTS

## 6.1 Test Equipment

The following test equipment is required:

1. A dc-regulated power supply, adjustable from 28 to 36 v dc and capable of supplying 2.5 amp.

2. An oscilloscope, dc to 10 Mc, 1 mv/cm sensitivity.

3. A differential voltmeter capable of resolving $10^{-4}$ v with inputs from 10 to 25 v dc.

4. A temperature test chamber.

5. A 20-ohm, 10-w resistor for dummy load.

## 6.2 Test Procedures

1. Adjust the power supply for 32 v dc output. Connect the positive terminal of the power supply to pin 9 of the regulator connector. Connect the negative terminal to pin 15 of the regulator connector P17.

2. Connect pin 4 of the regulator to the positive input terminal of the differential voltmeter. Connect pin 3 of the regulator to the negative input terminal of the voltmeter.

3. Adjust potentiometer R12 until the voltmeter reads 10.000 v.

4. Connect the oscilloscope probe to pin 4 of the regulator, and connect the probe ground lead to pin 3 of the regulator connector. Observe the oscilloscope trace for any evidence of oscillations with the oscilloscope sensitivity at 1 mv/cm.

5. Change the power supply output voltage from its 32 v dc setting to 28 v dc and observe the oscilloscope trace for evidence of oscillations. While observing both the differential voltmeter for changes in regulator output voltage and the oscilloscope trace for oscillations, adjust the power supply voltage slowly until 36 v dc output is reached. The change in regulator output voltage should not be greater than 1.0 mv from its value of 10.000 v. A typical change is less than 0.25 mv. Reset the power supply output voltage to 32 v dc.

6. Connect a 20-ohm, 10-w resistor across pin 4 and pin 3 of the regulator connector, and observe the voltage change on the differential voltmeter. The voltage change should not be greater than 1.0 mv. The typical change is 0.50 mv. Also, observe the oscilloscope trace for evidence of oscillations while the regulator is loaded.

7. Connect the positive terminal of the power supply to pin 15 of connector P17. Connect the negative terminal of the power supply to pin 10 of connector P17.

8. Connect pin 2 of connector P17 to the positive input terminal of the differential voltmeter. Connect pin 5 of connector P17 to the negative input terminal of the voltmeter.

9. Adjust potentiometer R20 until the voltmeter reads 10.000 v.

10. Connect the oscilloscope probe to pin 8 of connector P17, and connect the probe ground lead to pin 2 of connector P17. Observe the scope trace for any evidence of oscillations on 1 mv/cm sensitivity.

11. Repeat step 5. The change in the regulator output voltage should not be greater than 1.0 mv from its value of 10.000 v. A typical change is less than 0.25 mv. Reset the power supply voltage to 32 v dc.

12. Connect a 20-ohm, 10-w resistor across pin 8 and pin 2 of connector P17, and observe the voltage change on the differential voltmeter. The voltage change should not exceed 1.0 mv. The typical change is 0.5 mv. Observe the oscilloscope trace for evidence of oscillations while the regulator is loaded.

13. A temperature stability test can be made by placing the module in a temperature controlled oven. Approximately 15 min should be allowed for the module to reach equilibrium after the oven temperature is changed.

a. The +10 v voltage regulator can be tested by making the connections described in steps 1, 2, and 4. The oscilloscope trace should be observed for evidence of oscillations during the test. The output voltage of the +10 v dc voltage regulator should not change more than 14 mv from its 10.000 v dc value over the temperature range 10 to 55°C. A typical change is 5 mv.

b. The -10 v dc voltage regulator can be tested by making the connections indicated in steps 7, 8, and 10. Observe the oscilloscope trace for evidence of oscillations during the test. The output voltage of the -10 v dc voltage regulator should not change more than 14 mv from its 10.000 v dc value over the temperature range 10 to 55°C. A typical change is 5 mv.

ORNL-TM-1638
Part 21

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