Model 2701C

Programmable Precision DC Voltage / Current Standard

Operation Manual

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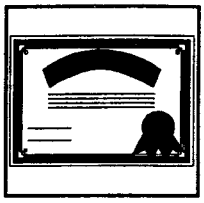
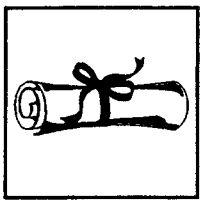
CERTIFICATION



Valhalla Scientific, Inc. certifies that this instrument was thoroughly tested and inspected and found to meet published specifications when shipped from the factory. Valhalla Scientific, Inc. further certifies that its calibration measurements are traceable to the National Institute of Standards and Technology to the extent allowed by NIST's calibration facility.

WARRANTY



The warranty period for this instrument is stated on your invoice and packing list. Please refer to these to determine appropriate warranty dates. We will repair or replace the instrument during the warranty period provided it is returned to Valhalla Scientific, Inc. freight prepaid. No other warranty is expressed or implied. We are not liable for consequential damages. Permission and a return authorization number must be obtained directly from the factory for warranty repairs. No liability will be accepted if returned without such permission. Due to continuing product refinement and due to possible parts manufacturer changes, Valhalla Scientific reserves the right to change any or all specifications without notice.

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SECTION I UNPACKING & INSTALLATION

1-1. Introduction

The Valhalla Model 2701C is a precision DC voltage source capable of delivering the signals necessary for a variety of testing. The stability and accuracy of the 2701C make it ideal for NIST traceable calibration of test equipment. The low voltage, low noise outputs are suitable for testing precision amplifier circuits, or as the input to other types of critical circuits.

The simplified controls of the 2701C make it a breeze to configure. Fully adjustable digits allow adjustment down to ±0.5PPM (at full scale output). The 2701C is capable of sourcing up to 25mA in the voltage output mode, and 4-wire compensation is available at the touch of a button. The brilliant high-voltage warning indicator alerts the operator to the presence of voltages greater than 30 volts, and a safety interlock automatically selects standby whenever the 1200V range is selected.

The 2701C is available with a variety of useful options including a low noise, low voltage option that is perfect for testing amplifiers. Automated testing is available using the IEEE-488 interface, which also may be connected to Valhalla's 12-amp current source (Model 2500EP) through the IRP port. An internal 120 milliamp current source (Option IT-2) is useful for low-level constant-current applications.

Warning! Hazardous voltages are routinely present on the terminals of this instrument. Please read this manual thoroughly before attempting to operate the 2701C. Contact with high voltage may cause injury or death.

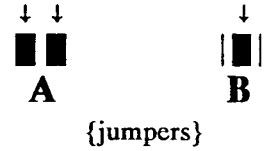
1-2. Inspection

If the shipping carton is damaged, request that the carrier's agent be present when the unit is unpacked. If the instrument appears damaged, the carrier's agent should authorize repairs before the unit is returned to the factory. If the unit fails to operate or fails to meet the performance specifications of Section 2, notify the carrier's agent and the nearest Valhalla Sales Office. Retain the shipping carton for the carrier's inspection. DO NOT return equipment to Valhalla Scientific or any of its sales offices prior to obtaining authorization to do so.

1-3. Initial Adjustments

The only adjustments required before placing the unit in operation are to verify that the instrument has been set for the proper local AC line voltage and to verify that the proper fuse has been installed as follows: 105 to 125 VAC = 1 Amp Slo-blo; 210 to 250 VAC = 0.5 Amp Slo-blo.

Line voltage is selected internally by the configuration of the jumpers on PL201 and PL202. The board is marked to indicate that the jumpers shall be placed in the "A" configuration for 115VAC and in the "B" configuration for 230VAC. Spare jumpers may be placed in any position on PL203 for possible future use.



{jumpers}

1-4. Instructions for Bench Use

The unit is supplied with all the hardware required for bench use and special instructions for use in this manner are not necessary. However, before connecting the unit to the local power source, verify that the power cord is equipped with a three-terminal connector.

1-5. Rack Mounting

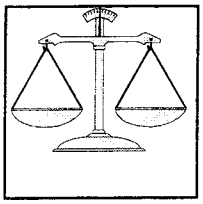
Optional brackets are available for mounting the Model 2701C in a standard 19" equipment rack. These are listed in Section 3. The size of the unit and the location of its center of gravity dictate that it must be supported on both sides along its entire length through the use of trays or slides. If it is to be transported while mounted in a rack, it should be supported so as to prevent upward or downward movement.

It is recommended that blank panels at least 1.75 inches high be installed between this and any other units in the rack to ensure freedom of air flow. Under no circumstances should the ambient air temperature around the unit exceed 50°C while the unit is in operation or 70°C when power is removed.

1-6. Safety Precautions

The power plug must be a three-contact device and should be inserted only into a three-contact mating socket where the third contact provides a ground connection. If power is provided through an extension cable, the ground connection must be continuous. **Any discontinuity in the ground lead may render the unit unsafe for use!**

SECTION II SPECIFICATIONS



2-1. Accuracy

The accuracy specifications are valid following a 2 hour warm-up at ±5°C from the calibration temperature within the range of 10°C to 35°C. The values stated below include the effects of line, load and temperature variations within the temperature window. To derive absolute accuracies relative to the National Institute of Standards and Technology (NIST) add 1.5 ppm (15 ppm for 120mA range) for Valhalla Scientific's traceability and transfer uncertainty.

	PPM OF SETTING ± RANGE NOISE	
	From Factory	1 Year
200mV	± 20ppm ± 1μV	± 30ppm ± 2μV
2V	± 15ppm ± 4μV	± 25ppm ± 6μV
20V	± 13ppm ± 13μV	± 22ppm ± 50μV
120V	± 14ppm ± 250μV	± 23ppm ± 400μV
1200V	± 15ppm ± 2.5mV	± 24ppm ± 4V
120mA[1]	± 45ppm ± 4μA	± 65ppm ± 6μA
[1] A 120mA constant current source is available as Option IT-2.		

2-2. Stability

Listed below are stability and noise specifications for the Model 2701C. These specifications apply provided that the line voltage, load and ambient temperature (within ±1°C) remain constant.

Range	Noise (0.1 to 10Hz)	24hr Stability (DC to 0.2Hz)
200mV	1μV	1μV
2V	2μV	±0.5ppm ±2μV
20V	15μV	±0.5ppm ±10μV
120V	150μV	±0.5ppm ±100μV
1200V	1.5mV	±0.5ppm ±1mV
120mA*	300nA	±1ppm ±500nA

* A 120 milliamp constant current source is available as Option IT-2.

2-3. Temperature Coefficient

The specifications below are valid after the 2701C has been allowed to stabilize at its new temperature. The stabilization time (thermal time constant) is 1 min/°C. These temperature coefficient adders are in addition to the specifications in Section 2-1 and apply only to temperatures outside the ±5°C window of the calibration temperature.

Range	Change per °C:	0°C to 35°C	35°C to 50°C
200mV		±2ppm ±0.1μV	±3ppm ±0.2μV
2V		±1ppm ±0.6μV	±2ppm ±1.0μV
20V		±1ppm ±6μV	±2ppm ±10μV
120V		±1ppm ±30μV	±2ppm ±50μV
1200V		±1ppm ±300μV	±2ppm ±500μV
120mA*		±6ppm ±250nA	±10ppm ±500nA

* A 120 milliamp constant current source is available as Option IT-2.

2-4. Performance Characteristics

The table below gives the general operating characteristics of the 2701C. *Resolution* refers to the minimum adjustment that may be made in the selected range. *Max Current* refers to the maximum amount of current that may be supplied by the selected range without affecting its accuracy (4-Wire mode must be used). *Wideband Noise* refers to the maximum amount of microprocessor and power supply noise (from 10Hz to 10kHz) that may be present on the output voltage. The *Linearity* of the 2701C is defined as the maximum allowable deviation from a straight line between the zero and fullscale outputs on each range. *Output Impedance* refers to the impedance of the voltage amplifier.

2701C Performance Characteristics

Range:	Resolution	Max Current	Wideband Noise	Linearity	Output Impedance
200mV	100nV	---	25μV$_{RMS}$	±0.5μV	450Ω
2V	1μV	25mA	80μV$_{RMS}$	±1μV±4ppm/sett	< 1mΩ
20V	10μV	25mA	130μV$_{RMS}$	±10μV±4ppm/st	< 5mΩ
120V	100μV	25mA	500μV$_{RMS}$	±100μV	< 50mΩ
1200V	1mV	25mA	800μV$_{RMS}$	±1mV	< 500mΩ
120mA[1]	100nA	[2]	10μA$_{RMS}$	±500nA	> 10MΩ

[1] A 120 milliamp constant current source is available as Option IT-2.
[2] ± 10VDC maximum compliance voltage.

2-5. Option LNF Specifications

The Model 2701C is available with a modification that reduces the wideband noise specifications of Section 2-4. This modification is designated as Option "LNF". A 2701C equipped with Option LNF has a maximum output voltage of ±40 volts. The following Wideband Noise specifications apply to instruments equipped with Option LNF only.

Range	10Hz to 1kHz	1kHz to 10kHz
200mV	$10\mu V_{RMS}$	$5\mu V_{RMS}$
2V	$10\mu V_{RMS}$	$10\mu V_{RMS}$
20V	$15\mu V_{RMS}$	$10\mu V_{RMS}$
120V*	$100\mu V_{RMS}$	$25\mu V_{RMS}$

* The 120V range may output a maximum of ±40 volts.

NOTE: These specifications apply to 2701Cs that have not been equipped with the IEEE-488 interface option (Option TL-3). For instruments equipped with Option TL-3, increase these specifications by 50%. The maximum reduction in wideband noise is obtained by making connections to the front panel SENSE terminals.

2-6. Output Settling Time

The Model 2701C requires a specified period of time to settle at its final output voltage. This time period is least when making small voltage level changes and greatest when making large changes, going from Standby to Operate, or when a range change has been made. The table below lists the time required to settle within a number of parts per million (ppm) of the final output voltage.

Range	0.5 Seconds	1 Second	10 Seconds
200mV	±20 ppm	±5 ppm	±2 ppm
2V	±20 ppm	±5 ppm	±2 ppm
20V	±20 ppm	±5 ppm	±2 ppm
120V	±30 ppm	±7 ppm	±3 ppm
1200V	±50 ppm	±10 ppm	±5 ppm
120mA*	±200 ppm	±150 ppm	±100 ppm

* A 120 milliamp constant current source is available as Option IT-2.

NOTE: If the change is a *decrease* in output voltage, add 2ms per volt of change to the settling time. If the change in voltage involved a range change, add 0.5 seconds + 2ms/volt to the settling time.

2-7. Operating Environment

Temperature range:
Operating: 0°C to 50°C
Storage: -30°C to 70°C

Humidity:
70% relative humidity maximum @ 40°C (non-condensing)

Warm-up time:
15 seconds to < 20 ppm of final value; 1 hour to < 3 ppm of final value

IEEE-488:
Compliance with IEEE-488 (1978) with subsets
SH1, AH1, T6, TE0, L4, LE0, SR1, RL1, PP2, DC1, DT0, CO

Power:
115VAC or 230VAC ±10% at 50Hz to 60Hz. 80VA max.

2-8. Physical Specifications

Size:
89mm (3.5") high x 432 mm (17") wide x 432 mm (17") deep

Weight:
9kg (19 lbs) net; 11kg (23 lbs) shipping

2-9. Recommended Calibration Interval

The calibration interval for the 2701C is dependent on the accuracy level required by the application. The user should consult the accuracy table in Section 2-1 to determine the number of days between calibrations to obtain the required accuracy. The recommended calibration interval is 1 year for most applications.

2-10. Verification of Specifications

Before attempting to prove that the 2701C is performing within its specifications the user must be aware of the following points:

1) The specifications in this section are valid for reasonable use of the 2701C during the specified period of time. If the 2701C has been transported then it has probably been subjected to shock and extremes of temperature. As with any precision instrument, some change in calibration will occur due to these factors. This effect has been carefully monitored by Valhalla Scientific and has been found to be less than 15 ppm even in extreme cases. However, the user can expect *some* effect due to transportation.

2) The specifications in this section are relative to the calibration standards used by Valhalla Scientific, Inc. (or, in some countries, the local Service Center for Valhalla products). The uncertainty of Valhalla Scientific's standards to NIST is 1.5 ppm, therefore this must be added to these specifications for verification purposes (if verification is attempted prior to calibration of the 2701C to the user's standards). If the 2701C was locally calibrated then the uncertainty of those standards must be added instead.

3) Prior to specification verification it is recommended that the user become familiar with the manual operating procedures described in Section 6. Ideally the 2701C should be allowed to stabilize at a constant temperature with power applied for 24 hours before attempting to verify the critical specifications in this section of the manual.

If the 2701C is found to be fully operational but not performing to specification, contact your nearest Valhalla Scientific Service Center before returning the unit for repair or attempting to repair it locally.

SECTION III OPTIONAL EQUIPMENT

3-1. Available Options

Listed below are the options available for use with the Model 2701C Programmable Precision DC Voltage Calibrator.

Option RX-3: Rack Ears

Option "RX-3" is a set of rack ears that permit mounting of the Model 2701C in a standard 19" equipment rack.

Option TL-3: IEEE Interface

Option "TL-3" is an IEEE-488 GPIB Talk-Listen interface that allows control via the IEEE-488 Bus for remote range programming and calibration. The Option TL-3 interface includes a port that interfaces with the Valhalla Model 2500EP Current Calibrator for remote current range programming. Refer to Section 7 for more details.

Options GP-1, GP-2: GPIB Cable

These are **1** *or* **2** *meter IEEE-488 GPIB interface cables for use with Option TL-3.*

Option BBL: Banana-to-Banana Cable

This option is a 48" long shielded cable terminated at both ends with high performance 3/4" spaced dual banana plugs. Use of this option is recommended for signal levels where inaccuracies of 1μV or more can be tolerated.

Option SL-48: Low-Thermal Cable

This option is a 48" low-thermal shielded cable terminated at each end in high quality gold-plated copper spade lugs. Use of this option is recommended for low voltage levels or whenever the best performance is required.

Option IT-2: Constant Current Source

Option IT-2 allows the 2701C to be used as a dual-function calibrator. This option is an internal constant current source providing up to ±120 milliamps of DC current. The output is fully adjustable down to the 100 nanoamp level. The current source has a maximum compliance voltage of ±10 volts.

Option C: Banana to Clip

Option C is a 48" shielded cable set that is terminated on one end in a dual banana plug and on the other end in separated red and black alligator clips. This lead set is recommended for use with Option IT-2.

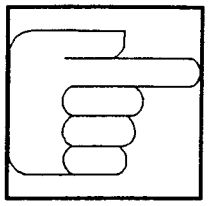
Option LNF: Wideband Noise Filter

Option LNF may be necessary in applications where background AC noise must be kept to a minimum. This option reduces wideband microprocessor and power supply noise by eliminating the switching power supply and adding extra filtering to the output circuitry. A 2701C equipped with Option LNF is limited to ±40 volts maximum output. See Section 2-5.

Option 2704A: Precision Divider

This external 100:1 voltage divider is available for use with the Model 2701C. This device may be desirable for low voltage, high impedance applications such as driving operational amplifiers or analog-to-digital converters. Option 2704A effectively adds a "20mV" range to the 2701C with a basic accuracy of ±0.01%. The recommended lead set for use with the 2704A is Option SL-48.

SECTION IV FRONT PANEL CONTROLS



4-1. General

This section outlines the use of each of the front panel controls and connectors. The user is advised to read Section VI to obtain full descriptions of the methods of operation of the 2701C in the various modes available.

The paragraph numbers used in this section correspond to the reference numbers used in the pictorial diagram of Figure 4-1.

4-1-1. OUTPUT SETTING Window

This window is used to display the 2701C output voltage or current setting. The unit of measure is *volts* unless the 2701C is in the optional 120mA current output mode in which the units are *milliamps*.

The rotary switches beneath each display window (with the exception of the far lefthand window) are used to increment (clockwise rotation) or decrement (counter-clockwise rotation) the respective digit, with full borrow/carry if required.

4-1-2. RANGE Section

The RANGE section of the keyboard allows the user to select the 2701C output voltage range. These keys are disengaged if Option IT-2 is fitted and the "120mA" mode selection is made, or if the unit is being controlled remotely via the IEEE-488 interface.

4-1-3. MODE Section

The MODE section of the 2701C keyboard allows selection of the various operating parameters such as: voltage or current output; local or remote control; output polarity; operate or standby; and 2-wire or 4-wire terminal configuration.

▲ **LOCAL/REMOTE Key**

This key may be used when operating the 2701C remotely via the IEEE-488 interface to return the instrument to front panel control. The key is illuminated (✱) in the REMOTE mode and extinguished (○) in the LOCAL mode. This key may only be used to return the instrument to local control but may not be used to place the 2701C into REMOTE.

▲ **± Key**

This key alternately selects positive or negative output polarity. The key is extinguished (○) in the normal mode in which the red binding post is positive and the black binding post is common. The key is illuminated (✱) in the reverse mode in which the red binding post is negative and the black binding post is common.

▲ **Volts/120mA Key**

This key is only used if the instrument has been fitted with the internal 120mA constant-current source, Option IT-2. The key illuminates (✱) when the current source has been selected. Pressing this key a second time extinguishes the LED (○) and returns the 2701C to the previously selected voltage range.

▲ **2-WIRE/4-WIRE Key**

This key alternately selects a 2 or 4-wire terminal configuration. The key is illuminated (✱) when the 2701C is configured for 4-wire operation. Note that 4-wire operation in the 200mV range or the 120mA mode is not possible.

The greatest accuracy is obtained by using the 4-wire terminal configuration due to the fact that the effects of the load are compensated for by the 2701C. The 4-wire configuration should be used whenever significant loads are present on the 2701C output terminals and/or significant lead lengths are in use.

In 2-wire mode the output voltage will be present on both the OUTPUT and SENSE terminals. It is recommended that the SENSE terminals be used in 2-wire mode to obtain the greatest accuracy. In the 120mA mode, the OUTPUT terminals *must* be used.

▲ **OPERATE/STANDBY Key**

This key alternately selects OPERATE (o) or STANDBY (*) modes of operation. In the STANDBY mode the output will be at zero on the selected range. In OPERATE mode the output will be at the level displayed in the OUTPUT SETTING window. Note that the key illuminates (*) when the 2701C is in STANDBY mode and is extinguished (o) when the 2701C is in the OPERATE mode.

4-1-4. POWER Section

This section contains the 2701C main power switch. Power is applied when the green dot is showing in the center of the switch.

4-1-5. OUTPUT Section

Connections to the 2701C are made to these terminals. The terminals are gold-plated and low-thermal. The best connection to the terminals is made with a Valhalla Option SL-48 or its equivalent.

▲ **OUTPUT Terminals**

These terminals provide the source voltage and are shorted to the SENSE terminals in 2-wire mode. In 4-wire mode these terminals provide the source voltage and current to the load. These terminals provide the output current in the 120mA mode.

▲ **SENSE Terminals**

These terminals provide the feedback to the voltage amplifier to allow it to compensate for varying loads. In the 2-wire mode the maximum accuracy is obtained by using these terminals instead of the OUTPUT terminals. In 4-wire mode these terminals should be connected directly to the load. No output current is available from these terminals in the 120mA mode.

▲ **Lightning Bolt Indicator**

This indicator is illuminated when an output voltage of 30V or more is selected and the 2701C is in OPERATE. Caution should be exercised around the unit whenever this indicator is illuminated.

▲ **CURRENT LIMIT Indicator**

This LED illuminates briefly when the current limit of the 2701C has been exceeded. When a current limit is detected by the 2701C, the STANDBY mode will be automatically selected.

The current limit circuitry is a safeguard to protect the 2701C from overload conditions. This circuitry may be triggered if the output terminals are accidentally shorted together or if the user attempts to drive too great a load. In this case, remove all leads and investigate the cause of the overload.

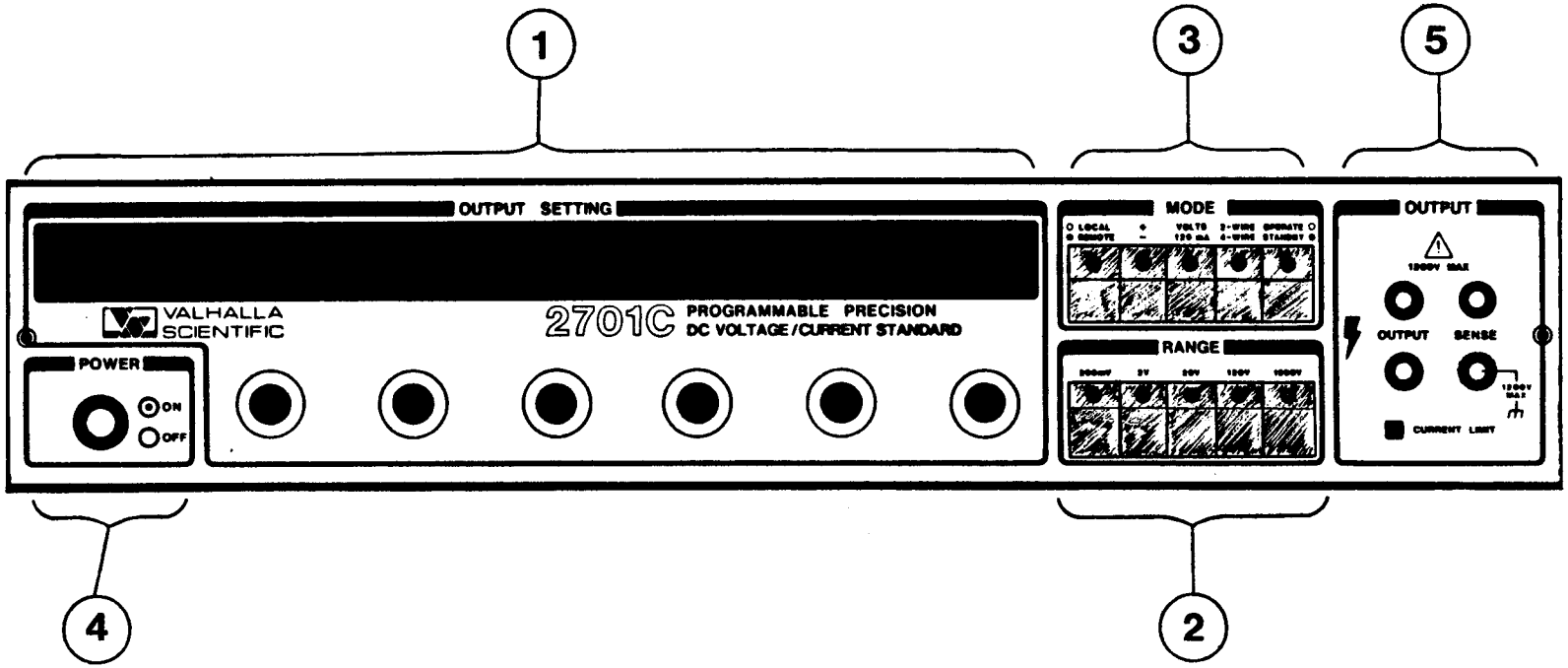
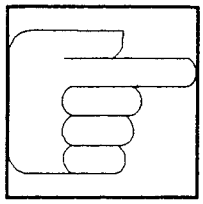


Figure 4-1. 2701C Front Panel

SECTION V REAR PANEL CONTROLS



5-1. General

The functions of the rear panel controls and connectors are described in the following paragraphs. The paragraph numbers correspond to the reference numbers in the pictorial diagram of Figure 5-1.

5-1-1. OUTPUT and SENSE Terminals

The rear panel terminals are identical in function to the front panel terminals discussed in Section 4.

CAUTION!

The rear panel terminals are wired in parallel with the front panel terminals!

5-1-2. GPIB (IEEE-488) Connector

This connector, if installed, is the General Purpose Interface Bus (GPIB) port. See Section 7 for details on this port.

5-1-3. IRP INTERFACE Connector

This connector, if installed, provides the signals and power required to remotely control the range of the Valhalla Model 2500EP Current Calibrator via the IEEE-488 interface. See Section 7 for details on this port.

5-1-4. AC Receptacle

The mating power cord is supplied as standard equipment with the 2701C. If using an extension cord or a power cord other than the one provided with the 2701C, care must be taken to ensure that a continuous ground connection is intact.

CAUTION!

Use of the Model 2701C without a continuous ground connection may be hazardous!

Before applying power to this receptacle, make sure that the instrument is configured for the proper local AC line voltage. See Section 1-2.

5-1-5. Fuseholder

This contains the main power fuse. The proper fuse values are shown below:

105-125VAC = 1 amp slo-blo
210-250VAC = 0.5 amp slo-blo

Replace blown fuses with their exact equivalent only!

5-1-6. IEEE ADDRESS Switches

These switches are used to set the address to which the 2701C will respond over the IEEE-488 bus interface. See Section 7 for details.

5-1-7. OPERATE/CALIBRATE Keyswitch

This switch is used to enable the calibration routine of the 2701C. Operation of this switch requires the use of the correct key. Refer to Section 8 for details. Two keys are provided as standard accessories for the 2701C. Extra calibration keys may be ordered from the factory, if desired.

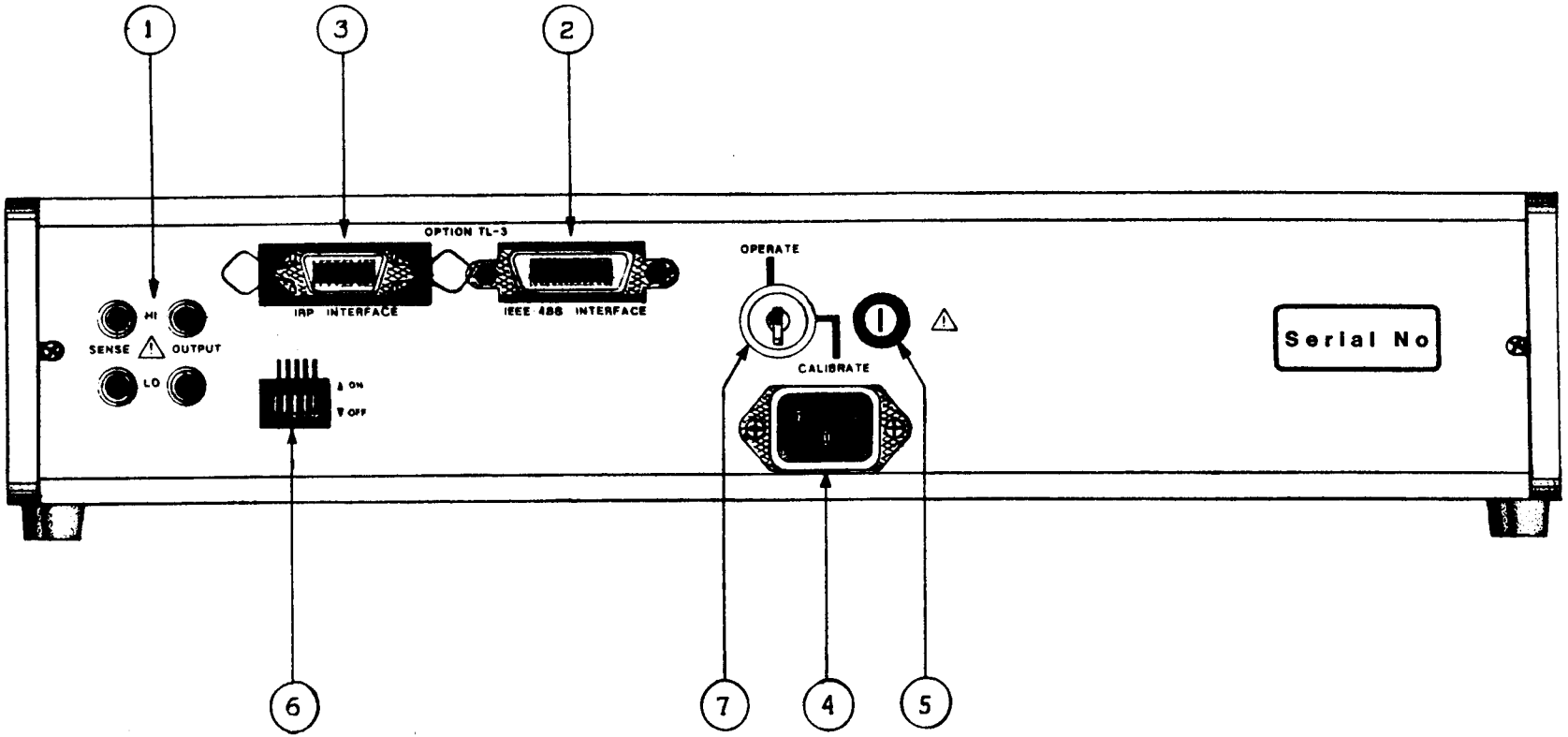
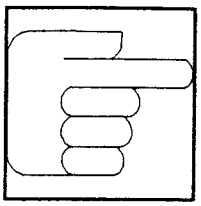


Figure 5-1. 2701C Rear Panel

SECTION VI MANUAL OPERATION



6-1. General

This section describes the manual operation of the 2701C. **Dangerous voltages are produced by this instrument during normal use!** The user is advised to become completely familiar with this section before attempting to operate the 2701C.

6-2. Power-Up Routine

When power is first applied to the 2701C the user is greeted with the following start-up routine:

a) **"HELLO"** This is accompanied by illumination of all Range and Mode LED's.

b) **"no IEEE"** or **"Addr #"** Indicates either that the IEEE interface is not installed or the selected address if the interface is installed. NOTE: If the 2701C displays **"no dAtA"** at this step, the calibration data of the instrument has been corrupted and will require repair and/or recalibration.

c) **"2701C-3"** Indicates the software version. The various versions are listed below:

2701C-1 = older models
2701C-3 = standard model
27011-2 = Option IT-2 installed
2701C40 = Option LNF installed
2701140 = Options IT-2 and LNF

d) **".1000000"** The initial range is 100mV in the Standby mode.

6-3. Connections

To preserve the full accuracy of the 2701C it is strongly recommended that 4-wire connections be utilized whenever possible to eliminate the possibility of errors due to lead resistance. The connections to the SENSE terminals determine the overall accuracy of the 2701C. It is strongly recommended that low-thermal emf shielded cabling (Valhalla Option SL-48 or equivalent) be used for connections to the SENSE terminals. Ordinary shielded cable may be used for connections to the OUTPUT terminals. See Figure 6-1.

For less crucial applications or when the user is certain that there will be negligible current drawn from the 2701C, 2-wire connections may be used. For 2-wire operation the SENSE terminals should be used for connections. When using the optional 120mA current source the connections must be 2-wire and must be made to the OUTPUT terminals. See Figure 6-2.

The 200mV range has an output impedance of 450 ohms and 4-wire operation is not available for this range, nor is it available when using the optional 120mA current mode.

6-4. Setting the Output Level

Use the following procedure to make manual adjustments to the output voltage or current level.

a) Select STANDBY mode and make the desired connections and terminal configuration selections.

b) Select the desired range by pressing the corresponding key in the RANGE section. The 120mA current source is selected by pressing the "VOLTS/120mA" key in the MODE section.

c) The output level is adjusted by rotating the corresponding knob under the desired digit. Clockwise rotation will increase the value of the output and counter-clockwise rotation will decrease it. The 2701C provides full borrow and carry from adjacent digits.

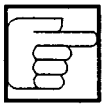
d) Select the required output polarity by pressing the ± key, if required. If the ± key is not illuminated (o), the output will be positive on the red binding post. If the ± key is illuminated (*), the output will be negative on the red binding post.

e) The output is enabled by taking the 2701C out of STANDBY mode. The STANDBY /OPERATE key is illuminated (*) in the STANDBY mode and extinguished (o) in the OPERATE mode.

WARNING

DANGEROUS VOLTAGES ARE PRESENT ON THE OUTPUT TERMINALS WHENEVER THE LIGHTNING BOLT ON THE FRONT PANEL IS ILLUMINATED!!

NOTE: The Model 2701C will automatically select the STANDBY mode whenever the 1200V range is selected. This is a safety feature designed to protect devices on the output from accidentally receiving a damaging voltage.



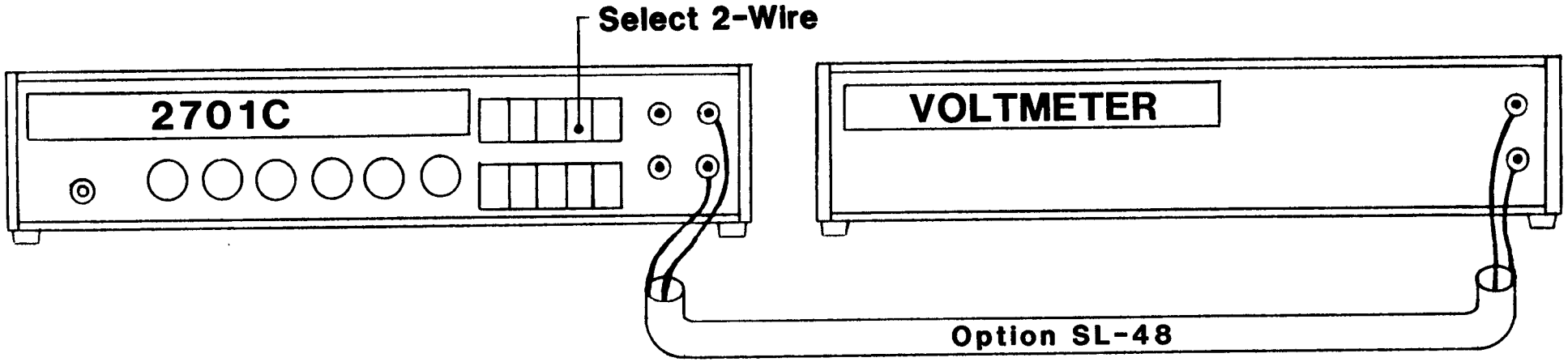
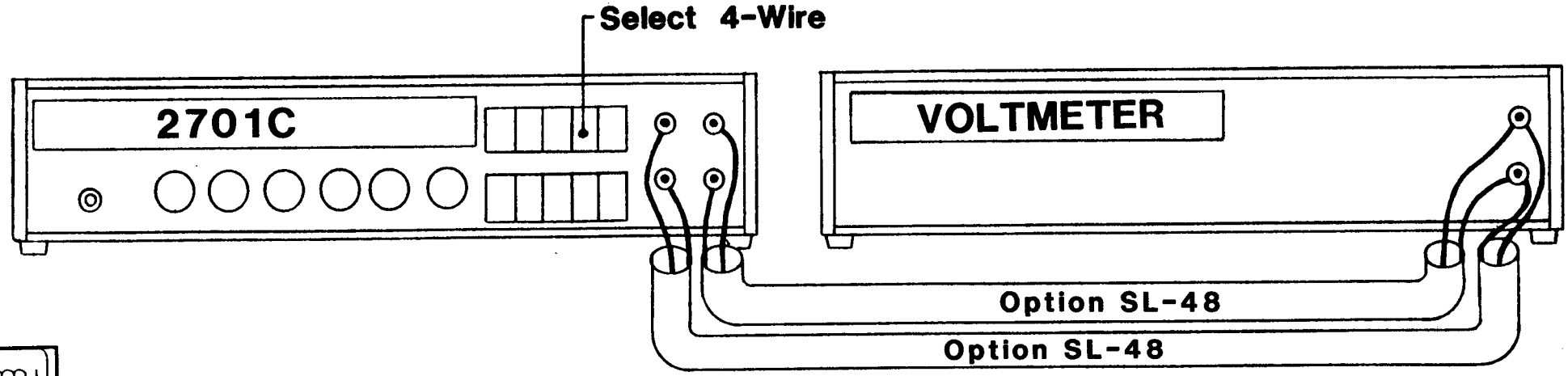
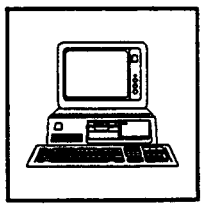


Figure 6-2. 2-Wire Connections

Figure 6-1. 4-Wire Connections



SECTION VII REMOTE OPERATION



7-1. Introduction

This section of the manual contains instructions for operating the Model 2701C Programmable DC Calibrator via the GPIB (IEEE-488) interface, if installed.

7-2. IEEE-488: An Explanation of the Bus

The reader who is not familiar with the requirements of the 1978 IEEE Standard 488 (IEEE-488) should review the following paragraphs which provide some basic explanations of terms and examples of commands. For a complete explanation of the requirements, refer to the 1978 IEEE-488 Standard.

7-3. Definitions

Listed below are definitions of the terms used to describe the IEEE-488 interface:

Bus: A data link which is usually a set of several parallel wires within a multi-wire cable.

Bi-Directional Bus: A "highway" used for two-way communication, with input and output data being carried on the same lines.

Bit-Parallel: A data transmission method in which all of the bits composing an item of data are present simultaneously on a group of wires in a bus.

Byte: A group of eight data bits which is treated as a single item of data.

Byte-Serial: A data transmission method in which information, in bit-parallel bytes, is transferred sequentially between devices.

Device Dependent Message: A message containing commands or data intended for a specific device.

Handshake: An exchange of signals between two devices which is used to control the transfer of data between them.

Interface: The part of an instrument or system which enables it to be connected to another via a bus.

Interface Message: A message intended for interface management.

Local Operation: Operation of a device by its front panel controls (also referred to as Manual Control).

Remote Operation: Operation of device under the control of another via the bus.

7-4. Bus Restrictions

The IEEE-488 Interfacing Standard (also known as IEC DTC66 (WG3), ANSI MC1-1, GP-IB, HP-IB, etc.), defines a bidirectional bus for interconnecting programmable instrumentation in a bit-parallel, byte-serial fashion. It defines limitations as follows:

1. A maximum of 15 devices may be interconnected by a single bus.

2. The total bus length may not exceed 20 meters, with a maximum interconnection length of 4 meters.

3. Maximum transmission rate is 1 megabyte per second.

4. All bus data is digital.

Of the devices on the bus, only *one* may be the controller which exercises control over all other devices, and is also capable of operating as a talker or listener. The other devices may be listeners (only able to receive data) or talkers (only able to send data), or both. The Model 2701C is capable of talking and listening. The controller may address other devices and command them to listen or talk. Only one device may talk at any one time.

The interconnecting cable consists of sixteen signal wires and eight ground returns linking devices into a complete system:

1. Eight data wires (DIO-0 thru DIO-7)

2. Five management wires (ATN, EOI, SRQ, IFC, and REN)

3. Three "handshake" wires (DAV, NRFD and NDAC)

Each cable connector is a plug/socket combination to permit "daisy-chaining" of units.

It should be noted that these wires use "inverse logic". That is to say that a low level indicates the true (asserted) state and a high level indicates a false (non-asserted) state.

7-5. Detailed Description

The five management wires are described as follows:

ATN: Asserted by the controller whenever an address or a command is present on the bus.

EOI: May be asserted by the controller or any talker. With ATN true, EOI indicates that the controller is polling devices. With ATN false, EOI is asserted by the talker to indicate the end of data.

SRQ: May be asserted by any device. This indicates that the device requires attention (e.g., a fault has occurred). Normally, the controller will respond by polling to determine which device requires service.

IFC: May be asserted only by the controller. This line initializes the bus to a reset state.

REN: May be asserted only by the controller. This signal places the addressed device into the remote mode.

The three handshake wires are described as follows:

DAV: May be asserted by any talker; indicates that a valid data byte is present on the data wires.

NRFD: May be asserted by any listener. Indicates that the listener is not ready to receive data.

NDAC: May be asserted by any listener. Indicates that the listener has not yet finished reading the data byte.

The transfer of data on the bus is controlled by these three handshake wires. It is important to note that the drivers for the handshake wires are all connected for wired-on operation. That is, as long as any of the devices on the bus asserts a handshake line, it will remain true. There must be a complete consensus among the devices for any handshake wire to be high (false).

The talker first waits for all devices to be ready to accept data (checks that NRFD is false) then puts one byte of data on the bus and asserts DAV. It waits for all devices to indicate that the data has been accepted (that is, NDAC to become false) before starting to transfer the next byte of data. This handshake protocol assures that data on the bus is transferred at the speed of the slowest device on the bus.

Data is sent in 8-bit bytes on the DIO wires, usually (as in the

2701C) using the ISO-7 standard ASCII characters. Table 7-1 lists each ASCII character and the bus messages applicable to each.

Note that the table is divided into two main groups; the primary command group and the secondary command group. The secondary command group is not utilized in the 2701C.

The primary command group is further divided into four subgroups as follows:

1. **Addressed Command Group** - applied only to addressed devices.

2. **Universal Command Group** - applied to all devices.

3. **Listen Address Group** - set of device listen addresses.

4. **Talk Address Group** - set of device talk addresses.

Data in the above command groups is sent with ATN "true". These type of commands are understood by all devices using the IEEE-488 standard. When data is sent with ATN "false", it is referred to as a *device dependent* command. A device dependant command is specific to a particular device, and may or may not be understood by other devices.

ISO BIT & DIO LINE NUMBER 7 6 5 4 3 2 1	0 (0 0 0) ASCII	MSG	1 (0 0 1) ASCII	MSG	2 (0 1 0) ASCII	MSG	3 (0 1 1) ASCII	MSG	4 (1 0 0) ASCII	MSG	5 (1 0 1) ASCII	MSG	6 (1 1 0) ASCII	MSG	7 (1 1 1) ASCII	MSG	ROW
0 0 0 0	NUL		DLE		SP	00	0	16	@	00	P	16	`		p		0
0 0 0 1	SOH	GTI	DC1	LLO	!	01	1	17	A	01	Q	17	a		q		1
0 0 1 0	STX		DC2		"	02	2	18	B	02	R	18	b		r		2
0 0 1 1	ETX		DC3		#	03	2	19	C	03	S	19	c		s		3
0 1 0 0	EOT	SDC	DC4	DCI	$	04	4	20	D	04	T	20	d		t		4
0 1 0 1	ENQ	PPC'	NAK	PPU	%	05	5	21	E	05	U	21	c		u		5
0 1 1 0	ACK		SYN		&	06	6	22	F	06	V	22	f		v		6
0 1 1 1	BEL		ETB		'	07	7	23	G	07	W	23	g		w		7
1 0 0 0	BS	GET	CAN	SPE	(	08	8	24	H	08	X	24	h		x		8
1 0 0 1	HT	TCT	EM	SPD	)	09	9	25	I	09	Y	25	i		y		9
1 0 1 0	LF		SUB		*	10	:	26	J	10	Z	26	j		z		10
1 0 1 1	VT		ESC		+	11	;	27	K	11	[	27	k		{		11
1 1 0 0	FF		FS		,	12	<	28	L	12	\	28	l		|		12
1 1 0 1	CR		GS		-	13	=	29	M	13	]	29	m		}		13
1 1 1 0	SO		RS		.	14	>	30	N	14	^	30	n		~		14
1 1 1 1	SI		US		/	15	?	UNL	O	15	_	UNT	o		DEL		15

COLUMN

ADDRESSED COMMAND GROUP (ACG) | UNIVERSAL COMMAND GROUP (UCG) | LISTEN ADDRESS GROUP (LAG) | TALK ADDRESS GROUP (TAG) | SECONDARY COMMAND GROUP (SCG)

PRIMARY COMMAND GROUP (PCG)

STANDARD ISO 7 CHARACTERS

'Requires Secondary Command

Notes:
1 Device Address messages shown in decimal
2 Message codes are

DCI	Device Clear	LLO	Local Lockout	SDC	Selected Device Clear
GET	Device Trigger	PPC	Parallel Poll Configure	SPD	Serial Poll Disable
GTI	Go to Local	PPU	Parallel Poll Unconfigure	SPE	Serial Port Enable

Table 7-1. ASCII Characters

7-6. Universal Commands

This section describes all of the IEEE-488 defined universal commands and their effect upon the operation of the 2701C. The following examples are given in HP Basic and it is assumed that the 2701C has its address set to 15.

NOTE: The example commands below are given in HP Basic. If you are using a language other than HP Basic, consult your user's manual for the proper command syntax.

7-6-1. Device Clear (DCL)

This command will cause all of the devices on the bus to enter their reset states (both interface and instrumental functions). The 2701C will perform a soft reset cycle when this is received.

This command can sometimes cause the interface to reset and then re-read the device clear command if the responding instrument is slow to release the handshake. This will be visible as a complete bus lockout with all of the devices continuously performing a device clear. Although every precaution has been taken to eliminate this problem with the IEEE-488 Standard, lockout may sometimes occur. It is recommended the Selective Device Clear Command be used if possible (7-6-2).

An example of this command in HP Basic is **CLEAR 7.**

7-6-2. Selective Device Clear (SDC)

This command will cause only the device at the specified address to perform a reset. This command will perform the same function as the DCL command in 7-6-1 but on individual devices only, thus overcoming the problem inherent with the DCL command.

An example of this command in HP Basic is **CLEAR 715** which causes only the device at address 15 to reset.

NOTE: To ensure that all wires are settled following a device clear or selective device clear command, it is recommended that a 3 second minimum delay is allowed prior to performing any bus operation with the 2701C. Note that the 2701C will not operate the IEEE-488 bus until the complete set of status messages have been displayed following a power-up or reset. Any bus activity with the 2701C during either of the above periods of time may cause undefined results.

7-6-3. Group Execute Trigger (GET)

The execution of this command is dependent on the particular device receiving it, the exact result not being defined by the IEEE-488 (1978) standard. Upon receiving this command the 2701C will handshake the command, but will not respond with any action.

The user should note that only the addressed form of this command is defined by the IEEE-488 (1978) standard however certain manufacturers also include an unaddressed form of this command. The result of receiving this "unofficial" command by the 2701C is not defined and may cause bus errors if used.

Examples of these commands in HP Basic are the statements **TRIGGER 715** for the addressed form, and **TRIGGER 7** for the unaddressed, "unofficial" form.

7-6-4. Go to Local (GTL)

This addressed command will cause the individual addressed device to enter the LOCAL state (i.e. enables manual operation of the device). This command is fully implemented in the 2701C and is executed in HP Basic by the statement **LOCAL 715.**

The user should note that many computers also have a similar unaddressed version of this

command (**LOCAL 7** for HP Basic). This command is actually quite different from the addressed command (it disasserts the REN line) but will cause all of the devices including the 2701C to enter the LOCAL state.

7-6-5. Interface Clear (IFC)

This command will cause all of the interfaces of the devices on the bus to enter an idle state. This is fully implemented in the 2701C and may be executed in HP Basic by the statement **RESET 7**.

7-6-6. Identify (IDY)

This command is also called "parallel poll". This will cause all devices on the bus to respond by simultaneously placing their parallel poll response byte onto the DIO bus wires. This command is implemented in HP Basic by the statement **PPOLL (7)**.

7-6-7. Local Lock Out (LLO)

This command will cause all of the devices on the bus to enter *REMOTE with Lock Out* state. The function of this command is to disable the manually operated LOCAL key or control of the devices on the bus. This command is implemented in HP Basic by the statement **LOCAL LOCKOUT 7**.

7-6-8. Parallel Poll Configure (PPC), Enable (PPE), Disable (PPD), and Unconfigure (PPU)

These commands are used to set the Parallel Poll response byte and to disable the parallel poll response. These commands are not implemented in the 2701C and are ignored if received.

7-6-9. Remote Enable (REN)

This command (the assertion of the REN wire on the bus) enables all devices on the bus to enter the REMOTE state. This command is applied to all devices on the bus in HP Basic by the statement **REMOTE 7**.

Many computers also have a command that includes the sending of the listen address which will place only the addressed device into the REMOTE state. This is accomplished in HP Basic by the statement **REMOTE 715**, which would place only the device at address 15 into the REMOTE state.

7-6-10. Serial Poll Enable (SPE) and Disable (SPD)

These commands control the process of performing a serial poll. The serial poll sequence is as follows:

A) The controller commands SPE.

B) The controller addresses a single device as a talker.

C) The addressed device returns its Serial Poll response byte.

D) The controller reads the response byte.

E) The controller may now repeat the sequence from step B or send SPD to end the serial poll.

The 2701C implements this function and may be commanded to send its serial poll response byte in HP Basic by the statement **SPOLL(715)**. This statement will implement the entire sequence once.

7-6-11. Take Control (TCT)

This command from the system controller to another potential controller will request that the other take over bus responsibilities. The 2701C does not have the capability of becoming a controller, thus this command is not implemented and will be ignored.

7-7. REMOTE and LOCAL States

A full explanation of the implementation of the LOCAL and REMOTE states is explained here. The 2701C is assumed to have its address set to 15 in all examples.

▸ LOCAL State

When the 2701C is in the LOCAL state the REMOTE/LOCAL key on the front panel is extinguished and full manual control of the 2701C as described in Section 6 may be exercised. Note that it is not possible to enter the REMOTE state from the 2701C front panel. The 2701C will accept commands from the IEEE-488 bus while in the LOCAL state but they will be discarded. The unit may however be read at any time without entering the REMOTE state.

The 2701C is placed in the LOCAL state using the HP Basic statement **LOCAL 715.**

▸ REMOTE State

If the 2701C receives its listen address while the REN line is asserted it will enter the REMOTE state. In this state the REMOTE/LOCAL key on the front panel is illuminated and all keys on the front panel are ignored except the LOCAL key. Pressing the REMOTE/LOCAL key will return the 2701C to the LOCAL state and reactivate the keys. The 2701C may only be returned to the REMOTE state by the controller.

The 2701C is placed into the REMOTE state using the HP Basic statement **REMOTE 715.**

▸ REMOTE with Lockout

This state is entered from the REMOTE state by sending the HP Basic statement **LOCAL LOCKOUT 7.** While in this state the 2701C will operate as in the REMOTE state, however all keys on the 2701C front panel are ignored, including the REMOTE/LOCAL key.

7-8. IEEE Commands for the 2701C (Device Dependent)

The Device Dependent command set for the 2701C is described in the following paragraphs. Command examples are given for each in which it is assumed that the 2701C has an address of 15 and that the computer is using HP Basic.

NOTE: The example commands below are given in HP Basic. If you are using a language other than HP Basic, consult your user's manual for the proper command syntax.

More than one command may be transmitted in one statement, and there is no *required* separator. However, the user must ensure that each command cannot be decoded as part of the previous command (using a comma is advised). Note that the 2701C will accept a maximum of 20 characters on one line. If more than 20 characters are sent to the 2701C without the proper terminator, the entire line will be discarded and an error condition generated.

Commands are not acted upon by the 2701C until an expected terminator is received. The 2701C accepts a line feed (LF) or EOI asserted with the last character as a terminator.

If an undecipherable command is received it will be ignored by the 2701C. In this case the 2701C may be instructed to generate an error message in the form of an SRQ. See Section 7-8-3-8.

7-8-1. Configuration Status Word

The 2701C may respond to an inquiry from the controller with a *configuration status word* which contains information regarding its present status. This status word may be read any number of times by the controller and the

2701C is not required to be in the REMOTE mode.

The status word is always returned in the format:

_SN.NNNNNNEsn_xxo

Where:

_ indicates a blank space.

S is + or - indicating the output polarity.

N are integers indicating the significant digits of the output setting.

E indicates the exponent that is to be
s applied to the number "N"; For example,
n E+2 would mean to multiply the number N.NNNNNN by 10^2.

xx is "V_" if the 2701C is in the voltage output mode and the IRP is not commanding a current range.

xx is "mA" if the 2701C is in the voltage output mode and the IRP is commanding a current range.

xx is "mA" if the 2701C is in the optional 120mA mode.

o is a blank space character in the OPERATE mode or an asterisk (*) character in the STANDBY mode

Using HP Basic the configuration status word is read by typing the following commands:

ENTER 715;A$
PRINT A$

7-8-2. Setting the IEEE Address

The IEEE address tells the system controller where to find a device when it wishes to communicate with it. The address of the 2701C is determined by the configuration of a 5-pole DIP switch on the rear of the instrument. This address may be any number from 1 to 30. The number is calculated using a binary-weighted code set by the switches on the rear panel. For example, address "15" would be set by placing the switches in the following configuration:

In this case, **8 + 4 + 2 + 1** = 15. In another example, the **16 + 8 + 1** switches would be enabled to set the address to 25.

The address you choose is entirely dependent on your application and by the type and quantity of devices on your IEEE bus. Some guidelines to follow are:

1) Each device on the bus must have its own unique address. Operating two devices at the same address will produce undefined results and is not recommended.

2) Avoid setting the 2701C to address 0 (all switches off) or to address 31 (all switches on) as this may interfere with the system controller.

3) If the IEEE address is changed, power must be reset to place the new address into memory.

7-8-3. 2701C Command Set

The following commands are used to control the output level, range and mode of the 2701C. Examples are given using HP Basic. If you are using a language other than HP Basic, consult your user's manual for the correct command syntax.

The following commands are used in normal operating modes and, with the exception of the "T" command, may not be used during calibration of the 2701C. See

Section 8-5. In all examples the 2701C is assumed to be set at address 15.

7-8-3-1. Setting Voltage Output

▸ **Recommended Method**

The voltage output may be set using the command "VO" and a free number format that instructs the 2701C to provide the requested output voltage level. Using this format instructs the 2701C to automatically select the proper range that provides the greatest accuracy. Some examples are shown below:

OUTPUT 715;"VO1.1234" = 1.1234 volts
OUTPUT 715;"VO1.234E-3" = .001234 volts
OUTPUT 715;"VO-1057" = -1057 volts
OUTPUT 715;"VO",A = variable A volts
OUTPUT 715;"VO0.0" = zero volts output

The 2701C automatically selects the OPERATE mode upon decode of this command. Note that the 2701C will disregard any extra digits and will assume that any missing digits are zeros.

▸ **Alternate Method**

An alternate method of setting the output voltage is available to provide compatibility with older Model 2701s. The voltage is set by sending the command "V" followed by a number of digits without a decimal point. Note that if all 6 digits are not included the remaining digits are left unchanged. Note also that this command does not affect the range of the 2701C and that displays above 1199999 are not available with this command. Some examples are:

OUTPUT 715;"V123456" = 0123456 display
OUTPUT 715;"V:12345" = 1012345 display
OUTPUT 715;"V;12345" = 1112345 display

The 2701C automatically selects OPERATE upon decode of a "V" command. The special characters : and ; are used to increment the most significant digits to either 10 or 11, respectively.

☞ If the rotary knobs on the front of the 2701C are moved while in the REMOTE state, the change will be registered in memory but will not be implemented until the 2701C is returned to the LOCAL state.

7-8-3-2. Setting Output Range

The "R" command sets the 2701C to the corresponding range as shown below. This command is not required when using the "VO" command.

R0	selects the 2V range
R1	selects the 20V range
R2	selects the 120V range
R3	selects the 1200V range

Note that this command cannot access the 200mV range. This command is included for compatibility with earlier 2701 series products and is not recommended for new applications.

7-8-3-3. Setting Output Current

The "II" command applies to instruments equipped with the optional 120mA current source. The code "II" is followed by the same free number format used with the "VO" command in Section 7-8-3-1. The 2701C automatically selects the 120mA, 2-Wire, and OPERATE modes upon decode of this command. This command deselects any IRP selections previously made with the "IO" command.

OUTPUT 715;"II87.56" = 87.5600 milliamps
OUTPUT 715;"II-110.2" = -110.2000 milliamps

7-8-3-4. 2500EP Range Programming

The 2701C may be used to remotely control the range of a Valhalla Model 2500EP current calibrator through its IRP port. This is accomplished using the "IO" command followed by a numeric value *in milliamps*. The 2701C will automatically deselect the 120mA

mode and select the 2V range upon receipt of this command. The numeric value uses the same free number format as the "VO" command in Section 7-8-3-1. The 2701C automatically selects OPERATE on its output however it cannot select the OPERATE mode of the 2500EP. Two examples are shown below:

OUTPUT 715;"IO1.3045" = an output of 1.304500 volts is selected on the 2701C and the 1mA range is selected on the 2500EP to produce 1.3045 milliamps

OUTPUT 715;"IO-11037" = an output of -1.103700 volts is selected on the 2701C and the 10A range is selected on the 2500EP to produce 11,037 milliamps

It is also possible to select the desired range on the 2500EP without affecting the 2701C. This command will control the range of a 2500EP connected to the IRP connector on the rear panel and will also control the polarity of the 2701C output. This is achieved using the "I" command followed by certain variables. The first character following the "I" will control the 2500EP through the IRP port as follows:

I9 selects the 100μA range
I: selects the 1mA range
I; selects the 10mA range
I< selects the 100mA range
I= selects the 1A range
I> selects the 10A range

Any other character in this position will cause the 2500EP to select *no range* and is not recommended. Note that selection of a range on the 2500EP has no effect on the settings of the 2701C itself. The third character is used to control the output polarity of the 2701C. A "0" as the third character will select a positive output polarity. A "1" will select a negative output polarity.

OUTPUT 715;"I;1" = 10mA range, negative
OUTPUT 715;"I=0" = 1A range, positive

7-8-3-5. 4- or 2-Wire Mode

The command "T" is used to select the terminal configuration. Note that the 4-wire mode is not available for the 200mV or 120mA ranges.

OUTPUT 715;"T0" = selects 2-wire mode
OUTPUT 715;"T1" = selects 4-wire mode

7-8-3-6. Standby or Operate Mode

Neither of these commands will affect the voltage range, IRP range, or mode of the 2701C. An "S" will select the STANDBY mode. A "V" will select the OPERATE mode. The "V" command is rarely used as the 2701C selects OPERATE automatically with most commands.

OUTPUT 715;"S" = selects STANDBY mode
OUTPUT 715;"V" = selects OPERATE mode

7-8-3-7. Output Delimiter

The "E" command instructs the 2701C to attach the desired output delimiter at the end of its data whenever it is read by the controller. Available combinations are:

(CR=carriage return LF=line feed)

E0 CR, LF
E1 CR, LF with EOI asserted
E2 CR
E3 CR with EOI asserted
E4 EOI asserted with the last character in the standard output

OUTPUT 715;"E2" = selects carriage return

7-8-3-8. SRQ Enable

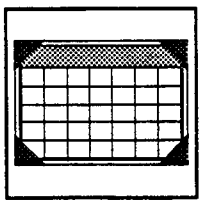
The 2701C may assert a service request (SRQ) if it receives an undecipherable command. This is enabled by sending "Q1" and disabled by sending "Q0". If enabled, the 2701C will assert SRQ whenever it receives a command it does not understand.

OUTPUT 715;"Q1" = enables 2701C to assert SRQ

7-9. Remote IEEE-488 Calibration

IEEE-488 controllable adjustment procedures make automatic calibration of the 2701C possible. The remote calibration procedure is discussed in Section 8-5.

SECTION VIII CALIBRATION PROCEDURE



8-1. General

This section provides general maintenance information and a procedure for calibrating the 2701C. The Model 2701C DC Voltage Calibrator should be calibrated on a routine basis (every 12 months is recommended) to ensure continued accuracy.

For best results, the 2701C should be warmed-up with the covers in place at the calibration temperature for at least 2 hours before performing the calibration procedure that follows.

8-2. Required Test Equipment

The following test equipment is required to calibrate the Model 2701C DC Voltage Calibrator:

1) A DC voltage measuring device capable of measuring the following ranges:

0 volts	±0.5μV
0.1 volts	±0.5μV
1 volt	±1μV
10 volts	±10μV
100 volts	±100μV
1000 volts	±1mV

2) A high quality low-thermal lead set must be used for maximum accuracy. The recommended lead set is Valhalla Option SL-48 or its equivalent.

3) If the 2701C is equipped with the optional 120mA output, a 10Ω ±0.005% precision resistor is required. Valhalla lead set Option C may be used to connect to the resistor.

8-3. Calibration Procedure

The 2701C offers 100% covers-on calibration that may be performed manually or via the IEEE interface bus, if installed. See Section 8-5 for the remote calibration procedure.

The 2701C provides 10 voltage calibration points that are always calibrated in the same sequence using the same adjustment procedure. Two additional points are provided if the 120mA option is installed. The 1200V range points are skipped in instruments equipped with Option LNF. The following section describes calibration using manual adjustments.

8-4. Manual Calibration

The following procedure should be used to perform a routine calibration on the 2701C. Readings should be allowed to settle for a minimum of 30 seconds before making any adjustment.

1) Make connections from the 2701C SENSE terminals to the voltmeter using the low-thermal lead set.

2) The calibration is initiated by turning the key-switch on the 2701C rear panel to the CALIBRATE position. Cal mode is confirmed by a "C" in the far right digit of the display.

3) **200mV Range, .000000C display.** Adjustments to the output are made using the rightmost three knobs on the 2701C front panel. The knob on the far right provides the least amount of change. The second from the right provides a medium amount of change while

the third from the right provides the greatest amount of change. Clockwise rotation of the knobs will increase the output while counter-clockwise rotation decreases the output.

Adjust the necessary combination of knobs to bring the output level to 0 ±1μV. The 2701C display will not change as the knobs are adjusted. The adjustment is entered into memory by pressing the STANDBY/OPERATE Mode key once. The 2701C will proceed to the next step.

NOTE: If a particular range requires no adjustment, it may be skipped without changing its value by pressing the STANDBY/OPERATE switch before any adjustment of the knobs is made.

NOTE: If a particular range is too far out of adjustment for the microprocessor to compensate for it, the words "**FAIL CAL**" may flash on the display. In this case, a problem with the instrument or the test setup is indicated.

4) **2V Range, 0.00000C display.** Adjust the three knobs as required to bring the output to 0 ±3μV. Enter the adjustment by pressing the STANDBY/OPERATE key.

5) **20V Range, 00.0000C display.** Make the required adjustments to bring the output to 0 ±20μV and enter the change.

6) **120V Range, 000.000C display.** Make the required adjustments to bring the output to 0 ±150μV and enter the change.

7) **1200V Range, 0000.00C display.** Make the required adjustment to bring the output to 0 ±1.5mV and enter the change. Note: This step is automatically skipped if the instrument is equipped with Option LNF.

8) If Option IT-2 is installed, the 2701C proceeds to the 120mA Mode and the display indicates 000.000C. If this option is not installed or if it will be calibrated separately, skip this step.

120mA Mode, 000.000C display. Connect the 10Ω resistor to the 2701C OUTPUT terminals. Monitor the voltage drop across the resistor with the voltmeter. Adjust the 2701C knobs as described above until the voltmeter reads 0 ±5μV. Enter the adjustment and remove the connections.

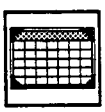
9) **200mV Range, .100000C display.** Reconnect the voltmeter to the 2701C SENSE terminals, if required. The knobs are weighted to affect the output as indicated below:

```
1 0 0 0 0 0 C        ≈ 0.25 ppm of range
      ↑

1 0 0 0 0 0 C        ≈ 4 ppm of range
    ↑

1 0 0 0 0 0 C        ≈ 64 ppm of range
  ↑
```

Make the required adjustments to bring the reading on the voltmeter to .1000000 volts ±0.5μV. Enter the adjustment by pressing the STANDBY/OPERATE key.

10) **2V Range, 1.00000C display.** Make the required adjustments to bring the output to 1.000000 volts ±5μV. Enter the adjustment.

11) **20V Range, 10.0000C display.** Make the required adjustments to bring the output to 10.00000 volts ±30μV. Enter the adjustment.



12) **120V Range, 100.000C display.** Make the required adjustments to bring the output to 100.0000 volts ±500μV. Enter the adjustment.

13) **1200V Range, 1000.00C display.** Make the required adjustments to bring the output to 1000.000 volts ±5mV. Enter the adjustment. Note: This step is automatically skipped if the instrument is equipped with Option LNF.

14) **"End CAL" display.** If the instrument is not equipped with Option IT-2, the 2701C proceeds to this display indicating that a successful calibration has been completed. Turn the rear panel key switch to OPERATE. This concludes the calibration procedure.

15) **120mA Mode, 100.000C display.** If the 2701C is equipped with Option IT-2, connect the 10Ω resistor to the OUTPUT terminals. Monitor the voltage drop across the resistor with the voltmeter. Adjust the output as necessary to bring the voltmeter reading to 1.00000 volts ±10μV. Enter the adjustment. The display should indicate **"End CAL"**. Return the rear panel key-switch to the OPERATE position. This concludes the procedure.

8-5. Remote (IEEE-488) Calibration

The 2701C may also be calibrated via the IEEE-488 interface, if installed. The calibration procedure must be enabled by turning the rear panel key switch to the CALIBRATE position. At the completion of the procedure, the key switch must be returned to the OPERATE position.

The sequence of calibration points is the same for both the remote calibration procedure and the manual calibration procedure, and the tolerances discussed in the preceding section apply as well. The method for making adjustments to the output is the only difference.

8-5-1. Increasing the Output

The output level at each calibration point is increased through use of the "U" command. This command, followed by the desired variable, determines the amount of increase. The variables are:

U0 ≈ 0.25 ppm of range
U1 ≈ 4 ppm of range
U2 ≈ 64 ppm of range

A sample command is shown below in HP Basic. If you are not using HP Basic, consult your operator's manual for the correct command syntax.

OUTPUT 715;"U1" = tells 2701C to increase the output by 4 ppm

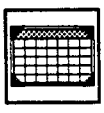
8-5-2. Decreasing Output

The output level at each calibration point is decreased through use of the "D" command. This command, followed by the desired variable, determines the amount of decrease. The variables are:

D0 ≈ 0.25 ppm of range
D1 ≈ 4 ppm of range
D2 ≈ 64 ppm of range

A sample command is shown below in HP Basic. If you are not using HP Basic, consult your operator's manual for the correct command syntax.

OUTPUT 715;"D0" = tells 2701C to decrease the output by 0.25 ppm



8-5-3. Entering the Data

The "N" command tells the 2701C to place the adjustment into non-volatile memory and move on to the next step. The "N" command may be used to skip a step without changing the calibration data.

A sample command is shown below in HP Basic. If you are not using HP Basic, consult your operator's manual for the correct command syntax.

OUTPUT 715;"N" = tells 2701C to store the adjusted data and move on to the next step. If no adjustment has been made, the existing data remains in memory and the 2701C moves on to the next step.

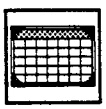
8-6. Periodic Maintenance

It is recommended that the 2701C be operated in a clean environment. If the environment is dusty, periodic cleaning of the unit will be required.

Loose dirt or dust which has collected on the exterior surfaces of the 2701C may be removed with a soft cloth or brush. Any remaining dirt may be removed with a soft cloth dampened in a mild soap and water solution. **Do not use abrasive cleaners.** The front panel may be cleaned with a soft cloth and a "Windex" type cleaner. **Do not use petroleum based cleaners on the front panel.**

If required, the 2701C interior may be cleaned by blowing with dry compressed air.

If the 2701C has become heavily contaminated with dirt or by other contaminants then it is recommended that the unit be completely overhauled at a Valhalla Scientific Service Center.



SECTION IX THEORY OF OPERATION

9-1. Troubleshooting

Apparent malfunctions are often the result of misinterpretation of specifications or due to an incomplete understanding of the instrument. **A thorough review of the operating instructions for this instrument is recommended prior to any component replacement, etc.** Check to be sure that cables and other test equipment are in good working order before attempting to troubleshoot the 2701C.

If the Model 2701C exhibits problems that cannot be eliminated by reviewing Section 6, the following guidelines have been established to help solve the problem.

WARNING!!

HAZARDOUS VOLTAGES ARE USED IN ALL SECTIONS OF THE 2701C. THESE VOLTAGES CAN BE LETHAL!

SERVICING PERSONNEL MUST TAKE EXTREME PRECAUTIONS TO AVOID CONTACT WITH HIGH VOLTAGES.

9-1-1. Localizing the Problem

The key to successful troubleshooting is to localize the problem as much as possible before trying to pin the problem down to a specific component. Certain questions should be asked such as "Does the problem occur on all ranges or on a specific range only?". The power supplies are also one of the first things that should be checked.

As it is not possible to anticipate all failure modes of the 2701C, servicing personnel should become familiar with this section of the manual to gain a complete understanding of the internal workings of this instrument.

9-1-2. Troubleshooting Guide

As a servicing aid, the troubleshooting chart below lists a number of fault symptoms and the possible causes. If the exhibited fault symptom is not shown or a check of the possible causes does not locate the source of the problem then it will be necessary to employ normal troubleshooting procedures.

Symptom	Possible Causes
No display	-Check AC Power source -Check AC line fuse -Check 5V DC power supply -Check microprocessor section
Displays Random Data	-Check microprocessor section -Try resetting power -Check IC109
Outputs a high voltage always	-Check TR6 thru TR12 -Check for stuck relays -Check IC108, TR202
Adjusting knobs does not affect output	-Check IC107 -Check IC110 & IC111 -Check IC5
Output noisy (Low freq)	-Check IC5 -Check IC110 and IC111 -Check power supplies
Output noisy (medium freq)	-Check IC8 & associated capacitors
Output noisy (high freq)	-Check IC5 & associated capacitors
Current Limit always ON	-Check IC9 and IC10

Output slow recovering from high voltage	-Check TR17, R220, R222 -Check RLJ -Check C17
Output way out on all ranges	-Check reference IC7 -Check IC110 and IC111
Output way out on one range	-Check relays -Check range resistors
Display flashes (no dAtA)	-Indicates corrupted cal data -Replace IC103 and recalibrate

9-1-3. Component Replacement

If the problem has been identified as a faulty component, the accuracy of the 2701C can be maintained only if the following precautions are taken:

- Use only the specified component or its exact equivalent. Spare parts can be ordered from your nearest Valhalla Scientific Service Center or directly from the factory by referring to the Valhalla Stock Number listed in the Parts Lists section at the back of this manual.

- Use only 63/37 grade rosin core electronic grade solder with a 50W or lower maximum power soldering iron.

- When soldering, heat the terminal of the component, *not* the solder. Apply solder smoothly and evenly. Do not move the component until the solder has cooled. **Bad solder joints can cause additional problems!**

- Static sensitive parts require special handling procedures. Always treat an unknown part as if it were static sensitive.

9-2. Functional Descriptions

This section describes the general operation of each section of the 2701C. The paragraph titles refer to the block diagram shown in Figure 9-1.

9-2-1. Microprocessor

This section contains the microprocessor and associated components which accept inputs from the keyboard, IEEE and overload detection circuitry and output the data to the display, IEEE, D-to-A converter and Relay drive circuitry. All data in the 2701C flows through this section.

9-2-2. IEEE

This section contains all of the interface circuitry required for communication between the IEEE-488 bus and the 2701C microprocessor.

9-2-3. Display

This section contains all of the displays and LEDs on the front panel of the 2701C and is driven under direct control of the microprocessor.

9-2-4. Keyboard

This section contains all of the front panel controls of the 2701C and provides this data to the microprocessor.

9-2-5. D-to-A Converter

This section of the circuitry generates a variable DC voltage signal from data provided by the microprocessor. This DC voltage is determined by data collected from the IEEE-488 bus or from the front panel settings.

9-2-6. Relay Drives

This section contains the drive circuitry for the various range and mode selection relays in the 2701C and is controlled by the microprocessor section.

9-2-7. Sense Feedback

This section compares the actual sensed output voltage with the output of the D-to-A convertor and alters the level of the Output Drive section to perform the required correction for any error present. It is this section and the D-to-A convertor section which determine the overall accuracy and performance of the 2701C.

9-2-8. Output Drive

This section is controlled by the Sense Feedback section and provides the actual output voltage from the 2701C. The user should note that this section does not affect the accuracy of the 2701C other than output drive capability.

9-2-9. Current Drive

This section performs the same function as the Output Drive section but generates the constant current output for the 120mA range (if installed), while the Output Drive section is configured to generate a constant output voltage (with up to 25mA source current).

9-2-10. Power Supply

This section provides all of the power rails required by the 2701C.

9-3. Detailed Descriptions

The paragraphs that follow use the same functional blocks as that used in Section 9-2, but give full details on their operation down to the individual component level. Throughout this section it is assumed that the reader has a knowledge of electronic principles and is familiar with the operation of the 2701C from the front panel (Section 6).

9-3-1. Microprocessor

The schematic for this section is contained in Sheet 2 of drawing number 2701-075 at the back of this manual. The microprocessor consists of five sub-sections as follows:

9-3-1-1. MC6802 Microprocessor

The microprocessor itself is IC101. All of the Random Access Memory (RAM) required is contained within the IC. A full description of the operation of the microprocessor is beyond the scope of this manual and user should refer to the manufacturers data sheets and publications for details on the operation of this microprocessor. Communication with the other sub-sections is by means of the two main busses:

1) The Data Bus - This consists of 8 lines (**D0** to **D7**) and is a 3-state bus for data and command transfers into and out of the microprocessor.

2) The Address Bus - This consists of 16 address lines (**A0** to **A15**) and 4 bus control lines: **R** (Read), **I** (Interrupt), **V** (Valid Memory Address) and **E** (Enable). The 16 address lines are used to specify the device to/from which the microprocessor is sending/reading data. The **R** line defines whether the microprocessor is reading (logic 1) or writing (logic 0) data. The **I** line is pulled low if a device wishes to interrupt the microprocessor (the IEEE interface does this). The **V** line is a logic 1 if the microprocessor is accessing a valid address. The **E** line is the bus clock which is 1.5MHz in the 2701C. Bus transactions are valid during the logic 1 portion of this signal.

9-3-1-2. ROM

The microprocessor instructions are stored in Read Only Memory (ROM) which is IC102. This is

an 8192 x 8 bit memory which is preprogrammed by Valhalla Scientific with the instructions for operating the 2701C.

9-3-1-3. NOVRAM

The calibration constants for the 2701C are stored in Non-Volatile Random Access Memory which is IC103. This is a 64 x 4 bit memory or a 256 x 4 bit memory if Option IT-2 is installed. The NOVRAM maintains the stored data even if power is removed. The updating of this non-volatile data is controlled by means of SW101 (the rear-panel key operated switch) which disables the microprocessor from writing data into this device except when this switch is in the CALIBRATE position.

9-3-1-4. Interfaces

The microprocessor interfaces with external circuitry through Peripheral Interface Adapters (PIA). These devices (IC108 and IC109) are used to latch the data output from the microprocessor and to enable the microprocessor to read the data input to it. These devices are used to interface with the relay drive, keyboard and display sections of the 2701C.

9-3-1-5. Address Decode

The various components of the microprocessor section are enabled by the address decoding devices IC104 and IC105. These devices take the most significant 6 address bus lines (**A10** to **A15**) and "split" the available address space into 15 portions. IC104 splits the entire address range into 8 portions, one of which is further split by IC105 into 8 portions.

9-3-2. IEEE Interface

This section of the 2701C is shown on the schematic number 2701-077 at the back of this manual. The interface is located on the PCB mounted on the rear panel of the 2701C and consists of two sub-sections:

9-3-2-1. IRP Interface

This interface is simply a latch providing 8 static lines under microprocessor control. The decoding device is designated as IC5. The outputs of this device drive the bases of six transistors (TR1 to TR6) via 1kΩ resistors (in RN2) to provide open collector type drives for the Valhalla Model 2500EP Current Calibrator.

9-3-2-2. GPIB Interface

This interface consists of an address switch (SW1) buffered through IC1 and an interface device (IC2) with bus transceivers (IC3 and IC4) for driving the bus itself. The operation of these devices is beyond the scope of this manual and the user should refer to the manufacturer's data sheets and publications for details.

9-3-3. Display

The display circuitry is located on the display PCB which is located immediately behind the acrylic front panel of the 2701C and is shown in the upper half of schematic 2701-076. The displays are multiplexed by the microprocessor by means of a code presented to the inputs of IC1. IC1 decodes this and enables one display at a time through PNP transistors TR1 thru TR10. The elements of each display are driven by the microprocessor via buffers IC113 and IC114 on the main PCB and the resistors in the resistor network RN3 which is located on the display board.

9-3-4. Keyboard and Rotary Switches

The keyboard circuitry is located on the display PCB which is located immediately behind the acrylic front panel of the 2701C and is shown in the lower half of the schematic number 2701-076. Each switch is individually polled by the microprocessor to check

for a depressed key or rotated knob. IC2 is used to sequentially enable the rotary switches and keypads. The status of the keys and rotary switches is read by the microprocessor through buffers IC3 thru IC8.

9-3-5. D-To-A Converter

This circuitry is located on the main PCB and is shown on the schematic 2701-075 sheets 1 and 2. The 2701C uses a variable duty-cycle fixed-frequency waveform to control the output voltage (or current) level. This waveform is generated in the microprocessor section and is controlled by the settings on the rotary switches. The microprocessor uses the calibration constants stored in the NOVRAM to determine the duty-cycle of the waveform that is sent to the Digital-to-Analog Converter (D-to-A).

The D-to-A averages this waveform by comparing it to a reference voltage generated by IC7 to determine the output level. Therefore the greatest output level is obtained when the duty-cycle of the waveform nears 100%. The lowest voltage is obtained when the duty-cycle nears 0%. This is achieved in the 2701C as follows:

1) A timing device (IC107) is used to provide two variable duty-cycle waveforms with a period ≈ 40ms under the control of the microprocessor.

2) These two waveforms and the system clock (1.5MHz) are buffered by IC106 and then optically isolated by IC110 and IC111 to transfer these signals to the analog section of the 2701C which is fully floating.

3) These signals are resynchronized to the system clock when IC112 latches these signals. These devices also supply the required true and inverted versions of the waveform for driving the switches TR13 thru TR16.

4) These four lines directly drive the switching MOSFETs TR13 thru TR16 which act to provide two variable duty-cycle waveforms switching from 0V to the reference voltage generated by IC7. IC11 buffers any switching transients caused by TR14 and TR16 from the other pair of switches TR13 and TR15.

5) The outputs of these two stages are summed by R34 thru R37 to provide the correct input to the Output Drive section.

6) The summed output of the two D-to-A convertors is provided to R38 which forms part of an active filter with IC8 and associated circuitry.

9-3-6. Relay Drives

All relays in the 2701C are of the two coil latching type and are driven by the microprocessor by several of the outputs from IC108. Whenever a change in the state of the relays is required the microprocessor selects the required combination of outputs from IC108 and then turns on TR113. This applies power to the coil of each relay. After a delay of ≈20ms the microprocessor will turn off TR113.

The relays are the latching type and therefore will remain in the desired state without the necessity of powering them continuously. The user should note that due to this procedure the coils of the relays are only driven for 20ms and only when a change in the state of the relays is required. The action of all of the relays in the 2701C is listed in Section 9-4.

9-3-7. Sense Feedback

This circuitry compares the actual output voltage (as present on the SENSE terminals) with the output

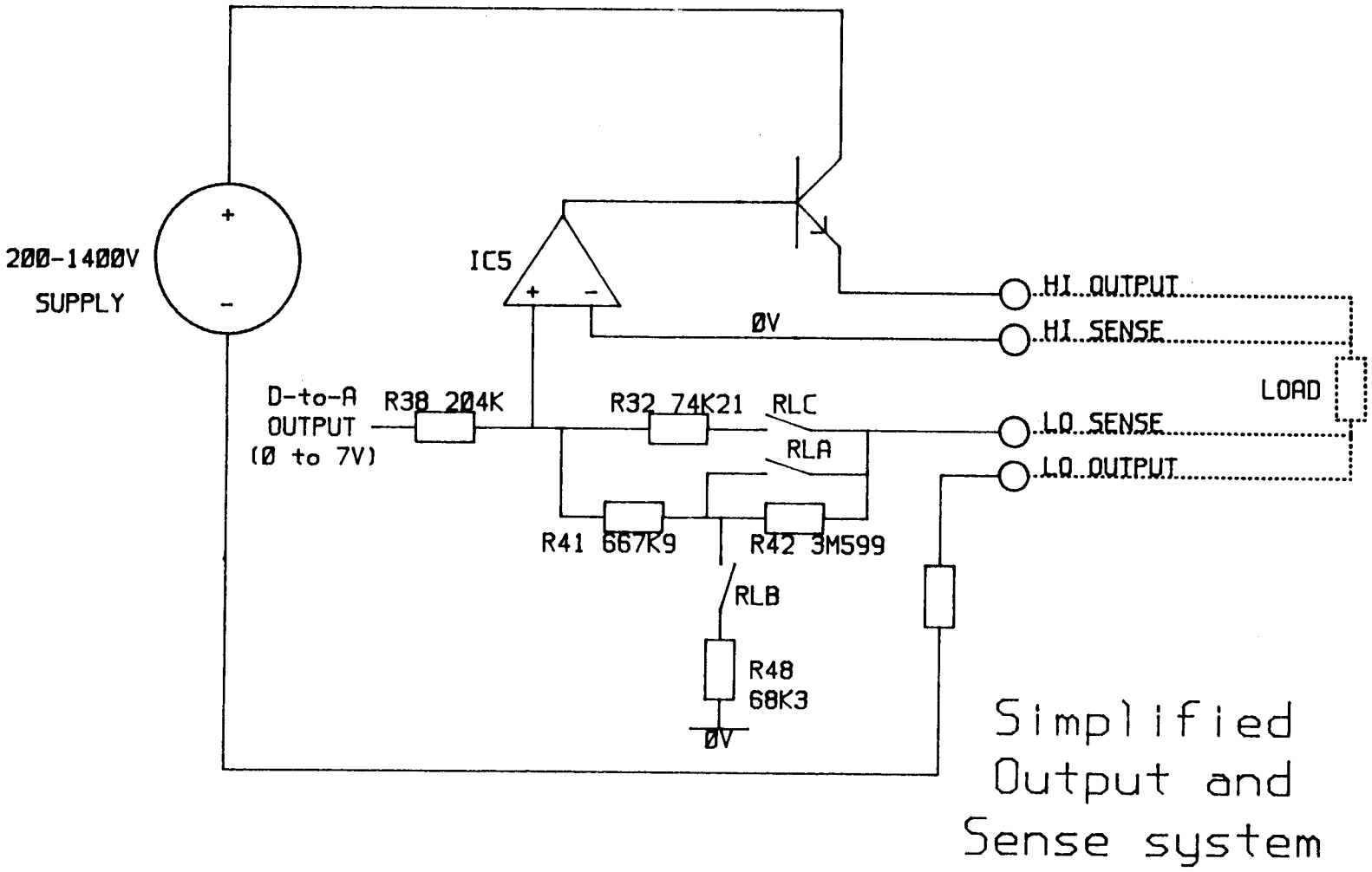

200-1400V
SUPPLY
+
-
IC5
+
-
ØV
HI OUTPUT
HI SENSE
LOAD
D-to-A
OUTPUT
(Ø to 7V)
R38 204K
R32 74K21
RLC
RLA
LO SENSE
LO OUTPUT
R41 667K9
R42 3M599
RLB
R48
68K3
ØV
Simplified
Output and
Sense system

Figure 9-2.

of the D-to-A converter and adjusts the Output Drive to maintain the correct voltage on the SENSE terminals. The main items in this circuitry are:

1) **The amplifier IC5.** This is a chopper stabilized amplifier powered from ±5V rails supplied by regulators IC4 and IC6. The output of this amplifier is provided to the Output Drive section to regulate the output voltage.

2) **Sense attenuator.** This is composed of R32, R41, R42, and R48. The configuration of these resistors is altered by the relays RLA, RLB, and RLC to provide the various ranges of the 2701C. The 200mV range is a divided output which is formed by the resistor-divider composed of R52 and R53.

Figure 9-2 shows a simplified diagram of the Sense and Output Drive system.

9-3-8. Output Drive

As can be seen from Figure 9-2 the output drive is basically a transistor. In the 2701C this is implemented by a cascaded set of MOSFET transistors, TR7-TR11. The main control transistors are TR12 and TR6 which are protected from over-voltage by zener diode D3. The fuse FS1 provides over-current protection on the output terminals.

9-3-9. Current Drive

The 120mA output of Option IT-2 is provided by the circuitry shown on sheet 4 of drawing number 2701-075. When this mode is selected, the Output Drive section of the 2701C is configured to provide 0 to 2V which is used as the input to the voltage-to-current converter formed by IC301, TR301, TR302 and associated components. The fuse FS301 provides over-current protection. The relays RLL and RLK provide Polarity selection and Mode selection respectively.

9-3-10. Power Supplies

The power supplies are shown on schematic number 2701-075 sheet 3. The power supply is in several sub-sections:

9-3-10-1. Earthy Supplies

The microprocessor, display board and IEEE interface circuitry are powered by a single +5V supply which is earth ground referenced. This supply is rectified from a secondary of the Low Voltage Transformer (T202) by D212 and D213. The unregulated output of the transformer is filtered by capacitors C212 and C213 and regulated to +5V by IC201.

9-3-10-2. Low Voltage Supplies

The analog circuitry in the 2701C is floating with respect to ground and is thus isolated from the ground referenced +5V supply. The supplies for the analog circuitry in the 2701C are generated from a secondary winding of the Low Voltage Transformer T202 by the rectifier package D214, the storage capacitors C208 and C209, and regulators IC202 and IC203.

The ±15V supplies are regulated by IC202 and IC203, respectively.

The ±5V supplies for IC5 are regulated from the ±15 volt supplies above by IC4 and IC6, respectively.

The +5V supply for IC110 and IC111 is regulated from the +15V supply by IC116.

The user should note that the supply for the 120mA current drive (Option IT-2) is provided by the unregulated input to IC203, and may vary from -18 to -23 volts.

9-3-10-3. High Voltage Supplies

The Output Drive section of the 2701C is powered by a variable 200 to 1400V switching power

of the D-to-A converter and adjusts the Output Drive to maintain the correct voltage on the SENSE terminals. The main items in this circuitry are:

1) **The amplifier IC5.** This is a chopper stabilized amplifier powered from ±5V rails supplied by regulators IC4 and IC6. The output of this amplifier is provided to the Output Drive section to regulate the output voltage.

2) **Sense attenuator.** This is composed of R32, R41, R42, and R48. The configuration of these resistors is altered by the relays RLA, RLB, and RLC to provide the various ranges of the 2701C. The 200mV range is a divided output which is formed by the resistor-divider composed of R52 and R53.

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The microprocessor, display board and IEEE interface circuitry are powered by a single +5V supply which is earth ground referenced. This supply is rectified from a secondary of the Low Voltage Transformer (T202) by D212 and D213. The unregulated output of the transformer is filtered by capacitors C212 and C213 and regulated to +5V by IC201.

9-3-10-2. Low Voltage Supplies

The analog circuitry in the 2701C is floating with respect to ground and is thus isolated from the ground referenced +5V supply. The supplies for the analog circuitry in the 2701C are generated from a secondary winding of the Low Voltage Transformer T202 by the rectifier package D214, the storage capacitors C208 and C209, and regulators IC202 and IC203.

The ±15V supplies are regulated by IC202 and IC203, respectively.

The ±5V supplies for IC5 are regulated from the ±15 volt supplies above by IC4 and IC6, respectively.

The +5V supply for IC110 and IC111 is regulated from the +15V supply by IC116.

The user should note that the supply for the 120mA current drive (Option IT-2) is provided by the unregulated input to IC203, and may vary from -18 to -23 volts.

9-3-10-3. High Voltage Supplies

The Output Drive section of the 2701C is powered by a variable 200 to 1400V switching power

supply (as indicated in Figure 9-2). This is generated by the High Voltage Transformer (T201), TR201, TR202, IC1, IC2 and their associated circuitry.

Refer to sheet 1 of schematic 2701-075. One amplifier of dual op-amp IC1 is configured to compare the voltage across the output transistor chain (TR6 thru TR12) with 200V and to turn on the opto-isolator IC2 if this voltage is high. The other half of IC1 is used to sync the switching supply to the AC line voltage by providing a short, pulsed, ON signal to the input of IC2 at each zero-crossing of the line voltage.

The LED which is the input to opto-isolator IC2 is used to enable its output transistor. There is no electrical connection inside IC2 and isolation is therefore maintained between the AC line and the switching power supply. Turning on the LED turns off TR201 and TR202, thus turning off the drive to the transformer T201. In the above manner this circuitry is used to maintain the output of the transformer T201 such that the voltage across the chain of transistors TR6 to TR12 is approximately 200V independent of the actual output voltage.

The rectifier bridge formed by D206 to D209 along with capacitors C203 to C206 perform the rectification and storage of the output of T201. As figure 9-2 shows, the decay of the high voltage supply is dependant on the load upon its output. Decay is achieved without the use of an external load by an additional "clamping" supply formed by D210, D211, C211 and C214. This is a 500V supply which forces a "bleed" current from the high voltage supply. In situations (such as going to STANDBY mode from a 1000 volt output) when a faster decay is required as sensed by the amplifier IC5, RLJ is energized to clamp the high voltage supply to reduce the voltage on the output terminals as quickly as possible.

9-4. Relay Selections

The user should note that all of the relays (except RLJ) in the 2701C are of the "latching" type. This type of relay does not require that the drive signal be present all of the time for the ON condition, or not present for the OFF condition. Instead it has two coils, either one of which may be pulsed to force the selection of the required state. With the absence of power on either coil the relay will remain in the same state. The states of this type of relay are called RESET and SET.

The truth tables for the relays in the 2701C are given below. The RESET condition is indicated by an "R" and the SET condition is indicated by an "S". If either condition may be found, this is indicated by an "X".

Range:	200mV	2V	20V	120V	1200V	120mA
RLA	S	S	S	R	R	S
RLB	R	R	R	R	S	R
RLC	S	S	R	R	R	R
RLD	(1)	(1)	(1)	(1)	(1)	X
RLE(2)	(1)	(1)	(1)	(1)	(1)	X
RLF	S	R	R	R	R	S
RLG(2)	S	R	R	R	R	S
RLH	R	(3)	(3)	(3)	(3)	S
RLK	R	R	R	R	R	S
RLL	X	X	X	X	X	(4)

Notes:

1) RLD and RLE are SET for positive voltage output, RESET for negative.

2) RLD/RLE and RLF/RLG are driven in tandems (i.e. RLD and RLE are always in the same state as each other as are RLF and RLG).

3) RLH is RESET for 2-wire, SET for 4-wire.

4) RLL is SET for positive current output, RESET for negative.

9-5. Microprocessor ROM

A full description of the internal workings of the 2701C main read-only-memory (ROM) is beyond the scope of this manual and is unnecessary for normal operating procedures. However

some knowledge of the structure behind this software is of benefit, thus this section contains a brief description of its operation.

The user should be aware of the following standard software organization features which are used in the 2701C:

1) **Power-on reset routine:** To initialize all data areas, perform tests etc. required at power-up.

2) **An executive control loop:** The loop which is normally being executed by the microprocessor (μP).

3) **Interrupt routines (also called "Real Time"):** To perform actions requiring immediate response to hardware input.

4) **Individual "action" routines:** Called from the executive loop to action events or perform duties.

9-5-1. Power-On Reset Routine

After a power-on reset the μP performs the following tasks in the order given:

1) Check RAM operation and stack area.
2) Initialize LEDs and displays.
3) Display greeting to user. (**HELLO**)
4) Initialize RAM volatile data.
5) Retrieve and check calibration data. ("**no dAtA**" if corrupted or missing)
6) Initialize IEEE interface and parameters. (**Addr 10**)
7) Check ROM and RAM operation and data contents. (**2701C-3**)
8) Main Executive duties

9-5-2. Main Executive Duties

This continuous loop is normally executed by the μP all of the time. The process leaves this loop only temporarily to perform one of its other duties. The duties within this loop are as follows:

1) Select required keyboard action level.

2) Perform action for keyboard selection.

3) If an IEEE command is received, act on that command.

4) Following a delay, perform the required action based on input from keyboard or IEEE.

5) Repeat loop.

9-5-3. Interrupt Routines

There are two sources of interrupts to the μP in the 2701C. These are:

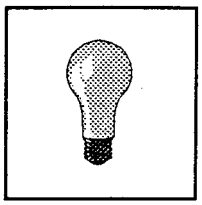
1) **Periodic Interrupt:** This interrupt is generated by IC115 and occurs every 667μS (approx). The μP uses this interrupt to multiplex the displays and also for timing functions.

2) **IEEE Interface Interrupt:** This interrupt is generated by the IEEE-488 interface circuitry whenever an event on the bus has occurred which requires activity by the 2701C μP. Examples of this are: reception of a character, transmission of a character, or reception of a command. This interrupt performs all of the required duties to complete the event and release the IEEE-488 bus. It informs the main executive when a complete character string has been received from the controller so that it may be acted upon.

9-5-4. Individual "Action" Routines

This set of routines control the reaction of the 2701C due to an event. Examples of events are: a Mode or Range key being pressed, a dial being rotated, or an IEEE command line being received. The 2701C accesses the appropriate routine to fulfill all of the actions prescribed by the event.

SECTION X SPECIAL PROCEDURES



10-1. Getting the Most Out of Your 2701C

As with all precision instrumentation there are some general caretaking procedures that will help the user obtain the maximum performance. Most of the points listed below are good habits for any piece of equipment, and if followed should enhance the performance of all calibration equipment at a minimal cost.

1) Leave equipment powered at all times. This greatly reduces the drift and unreliability caused by temperature stresses during warm-up and cool-down.

2) Avoid operating equipment in direct sunlight (e.g. through a window). Very high surface temperatures can be reached and the highly uneven temperature distribution will considerably affect the performance and reliability of the equipment.

3) Avoid operating equipment directly under an air-conditioning outlet duct. This will cause similar effects as in item 2 above. If there is significant air movement over the terminals then cover them and the cabling by a cloth cover (Not synthetic! Static will cause worse problems) or use some other type of air block to reduce airflow.

4) Avoid other causes of temperature shock. If it is necessary to transport equipment then always ensure that it is well packed and thermally lagged. Also ensure that no rain or condensation can penetrate into the equipment.

5) Avoid static electricity. Discharges into the case or terminals of equipment can cause damage and will certainly cause noisy measurements to be made. Even a charged body (e.g. a person) which is moving can cause noise if impedance levels are sufficiently high, thus always sit or stand on a conductive surface and avoid movement whenever sensitive measurements are being made.

6) Avoid high energy electromagnetic fields. Although modern equipment is relatively insensitive to fields, they *will* produce errors. Always use shielded cabling wherever possible and always ensure that the shield is connected to a low impedance node (common).

7) Always use the highest quality cables. Many "good looking" cables do not actually use pure copper for conductors and can cause several microvolts of thermal emfs. The recommended cable set for the 2701C is the Valhalla Option SL-48.

   Many standard banana jacks are actually made of steel or similar materials and can cause many microvolts of thermal emfs. If you are unsure if your cables are causing a problem, try reversing your connections and compare the measurements. There should be no difference.

8) Keep connectors and cables clean and free from grease. Corrosion can cause what was a perfectly good, high quality connector to become one that is worse than a "cheap" one. Surface grease will collect moisture and further grease, and also produce a significant leakage path. This can seriously affect high impedance and/or high accuracy measurements.

9) Keep handling of terminations and cabling to a minimum. This reduces grease build up on these items (as in item 8 above) and also reduces the errors caused by thermal emfs.

10) Always try to balance cabling. Even with the highest quality cabling and terminals, several microvolts of thermal emfs can occur if there is significant temperature difference. Therefore always use the same gauge and type of wire to both terminations of sensitive measuring and generating devices (such as the 2701C) to reduce the temperature differential between conductors. Care in balancing the routing of cables (i.e. route the Hi and Lo conductors close together) will also reduce thermals and interference pick-up.

11) Do not stack pieces of equipment on top of each other. Most instruments require air flow around them and any restriction will decrease their performance. Also, the top instrument in a pile of several can be 10 or even 20 degrees hotter than the bottom one.

12) Treat your equipment correctly and it will treat you correctly. Keep equipment clean. Do not attempt any measurement that could yield damaging voltages or currents without taking reasonable precautions to protect the instrument. Frequent breakdowns may be due to faulty equipment or design, but are more often caused by a lack of care and/or understanding of the product. **Read all instructions thoroughly!**

10-2. Dielectric Storage in Cabling

The effect of dielectric storage in cabling is often overlooked by many users but can have significant effects on the accuracy and/or repeatability of measurements.

All cables have dielectric storage. Many people believe that there a relationship between dielectric storage and the published loss (also called dissipation factor) data for cables and capacitors. The answer is that there is, and there is not! There are two major factors to dielectric storage:

1) The initial stored quantity, and

2) The time constant of the discharge.

Dielectric storage (or *absorption* as it is also called) can be simulated by placing a very small capacitance in series with a very large resistance in parallel with the actual capacitance of the cable (or capacitor). The initial stored quantity is dependent on the value of the "very small capacitance" while the time constant is dependent on this and the "very high resistance".

In practice, most materials behave as if they have several of these capacitor-resistor combinations with widely varying values and time constants. The use of polyethylene insulated cables (never use PVC or Teflon) will help reduce this effect.

If the user is unsure or just wishes to see the effect, try the following test on a two-conductor cable. The user is warned that this can be a dangerous test and extreme caution must be exercised!

1) Ensure that neither end of the cable has any connections and is not shorted.

2) Connect one end of the cable to a 100VDC source and wait for several minutes with 100 volts applied.

3) Connect a 1 megohm resistor across the input terminals to a DVM having 1μV sensitivity and a sample rate of greater than 1 per

second. Allow sufficient time for the reading to settle.

4) Very carefully and quickly disconnect the cable from the 100VDC supply (do *not* set the 2701C to zero or STANDBY first) and connect instead to the DVM. The user will see many microvolts (millivolts for bad cables) of dielectric storage which may take several minutes to decay.

The effect of dielectric storage is most visible when making resistance measurements, particularly at higher values (above 10KΩ), but is also very noticeable when performing measurements of standard cells or the outputs of voltage dividers. In both of these cases the impedance levels are quite high and very long settling times can result if "bad" cabling is used.

With the 2701C, this effect can be easily seen. If the output has been at 1000V for some time and then a divided output (100mV for instance) is selected, there will appear to be a relatively large error at the 100mV level which will slowly disappear (it will look like thermal emfs). This is caused by the dielectric storage discharging into the 450Ω output impedance of the divider. It is recommended that if this sequence of events is to take place that the user should change the cable after subjecting it to 1000V and leave it to discharge for several minutes before using it again.