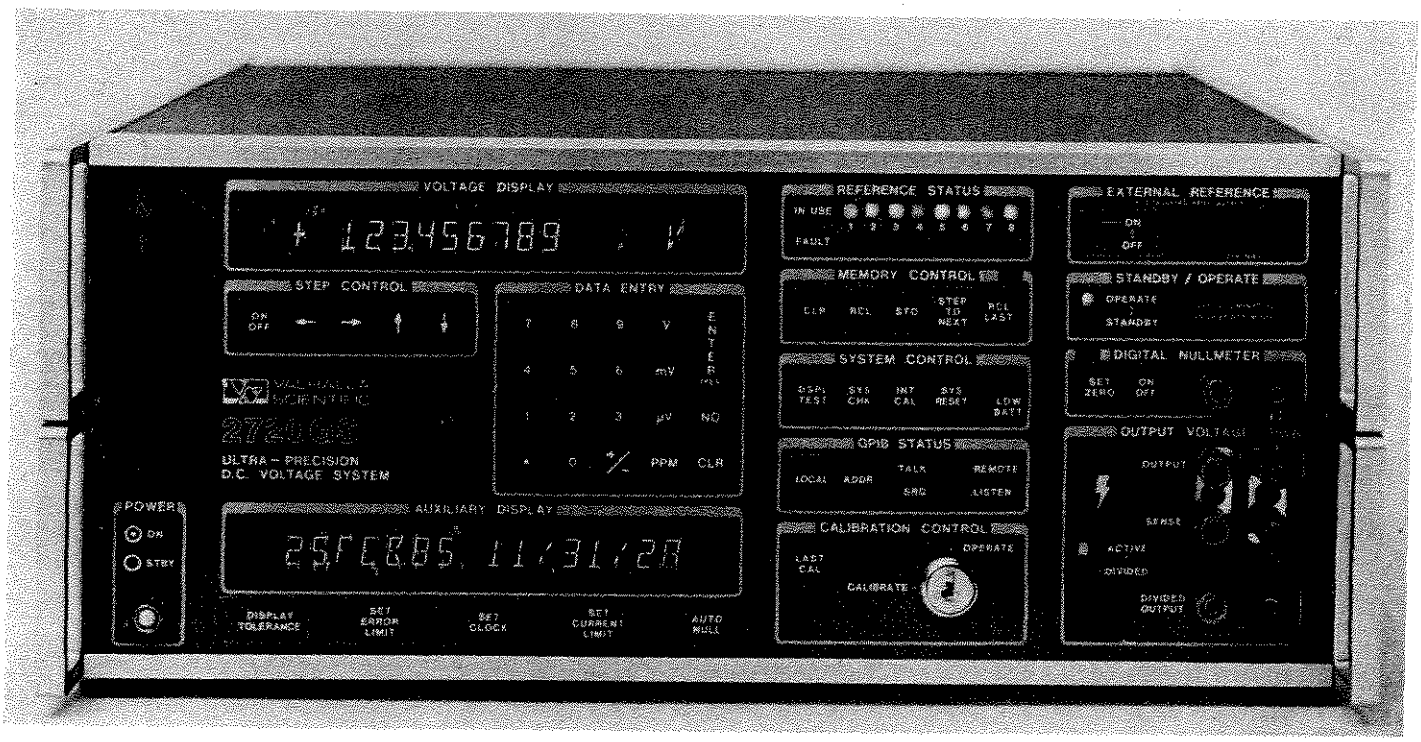
VOLUME 1

2720 GS

ULTRA-PRECISION DC VOLTAGE SYSTEM

OPERATION AND MAINTENANCE MANUAL



VALHALLA SCIENTIFIC

9955 Mesa Rim Rd
San Diego, Ca 92121
Phone (619)457-5576
Telex 181750

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SECTION I

UNPACKING AND INSTALLATION

1.1 Unpacking

If the shipping carton is damaged, request that the carriers' agent be present when the 2720GS is unpacked. If the 2720GS appears damaged when unpacked then notify the carriers' agent who should authorize repairs before the 2720GS is returned to Valhalla Scientific or Service Center. Even if the 2720GS appears undamaged it may have suffered internal damage in transit that may not be evident until the 2720GS is operated or tested to verify performance. If the 2720GS fails to meet the performance specifications in section II then notify the carriers' agent and Valhalla Scientific or Service Center. Retain the shipping carton for the carriers inspection, DO NOT RETURN EQUIPMENT TO VALHALLA SCIENTIFIC OR ANY OF ITS SERVICE CENTERS PRIOR TO OBTAINING AUTHORIZATION TO DO SO.

1.2 Initial Adjustments

The only adjustments required prior to operation of the 2720GS are the correct selection of the local power source voltage on the rear panel switch and to verify that the correct fuse for this voltage is fitted. The supply voltages and fuses are listed below:

105 to 128VAC 50/60Hz	3 Amp SLO BLO fuse
210 to 256VAC 50/60Hz	1.5 Amp SLO BLO fuse

ENSURE THAT THE CORRECT SELECTION IS MADE PRIOR TO APPLYING POWER TO THE 2720GS.

1.3 Instructions for Bench Use

The 2720GS is delivered for operation in bench use and special instructions for use in this manner are not required. However, before connecting the 2720GS to the AC power source the user should verify that the power cord is equipped with a three-terminal connector (see the Safety precautions in 1.5).

1.4 Instructions for Rack Mounting

Optional rack mounting brackets are available for mounting the 2720GS in a standard 19" equipment rack. These are listed in Section III of this manual. The size and weight of the 2720GS dictate that the unit should be supported on both sides along its entire length (by the use of "trays" or "slides"). If it is to be transported while mounted in a rack then it MUST BE SUPPORTED SO AS TO PREVENT UPWARDS or DOWNWARDS MOVEMENT.

The user should note that the specifications of the 2720GS become degraded at high temperatures (particularly above 40C) thus it is recommended that sufficient room be allowed for airflow around the 2720GS. This may be achieved by placing at least 1.75" high blank panels above and below the 2720GS in the rack and ensuring that at least 4" of unobstructed airspace is present behind the

unit.
If the unit placed beneath the 2720GS has an exceptionally hot exterior top surface and it is not possible to alter its location then the user is recommended to fit an aluminum "reflector" plate between this unit and the 2720GS.
Under no circumstances should the ambient air temperature surrounding the 2720GS be allowed to exceed 50C while in operation or 70C while not in operation.

1.5 Safety Precautions

The power connector should be a three-contact device meeting the safety requirements of the area in which the 2720GS is to be used, and should only be mated with a three-contact connector where the third contact provides a ground connection. If power is provided through an extension cable then the ground connection must be continuous throughout this cable to the 2720GS.
If a ground contact is not available in the power connector then the gold colored ground terminal on the rear panel of the 2720GS MUST be connected to a local ground connection.

FAILURE TO PROVIDE A CONTINUOUS GROUND CONNECTION TO THE 2720GS MAY RENDER THE UNIT UNSAFE FOR USE.

SECTION II

SPECIFICATIONS

2.1 General

The specifications of the 2720GS ULTRA-PRECISION D.C. VOLTAGE SYSTEM are listed in the following paragraphs. The specifications of options "HSR" and "54-4T" are also listed where they differ from the standard 2720GS.

2.2 Accuracy

The accuracy specifications are valid for +/-6C from the calibration temperature within 10 to 35C. The values stated below include the effects of line, load and temperature variations within the above window and require the use of Internal Calibration every 30 days. To derive absolute accuracies relative to the National Bureau of Standards add 1.5ppm for Valhalla Scientific's traceability and transfer uncertainty.

2.2.1 2720GS Accuracy (ppm of setting +/- uV)

Range	30day	90day	180day	1year	3years
650mV*	2.3+0.2	2.9+0.2	3.8+0.2	5.3+0.2	10.6+0.2
1300mV*	2.5+0.3	3.1+0.3	4.0+0.3	5.5+0.3	10.8+0.3
0.65V	2.3+0.3	2.9+0.3	3.8+0.3	5.3+0.3	10.6+0.3
1.3V	2.5+0.4	3.1+0.4	4.0+0.4	5.5+0.4	10.8+0.4
6.5V	1.5+1.2	2.0+1.2	2.7+1.2	4.0+1.2	8.9+1.2
13V	1.7+2.3	2.2+2.3	2.9+2.3	4.2+2.3	9.1+2.3
26V**	2.2+5.0	2.7+5.0	3.4+5.0	4.7+5.0	9.6+5.0
65V	2.5+15	3.1+15	4.0+15	5.5+15	10.8+15
130V	2.7+30	3.3+30	4.2+30	5.7+30	11.0+30
600V	2.7+150	3.3+150	4.2+150	5.7+150	11.0+150
1200V	2.9+300	3.5+300	4.4+300	5.9+300	11.2+300

* Divided output (Zo=450ohm, specification valid at SENSE outputs)
** Only available on units with serial numbers after 20-127.

2.2.2 2720GS Option "HSR" Accuracy (ppm of setting +/- uV)

Range	30day	90day	180day	1year	3years
650mV*	2.0+0.2	2.3+0.2	2.8+0.2	3.7+0.2	6.7+0.2
1300mV*	2.2+0.3	2.5+0.3	3.0+0.3	3.9+0.3	6.9+0.3
0.65V	2.0+0.3	2.3+0.3	2.8+0.3	3.7+0.3	6.7+0.3
1.3V	2.2+0.4	2.5+0.4	3.0+0.4	3.9+0.4	6.9+0.4
6.5V	1.4+1.2	1.7+1.2	2.2+1.2	3.0+1.2	5.6+1.2
13V	1.6+2.3	1.9+2.3	2.4+2.3	3.2+2.3	5.8+2.3
26V**	2.1+5.0	2.4+5.0	2.9+5.0	3.7+5.0	6.3+5.0
13V	1.6+2.3	1.9+2.3	2.4+2.3	3.2+2.3	5.8+2.3
65V	2.2+15	2.5+15	3.0+15	3.9+15	6.9+15
130V	2.4+30	2.7+30	3.2+30	4.1+30	7.1+30
600V	2.4+150	2.7+150	3.2+150	4.1+150	7.1+150
1200V	2.7+300	3.0+300	3.5+300	4.4+300	7.4+300

2.2.3 2720GS Option "54-4T" Accuracy (ppm of setting +/- uV)

Range	30day	90day	180day	1year	3years
650mV*	3.5+0.2	4.9+0.2	7.3+0.2	12.1+0.2	24.2+0.2
1300mV*	3.7+0.3	5.1+0.3	7.5+0.3	12.3+0.3	24.4+0.3
0.65V	3.5+0.3	4.9+0.3	7.3+0.3	12.1+0.3	24.2+0.3
1.3V	3.7+0.4	5.1+0.4	7.5+0.4	12.3+0.4	24.4+0.4
6.5V	2.8+1.2	4.1+1.2	6.4+1.2	11.0+1.2	22.5+1.2
13V	3.0+2.3	4.3+2.3	6.6+2.3	11.2+2.3	22.7+2.3
65V	3.7+15	5.1+15	7.5+15	12.3+15	24.4+15
130V	3.9+30	5.3+30	7.7+30	12.5+30	24.6+30
600V	3.9+150	5.3+150	7.7+150	12.5+150	24.6+150
1200V	4.5+300	5.9+300	8.3+300	13.1+300	25.2+300

2.3 Stability

The 24 hour stability specifications below apply for constant line, load and temperature (within 1C) and are measured over a bandwidth of DC to 2Hz.

Range	2720GS	2720GS/HSR	2720GS/54-4T
650mV	0.23ppm+0.06uV	0.19ppm+0.06uV	0.36ppm+0.1uV
1300mV	0.23ppm+0.1uV	0.19ppm+0.1uV	0.36ppm+0.15uV
0.65V	0.23ppm+0.2uV	0.19ppm+0.2uV	0.36ppm+0.25uV
1.3V	0.23ppm+0.3uV	0.19ppm+0.3uV	0.36ppm+0.35uV
6.5V	0.23ppm+0.6uV	0.19ppm+0.6uV	0.36ppm+0.7uV
13V	0.23ppm+1.0uV	0.19ppm+1.0uV	0.36ppm+1.5uV
26V**	0.23ppm+2.0uV	0.19ppm+2.0uV	----------
65V	0.23ppm+5.5uV	0.19ppm+5.5uV	0.36ppm+7uV
130V	0.23ppm+10uV	0.19ppm+10uV	0.36ppm+13uV
600V	0.23ppm+50uV	0.19ppm+50uV	0.36ppm+70uV
1200V	0.23ppm+100uV	0.19ppm+100uV	0.36ppm+140uV

** Only available on units with serial numbers after 20-127 for 2720GS and option "HSR" only.

2.4 Temperature Coefficient

These specifications apply following stabilization to a change in temperature (thermal time constant of unit is approximately 2min/C). The temperature coefficient adder is applicable only when outside of the +/-6C window of the calibration temperature. If the user is unsure of the temperature or of which table to use then the "DISPLAY TOLERANCE" key on the 2720GS should be used, this will display the actual accuracy of the 2720GS (including the options fitted) at the actual operating conditions prevailing at that time and temperature.

2.4.1 With the use of Internal Calibration

The table below gives the temperature coefficient adders for all 2720GS options when Internal Calibration of the "Output Gain" is used to compensate for output scaling errors. The uV offsets may also be eliminated if desired by the use of Internal Calibration of "Output Zeroes".

Range	0-35C	35-50C
650mV	0.04ppm+0.01uV	0.34ppm+0.01uV
1300mV	0.04ppm+0.02uV	0.34ppm+0.02uV
0.65V	0.04ppm+0.02uV	0.34ppm+0.02uV
1.3V	0.04ppm+0.03uV	0.34ppm+0.03uV
6.5V	0.01ppm+0.1uV	0.05ppm+0.2uV
13V	0.01ppm+0.2uV	0.05ppm+0.4uV
26V	0.04ppm+0.5uV	0.34ppm+1uV
65V	0.04ppm+1uV	0.34ppm+2uV
130V	0.04ppm+2uV	0.34ppm+4uV
600V	0.04ppm+10uV	0.34ppm+20uV
1200V	0.04ppm+20uV	0.34ppm+40uV

2.4.2 Without the use of Internal Calibration

The table below gives the temperature coefficient adders for all 2720GS options when Internal Calibration is not used, this constitutes the "worst-case" condition where the user is unaware that a temperature change has occurred.

Range	0-10C	10-35C	35-50C
650mV	0.04ppm+0.01uV	0.04ppm+0.01uV	0.34ppm+0.01uV
1300mV	0.08ppm+0.02uV	0.08ppm+0.02uV	0.48ppm+0.02uV
0.65V	0.04ppm+0.02uV	0.04ppm+0.02uV	0.34ppm+0.02uV
1.3V	0.08ppm+0.03uV	0.08ppm+0.03uV	0.48ppm+0.03uV
6.5V	0.01ppm+0.1uV	0.01ppm+0.1uV	0.05ppm+0.2uV
13V	0.04ppm+0.2uV	0.04ppm+0.2uV	0.25ppm+0.4uV
26V	0.34ppm+0.5uV	0.14ppm+0.5uV	0.5ppm+1uV
65V	0.34ppm+1uV	0.14ppm+1uV	0.49ppm+2uV
130V	0.39ppm+2uV	0.19ppm+2uV	0.54ppm+4uV
600V	0.34ppm+10uV	0.14ppm+10uV	0.49ppm+20uV
1200V	0.39ppm+20uV	0.19ppm+20uV	0.54ppm+40uV

2.5 General Performance Characteristics

The table below gives the general operating characteristics of the 2720GS.
The Resolution is the displayed resolution of the requested output voltage, the actual resolution of the 2720GS is actually better than these figures.
The Measurement accuracy is the overall 90day +/-6C specification of a 2720GS when used to measure an unknown voltage using "AUTO NULL" with the division ratio entered as 0.5 (see 4.1).
The Linearity of the 2720GS is defined as the maximum allowable deviation from a straight line between the zero and full-scale outputs on each range.

Range	Resolution	Measurement Accuracy	Maximum Current	Wideband Noise 10Hz-10KHz	Linearity
650mV	10nV	2.9ppm+0.3uV	-----	10uV RMS	0.14uV
1300mV	10nV	3.1ppm+0.4uV	-----	10uV RMS	0.26uV
0.65V	10nV	2.9ppm+0.4uV	100mA	30uV RMS*	0.22uV
1.3V	10nV	3.1ppm+0.5uV	100mA	30uV RMS*	0.32uV
6.5V	10nV	2.0ppm+1.3uV	100mA	30uV RMS*	0.9uV
13V	100nV	2.2ppm+2.4uV	100mA	30uV RMS*	1.8uV
26V**	100nV	2.7ppm+5.1uV	100mA	50uV RMS	3.6uV
65V	100nV	3.1ppm+15uV	100mA	150uV RMS	10uV
130V	1uV	3.3ppm+30uV	100mA	150uV RMS	18uV
600V	1uV	3.3ppm+150uV	30mA	300uV RMS	85uV
1200V	10uV	3.5ppm+300uV	30mA	300uV RMS	165uV

* Add 20uV RMS if a current limit >15mA is selected

2.6 Output Settling Times

The table below gives the errors remaining after the given time following a change in output voltage. The errors are given in ppm of output voltage change. For changes requiring a change of range, or changes between Standby and Operate, then the error is in ppm of final output voltage.

Range	1second	3seconds	10seconds
13V and below	5ppm	2ppm	1ppm
26,65 and 130V	5ppm	3ppm	1.5ppm
600 and 1200V	----	4ppm	2.5ppm

2.7 Digital Nullmeter Performance Specifications

The accuracy specifications listed below are valid for temperatures between 0 and 50C and for 3 years.

Range	Resolution	Accuracy	Input Impedance
0-200uV	10nV	0.2%+100nV	>10Gohm (10^{10}ohm)
0.2-2mV	100nV	0.2%+200nV	>100Gohm (10^{11}ohm)
2-20mV	1uV	0.2%+1uV	>1Tohm (10^{12}ohm)
20-200mV	10uV	0.2%+10uV	>10Tohm (10^{13}ohm)
0.2-2V	100uV	10%+1mV	66Mohm nominal
2-20V	1mV	10%+2mV	,, ,,
20-200V	10mV	10%+10mV	,, ,,
200-2000V	100mV	15%+100mV	,, ,,

Maximum Input Current : 0-35C : 25pA
35-50C : 60pA

Common mode Impedance (to Output LO) : >1Tohm (10^{12}ohm)

Zero stability : 50nV per hour + 30nV per C

Maximum Safe Input voltage (either terminal with respect to ground)
: 2500V peak.

2.8 Real Time Clock/Calendar

Accuracy : 2ppm
Battery Life : 5000 hours with no power applied
: 10 years maximum
Display Format : Day/Month/Year Hour:Minute:Second
: User selectable 12 or 24 hour format

2.9 Miscellaneous

Warmup Time : 5 minutes to <5ppm of final value
: 15 minutes to <1ppm of final value
: Double above figures if unit not in STBY
: or Option BAT/EBU not fitted.

IEEE-488 : Compliance with IEEE-488(1978) with subsets
: SH1AH1T6TE0L4LE0SR1RL1PP2DC1DT1C0

Power : 115/230V +/-10% at 45 to 65Hz at 125VA

2.10 Physical

Size : 178mm(7") high x 432mm(17") wide x 483mm(19")deep
Weight : 23Kg(48lbs) net, 25Kg(55lbs) shipping

2.11 Environmental

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

Humidity : 70% RH max at 40C (non-condensing)

2.12 Recommended Calibration Interval

The calibration interval for the 2720GS is dependent on the accuracy the user wishes to maintain. The user should consult the accuracy tables in 2.2 to determine the number of days between external calibrations to obtain the required accuracy.

The recommended Internal Calibration interval is 30 days although there will be a slight gain in accuracy if this is performed at intervals down to every two days (only the "Output Gain" portion of the Internal calibration procedure need be performed at this interval, see 6.21 for details).

SECTION III

OPTIONS AND ACCESSORIES

3.1 General

The following options are available for the 2720GS ULTRA-PRECISION DC VOLTAGE SYSTEM.

3.2 Option "BAT"

This is a rear panel mounted gel-cell battery pack providing power for 12 hours for the references, reference ovens, external reference and nullmeter. Option "BAT" is fully self-contained in an aluminum enclosure with the charging circuitry and logic connections internal to the 2720GS.

3.3 Option "EBU"

If a longer battery life than provided by option "BAT" is required, then this may be obtained by the use of option "EBU". This option provides logic interface and isolation circuitry for a user supplied 11-18V DC supply (e.g. an automotive battery) with 1500V isolation between the external DC source and the output terminals and chassis of the 2720GS. The user should note that this option will draw upto 3.5 amps from the DC source and will draw a quiescent current of approximately 0.8 amps when the reference ovens are at a stable temperature.

3.4 Options "EXR1","EXR7" and "EXR10"

These options allow the user to reference the 2720GS to an external 1V, 7V or 10V source respectively. The current drawn from the external reference is <50pA thus allowing direct connection to high impedance reference sources such as standard Weston cells. The actual value of the external reference can be input via the unit's data entry keyboard or over the IEEE-488 interface and may be within +/-5% of the nominal input voltage for the option. Calibration of this option is completely internal.

Use of this option causes the specification of the 2720GS to become the 30day accuracy figures (plus the inaccuracy of the external reference) plus 0.5ppm + 0.1ppm/C + 1uV/Vref.

The allowed range of input reference voltages are as follows :

EXR1 : 0.95 to 1.05V
EXR7 : 6.1 to 7.5V
EXR10 : 9.5 to 10.5V

3.5 Option "54-4T"

When budgetry constraints or less crucial applications exist, this option provides cost savings by a reduction of two zener references from the units' reference system (to a total of four). Resolution is reduced by a factor of ten and a reduced specification applies (see Section II for complete specifications). Upgrade back to 2720GS standards can be achieved easily at a later date, contact your nearest Valhalla Scientific sales office for details.

3.6 Option "HSR"
For the ultimate in DC Voltage performance the "HSR" option replaces the six standard 2720GS references with eight premium grade references. These references are specially selected and aged for optimum performance. Refer to Section II for complete specifications for this option.

3.7 Option "RX7"
This option allows rack mounting of the 2720GS in a standard 19" equipment rack.

3.8 Option "BBL"
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 1uV or more can be tolerated.

3.9 Option "SL-48"
This option is a 48" long shielded cable terminated at each end by high quality gold plated copper spade lugs. Use of this option is recommended for low signal levels or whenever the best performance is required.

3.10 Options "GP1" and "GP2"
These options are IEEE-488 cables of 1 meter and 2 meter lengths respectively.

3.11 Option "SP-2"
This option provides a selection of the most likely parts to fail during the first two years of operation.

3.12 Option "XB20"
This option provides the user with a set of extender PCBs to ease the maintenance of the 2720GS.

SECTION IV

FRONT PANEL CONTROLS AND CONNECTORS

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 method to operate the 2720GS in the various modes available.
The user should note that there is an internal "beeper" which sounds whenever a key is pressed (this may be disabled if desired) or whenever a failure or error message is displayed.
The paragraph numbers used in this section correspond to the reference numbers used in Figure 4-1.

4.1.1 "VOLTAGE DISPLAY"

The voltage display is used to display the 2720GS' output voltage with the appropriate unit in the rightmost window(s). The unit used for display is the same as the unit used for entry of the voltage with a default unit of "V". The output polarity (either "+" or "-") is displayed in the leftmost window. Both leading and trailing zero suppression are provided, with the resolution being limited to the specified figures given in Section II.
During the power up cycle, System Check, Internal Calibration or External Calibration this display area is used for user information purposes.

4.1.2 "STEP CONTROL" Section

The STEP CONTROL section of the keyboard provides the means to alter the output voltage, digit by digit, without having to enter the new voltage directly via the DATA ENTRY keys.

4.1.2.1 "ON OFF" Key

This key alternately selects and deselects the Step Control mode of operation. The unit automatically selects the window giving 1ppm (or 10nV for small voltages) resolution as the initially selected window for edit. Neither selection or deselection of Step Control alters the output voltage.
When Step Control is initially selected, the "nominal" (the voltage from which the deviation is computed) is set to the currently selected output voltage.
While in Step Control the lower or AUXILIARY DISPLAY will indicate the deviation from the "nominal" voltage (in V, mV, uV or ppm as required).

4.1.2.2 Left and Right Arrow Keys

These keys move the window to be edited, either to the left or right respectively. The window to be edited is highlighted by means of it flashing. The user may select any window to be edited even if it is not normally displayed due to the action of leading or trailing zero suppression.

4.1.2.3 Up and Down Arrow Keys

These keys enable the user to edit the requested window of the output voltage display by either incrementing or decrementing the output voltage by that quantity. The user should note that for user convenience the "Up Arrow" key will always increase the output voltage in a positive manner (i.e. decrease the numeric quantity if the polarity is negative) and the "Down Arrow" key will always decrease the output voltage. Full carry and borrow is implemented with the capability of stepping the output through zero if required.

4.1.3 "DATA ENTRY" Section

The Data Entry section of the front panel is used for all prompted and unprompted data entry from the user of the 2720GS. All data is displayed in the lower or AUXILIARY DISPLAY as each key is pressed, the entered data is not used until the ENTER key is pressed. When applicable, the units keys ("V","mV","uV" or "PPM") may be used at any time during data entry to set the required unit for the data. If an error is made during data entry then the CLR key will erase the entry and allow the user to re-enter the data. If the user wished to abort a data entry completely then the use of the "NO" key will achieve this.
Several of the Data Entry section keys have specialized uses when the user is not entering data, these special uses are outlined below.

4.1.3.1 "CLR" key During Step Control

If this key is pressed while the user is performing Step Control editing (see 4.1.2) then the nominal voltage is reset to the present output voltage, thus resetting the Deviation shown in the AUXILIARY DISPLAY to zero.

4.1.3.2 "NO" key During Step Control

If this key is pressed while the user is performing Step Control editing (see 4.1.2) then the 2720GS will exit Step Control and return to the "nominal" output voltage (i.e. the voltage present when Step Control was turned ON).

4.1.3.3 "V", "mV", "uV" or "PPM" keys Not During Data Entry

These keys are used to select the unit in which the 2720GS displays the Deviation data (while in Step Control) or Nullmeter reading data. The unit will automatically select "uV" units at power on and will also automatically select "mV" or "V" or "%" if required due to the magnitude of the data.
The user should note that the "PPM" units selection will cause the deviation or nullmeter data to be displayed in "PPM" or "%" of the present "nominal" output voltage.

4.1.3.4 "+/-" Key Not During Data Entry

If this key is pressed while the user is not entering data then the output voltage polarity will be automatically reversed.

4.1.4 "AUXILIARY DISPLAY"

The Auxiliary Display is used to display general information to the user. The possible types of data/messages are listed below in increasing order of priority:

a) Date and time of day data. (Lowest Priority)
b) Deviation data (if in Step Control or Auto Null).
c) Nullmeter reading data (if the Nullmeter is ON).
d) 2720GS tolerance data (if in DISPLAY TOLERANCE mode)
e) User data entries.
f) Prompts for user data entries.
g) Error or Failure messages. (Highest Priority)

4.1.5 "POWER"

This switch controls the power to the 2720GS. When in the "ON" position (depressed with the yellow dot showing), and with AC power applied, the unit will be operational. When in the "STBY" position (not depressed), and with AC power applied, the 2720GS will be in a standby mode, with power only applied to the references, reference ovens, nullmeter and external reference (if fitted).
If option "BAT" is fitted this option will always be under trickle (or full if necessary) charge while AC power is applied or will supply the units standby power if the the Power switch is in the "STBY" position with no AC power.
If option "EBU" is fitted then this option will supply the standby power to the 2720GS if the DC power is applied to the option package and no AC power is applied to the 2720GS.
The user should note that neither option "BAT" or "EBU" will supply power to the 2720GS to perform full operation with the power switch in the "ON" position, however they both will supply uninterupted power to the references etc. if the AC power source is interrupted.

4.1.6 "DISPLAY TOLERANCE" Key

Pressing this key will alternately select and deselect the Display Tolerance mode of operation. While in Display Tolerance mode the Auxiliary Display will display the present accuracy specification of the 2720GS with all parameters taken into account (e.g. temperature, time since calibration, reference grades etc.). The data will be displayed in the required units (see 4.1.3.3) and will automatically be updated every 10 minutes to the latest data (every 1 minute during the warm up period). The LED will be illuminated while in this mode. Display tolerance mode is automatically deselected upon pressing any other key.

4.1.7 "SET ERROR LIMIT" Key

The use of this key enables the user to enter the required error limit into the 2720GS. This data is used to compare the deviation or nullmeter reading data with and to produce a Pass/Fail status. The user should note that the entered data is non-volatile (i.e. retained during power outages by an internal battery) and may be entered in any unit. Entries with the unit of "PPM" will always be displayed with a unit of "%" when recalled. The LED will be illuminated while in this mode.

4.1.8 "SET CLOCK" Key

The use of this key enables the user to enter time of day data into the 2720GS by the use of the data entry keys. The user should note that the internal clock is not updated until the ENTER key is pressed, thus facilitating accurate setting of the clock to an external clock. The LED is illuminated while in this mode. Pressing any key (other than data keys) will cause this mode to be deselected without changing any time data.

4.1.9 "SET CURRENT LIMIT" Key

The use of this key enables the user to set current limits (in mA) for each of the three output amplifiers and also upper and lower voltage limits beyond which the 2720GS will not allow entries of output voltage data from any source. The user should note that these data are non-volatile thus it is not necessary to re-enter this data following a power outage. The LED is illuminated while in this mode. Pressing any key (other than data keys) will cause this mode to be exited only having changed any data entered so far.

4.1.10 "AUTO NULL" Key

The use of this key alternately selects and deselects the Auto Null mode of operation of the 2720GS. While in the Auto Null mode of operation the LED will be illuminated and the 2720GS will automatically alter its output voltage to obtain a null reading from the nullmeter. The Auto Null mode is automatically disabled when the 2720GS is in the STANDBY mode of output and will automatically disallow any egress of the output voltage beyond the voltage limits prevailing (see 4.1.9). The user may utilize a divider on the output of the 2720GS if so desired, the user being prompted for entry of the division ratio.

4.1.11 "SYSTEM CONTROL" Section

This section of the keyboard enables the user to perform overall 2720GS system control functions.

4.1.11.1 "DSPL TEST" Key

When pressed, the unit will illuminate all LEDs and Display elements in both displays while remaining in normal operation. This mode enables the user to perform a complete visual check that all elements of the displays are fully operational without interrupting the output voltage or other functions of the 2720GS.
This mode is deselected when any key is pressed or if the 2720GS has an error or failure message to display.

4.1.11.2 "SYS CHK" Key

When pressed, this key will start a user interactive system check procedure. See 6.13 for full details.

4.1.11.3 "INT CAL" Key

When pressed, this key will start a user interactive calibration of all 2720GS circuitry which can be calibrated without the use of external standards. See 6.21 for full details.

4.1.11.4 "SYS RESET" Key

When pressed, this key will cause the 2720GS to return to the power-on condition and any calibration or other procedure in progress will be aborted. This key may also be used to recover from any major failure found during the normal operation of the 2720GS and will cause the condition to be rechecked and proceed if no failure is found.

4.1.11.5 "LOW BATT" LED

This LED will illuminate if either the internal battery or any external option "BAT" or "EBU" has a low voltage or is not fully charged (option "BAT" only).

4.1.12 "CALIBRATION CONTROL" Section

This section contains the keys required to obtain data from, or to enter data into, the calibration data banks of the 2720GS.

4.1.12.1 "LAST CAL" Key

The use of this key will cause the 2720GS to display the number of days since the following calibration operations were last performed:

Reference data (i.e. a 10V external calibration)
Divider data (i.e. a 1V external calibration)
Internal calibration data
Nullmeter calibration data
Nullmeter Set Zero operation
External Reference calibration (if fitted)

4.1.12.2 "CALIBRATE/OPERATE" Key Operated Switch

When this switch is turned to the "CALIBRATE" position the 2720GS will perform a user interactive external calibration procedure which cannot be terminated until this switch is returned to the "OPERATE" position. The first step in this procedure is the correction of the date data in the real time clock and if this is the only item requiring setting then the switch should be returned to the "OPERATE" position following correction of the date (by the use of the Step Control arrow keys followed by the ENTER key).

4.1.12.3 "DATA REPAIR" Hidden Key

Immediately below the "LAST CAL" key there is another key which is known as the data repair key. The use of this key is only enabled while the key operated calibration switch is in the "CALIBRATE" position. After pressing this key the 2720GS will prompt the user for a password, after correct entry of this password (only available from your nearest Valhalla Scientific service center) the 2720GS will perform a comprehensive test and repair of all calibration data, including the automatic internal calibration of any lost data items which can be achieved without the use of external equipment or connections.

4.1.13 "GPIB STATUS" Section

This section provides indication of the current status and control of the GPIB (IEEE 488) bus. See Section VII for full details.

4.1.13.1 "LOCAL" Key

When enabled by the IEEE-488 interface, pressing this key will return the 2720GS to local control.

4.1.13.2 "ADDR" Key

The use of this key enables the user to display and/or change (only when in LOCAL) the IEEE-488 address of the 2720GS. This address is non-volatile and it is not necessary to re-enter this data following a power outage. If this key is pressed while the 2720GS is in the REMOTE state then the address will be displayed for 1 second before proceeding.

4.1.13.3 IEEE-488 Bus Status Indicator LEDs

These LEDs indicate the current status of the IEEE-488 bus interface within the 2720GS.
The REMOTE LED is illuminated whenever the 2720GS is in the REMOTE state or REMOTE-WITH-LOCAL-LOCKOUT state.
The SRQ LED is illuminated whenever the 2720GS is performing a SERVICE REQUEST over the IEEE488 bus.
The LISTEN LED is illuminated whenever the 2720GS is in the LISTEN state (i.e. is obtaining data from or awaiting data from the IEEE-488 bus)
The TALK LED is illuminated whenever the 2720GS is in the TALK state (i.e. is transmitting data or waiting to transmit data to the IEEE-488 bus)

4.1.14 "OUTPUT VOLTAGE" Section

This section contains the outputs from the 2720GS and the selection key to enable the use of the internal divider for generation of high accuracy low-level signals.

4.1.14.1 "OUTPUT" Terminals

These terminals carry the output of the 2720GS. The user should note that these terminals provide the current to the load and thus should not be used as the inputs to the UUT (e.g. DVM), the SENSE outputs should be used since this will ensure that thermal emfs or other voltage drops between the OUTPUT and SENSE terminals will not effect the accuracy of the output.

4.1.14.2 "SENSE" Terminals

These terminals are the inputs to the sense feedback control circuitry inside the 2720GS. When a DIVIDED output is selected these terminals also provide this output at full accuracy. The 2720GS is specified when its' output is measured at these terminals with up to 1 ohm of impedance between each pair of SENSE and OUTPUT terminals for all output currents up to the maximum allowed. For two terminal operation, it is advised that the corresponding OUTPUT and SENSE terminals be linked and the SENSE terminals used as the output, however, if so desired, the OUTPUT terminals may be left open circuited and the SENSE terminals used with increased wideband noise.

4.1.14.3 "DIVIDED OUTPUT" Terminals (not fitted on all 2720GSs)

These terminals provide direct connection at all times to the output of the internal divider. Since the divided output ranges are calibrated at the SENSE terminals there will be some loss of accuracy if the divided output terminals are used, however they do provide slightly less thermal emfs than the SENSE terminals. If a divided output is not selected, then any connections to these terminals should be removed since they may cause some loss of accuracy at the SENSE outputs.

4.1.14.4 Lightning Bolt Indicator

This indicator is illuminated whenever the internal circuitry monitoring the output terminals shows that a voltage of over approximately 29 volts is present. This indication is independent of the selected output voltage, thus will illuminate even if the voltage is caused by a fault or incorrect external connection.

4.1.14.5 "ACTIVE/DIVIDED" Key

If the output voltage is below 1.3V, the user may use this key to alternate between the active and divided output modes of the 2720GS. The present mode is indicated by the two LEDs within the key. For output voltages above 1.3V, the divided output mode is not available.

4.1.15 "DIGITAL NULLMETER" Section

This section contains the digital nullmeter input terminals and control keys.

4.1.15.1 Digital Nullmeter Terminals

These terminals are the input terminals to the digital nullmeter. CARE should be taken to ensure that low thermal shielded cables are always used to connect to these terminals since the sensitivity of the nullmeter is sufficient to show any noise or other extraneous voltages present.

4.1.15.2 "ON OFF" Key

This key alternately selects and deselects the nullmeter. While the nullmeter is off it is still actually connected to the terminals, however it is fixed on the 2000V range for protection. While the nullmeter is on then the lower or AUXILIARY display will show the nullmeter reading in the desired units and full auto-ranging is enabled.

When Auto Null mode is selected (indicated by the Auto Null LED being illuminated) the nullmeter is automatically turned on, pressing the Auto Null or Nullmeter ON OFF keys will deselect both the nullmeter and Auto Null modes.

The DIGITAL NULLMETER LED is illuminated whenever the nullmeter is in use.

4.1.15.3 "SET ZERO" Key

This key enables the user to "digitally" zero the nullmeter. Pressing this key causes the 2720GS to store the present, non zero corrected, nullmeter reading as the nullmeter offset to be subtracted from all future readings. The user should always ensure that the nullmeter is ON and the desired nullmeter reading is indicated before pressing this key.

4.1.16 "STANDBY/OPERATE" Section

The key in this section alternately selects STANDBY or OPERATE output modes of operation. The OPERATE mode is indicated by the OPERATE LED being illuminated.

The 2720GS has two types of STANDBY modes (open circuit and driven zero volts) with only the driven zero volts type being available through the front panel. After power up or RESET operation, the unit is automatically placed in open circuit standby mode.

4.1.17 "EXTERNAL REFERENCE" Section

This section contains the inputs and control key for the external reference option EXR1, EXR7 or EXR10 (if fitted). Units with no EXR option fitted have no terminals and will display a message if the External Reference ON OFF key is pressed.

4.1.17.1 External Reference Input Terminals

These terminals are the input terminals to the External Reference option. The external reference circuitry is powered whenever power is applied to the 2720GS independent of the state of the power switch, thus connections may be maintained to these terminals at all times (particularly if option "BAT" or "EBU" is fitted). Careful note should be made of the allowable range of input voltages for the option fitted before making connections.

4.1.17.2 "ON OFF" Key

This key alternately selects or deselects the external reference input to the 2720GS, when pressed. The user is prompted for the actual voltage of the external reference source when required.

4.1.18 "REFERENCE STATUS" Indicators

These LEDs indicate the current status for each of the six (four in option "54-4T", eight in option "HSR") references. The "IN-USE" LEDs indicate which references are currently in use, while any faulty references are indicated by the "FAULT" LEDs. The user is advised to read Section VIII for details of the operation of the OBRMS system in the 2720GS for details regarding the various statii for each reference.

4.1.19 "MEMORY CONTROL" Section

The 2720GS has 558 non-volatile, user definable, memory locations which are made available through the use of this section of the keyboard.

4.1.19.1 "STO" Key

This key will start a user interactive sequence to enable the user to store output voltage, error limit and standby status data into a selected memory location.

4.1.19.2 "STO" and "CLR" Keys Pressed Together

When these two keys are simultaneously pressed the entire contents of all memory locations are initialized to zero volts output, a 1200V error limit, and standby status.

4.1.19.3 "RCL" Key

This key enables the user to recall data from a user specified memory location.

4.1.19.4 "RCL LAST" Key

This key enables the user to recall data from the memory location preceding the presently used memory location (e.g. if the present output voltage was recalled from address 125 then this key will recall data from address 124).

4.1.19.5 "STEP TO NEXT" Key

This key enables the user to recall data from the memory location following the presently used memory location (e.g. if the present output voltage was recalled from address 326 then this key will recall data from address 327).

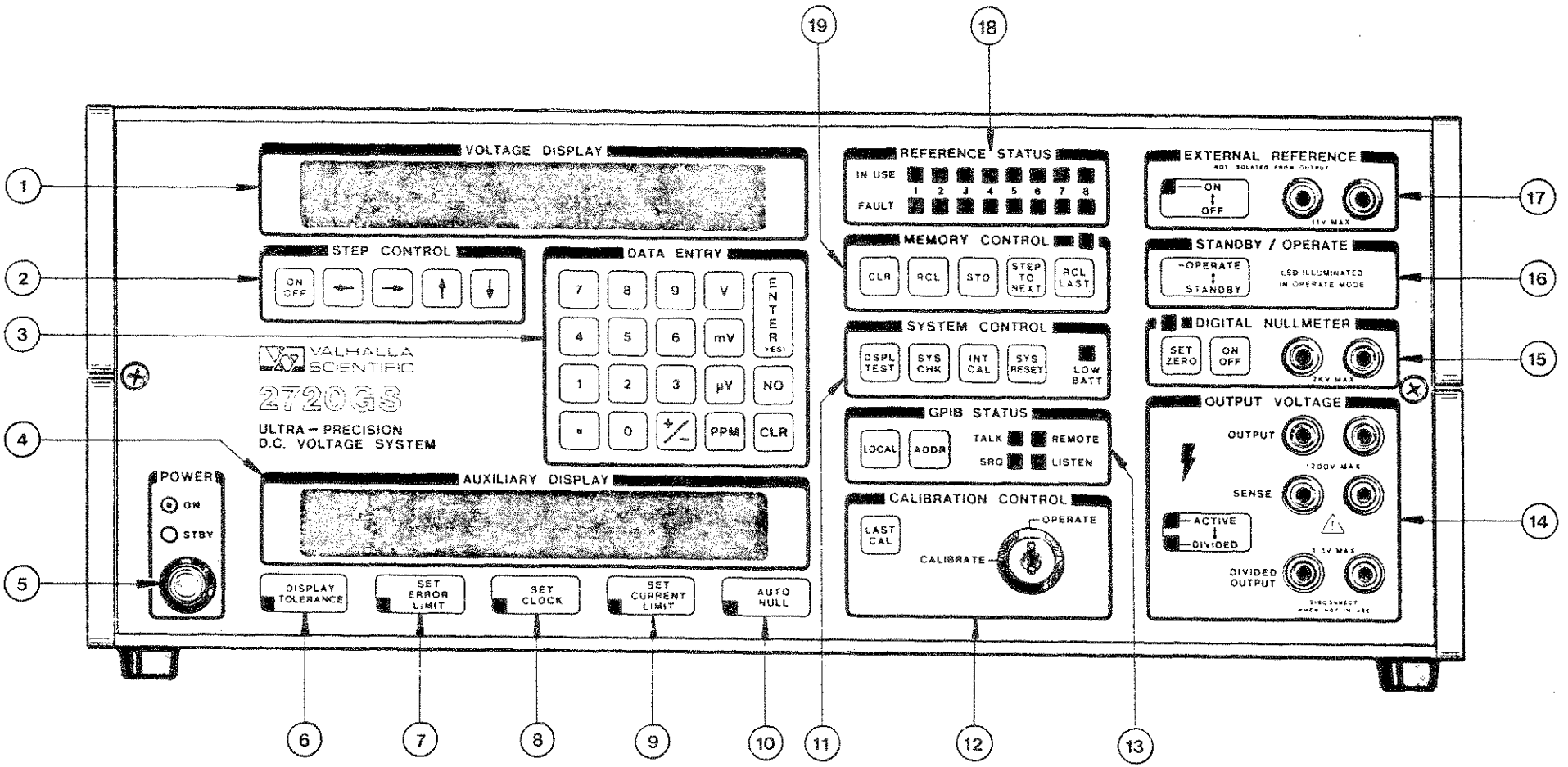


FIGURE 4-1: FRONT PANEL CONTROLS AND CONNECTORS

1 → BEEPER ON

2 →

3 →

4 → 24 HR CLOCK FORMAT

5 ← DISABLE VARI-SAFE

6 ← RESET I LIMITS

7 →

8 → DISPLAY MESSAGES AT RESET

SECTION V

REAR PANEL CONTROLS AND CONNECTORS

5.1 General

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

5.1.1 Rear Panel Output and Option Terminals

These low thermal emf terminals are wired in parallel with the respective front panel terminals.

5.1.2 CONFIGURATION SWITCH

This eight section switch is use to select several user variable options.

5.1.2.1 Section 1 (Leftmost switch)

When this section is in the on (down) position, the internal beeper is disabled from sounding when a key is pressed. The beeper will still sound when a Pass or Failure message is displayed however.

5.1.2.2 Section 2

When this section is in the on (down) position, the 2720GS will completely initialize the battery backed up data (except for the real time clock) whenever the 2720GS is reset. The user should note that it is not recommended that the user leave this switch in the on position as the 2720GS will "forget" any faults detected if this switch is on when the power is re-applied or the 2720GS is reset.

5.1.2.3 Section 3

This section is not currently used.

5.1.2.4 Section 4

When this section is in the on (down) position, the time data is displayed in a 12 hour format.

5.1.2.5 Section 5

When this section is in the on (down) position, the 2720GS' Vari-Safe system is disabled (i.e. the 2720GS will not automatically select STANDBY when a large change in output voltage is requested).

5.1.2.6 Section 6

When this section is in the on (down) position, the 2720GS will automatically reset the current limits to the following values (defaults) upon reset:

13V amplifier to 10mA
130V amplifier to 100mA
1200V amplifier to 30mA

5.1.2.7 Section 7
This section is not currently used.

5.1.2.8 Section 8 (Rightmost Switch)
When this section is in the on (down) position, the 2720GS will not display the status messages at power up or after a SYSTEM CHECK. This facility is useful when a 2720GS is being tested for malfunctions and the user wishes the fastest possible turn-around following a power up or system check.

5.1.3 GPIB (IEEE-488) Connector
This is the IEEE-488 interface connector.

5.1.4 Power Connector
This is the AC power connector. The user should note that the 2720GS will always draw AC power from the source if it is connected.

5.1.5 Fuseholder
This contains the 2720GS' main power fuse. Please refer to Section 1.2 for the correct value of fuse.

5.1.6 Line Voltage Selector
This slide switch selects the AC power supply voltage. It may be set to either 115V or 230V positions by sliding action. Please refer to section 1.2 for details and fuse selection.

5.1.7 Option "BAT" or "EBU" connector
When installing either option, the user must ensure that power is completely removed from the 2720GS and that the connectors mate correctly before tightening the mounting screws.

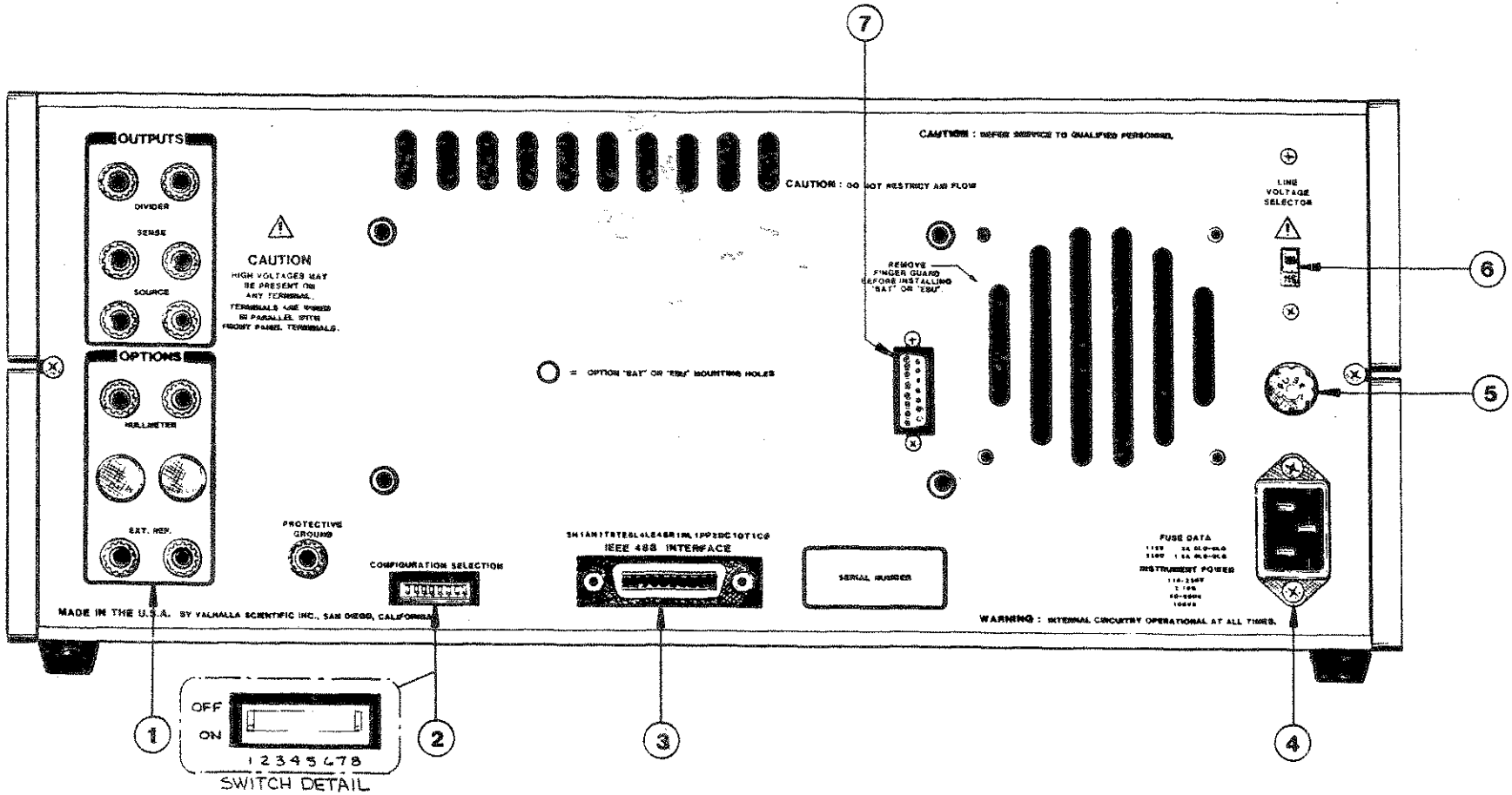


FIGURE 5-1: REAR PANEL CONTROLS AND CONNECTIONS

SECTION VI

MANUAL OPERATION

6.1 General

The following paragraphs describe the manual operation of the 2720GS and available options and should be used along with Section IV when using the unit. The user is advised to fully read both this section and Section IV before attempting to operate the 2720GS manually.
This section describes various commonly performed operations followed by some examples of using the 2720GS to perform calibration of various types of devices.

6.1.1 Applying AC Power

Before applying AC power to the 2720GS, the user is advised to ensure that the 2720GS power switch is in the STBY position (no Yellow dot showing). After applying power the user will notice that the fan, mounted internally towards the rear of the unit, will operate. **If the fan does not operate then do not proceed, remove the AC power and place the unit aside, the 2720GS requires maintenance.**
Push the power switch. The unit will respond by greeting the user in both displays, followed after approximately 1 second by the following sequence (if enabled by section 8 of the rear panel configuration selection switch, see section V):

a) The lower display will show the software revision of the unit (e.g. VERSION 43.43)

b) The upper display will have SELF TEST showing and the lower display will show any faults found in the internal power up checks plus any previously found faults. The lower display will also show the computed warm up time for the unit.

c) The unit will commence normal operation.

Should the following procedure fail to occur, turn off the power switch and set the 2720GS aside for maintenance after first checking that section eight of the Configuration Switch on the rear panel is not on (or down).

6.2 Connections

To preserve the full accuracy of the 2720GS it is strongly recommended that four terminal connections be utilized whenever possible to eliminate the possibility of errors due to lead resistance. The user should note that it is the connections to the SENSE terminals which determine the overall accuracy of the 2720GS (like any other voltage source) thus it is strongly recommended that low thermal emf shielded cabling be used for the SENSE connections while ordinary shielded cable may be used for the OUTPUT connections. For less crucial applications or when the user is certain that there will

be negligible current drawn from the 2720GS then two terminal connections may be used. For two terminal operation the corresponding OUTPUT and SENSE terminals should be linked together and the SENSE terminals used for connections. The user should note that this connection system will eliminate any thermal emfs in the links used, thus facilitating the use of ordinary quality links.
The user is reminded to ensure that the correct current limit setting is used before connecting leads and that the unit is in STANDBY to protect the user from any dangerous voltages. The user is further reminded that the DIVIDED output (if selected) presents an output impedance of 450 ohms and that four terminal operation is not possible in this mode.

WARNING

DANGEROUS VOLTAGES ARE PRESENT ON THE OUTPUT TERMINALS WHENEVER THE LIGHTNING BOLT ON THE FRONT PANEL IS ILLUMINATED. THESE VOLTAGES MAY CAUSE

DEATH

ON CONTACT. NEVER TOUCH THE CONNECTIONS WHILE THE OUTPUT IS IN OPERATE OR THE LIGHTNING BOLT IS ILLUMINATED.

6.3 Setting an Output Voltage

To manually set an output voltage the following procedure may be followed:

a) If connections are to be made or adjusted then first select the STANDBY mode (if the OPERATE LED is illuminated then press the STANDBY/OPERATE key) before adjusting or making the connections.

b) Enter the desired output voltage in V, mV or uV as desired using the DATA ENTRY section of the keyboard. Note that the polarity of the required output must be entered after the first (or any other) digit of the numeric data is pressed. The output voltage will not be updated until the ENTER key is pressed.

c) Select OPERATE if required (i.e. if OPERATE LED is not illuminated).

6.4 Vari-Safe Feature

The user will note that the 2720GS will automatically select the STANDBY mode after a large change in output (this may be disabled, see Section 5). This facility is called the Vari-safe feature and will select STANDBY if the user changes the output voltage by more than 30 volts+25% of the previous output. The STANDBY mode selected is normally the zero volt STANDBY mode, however the open circuit mode will be selected if the 2720GS nullmeter

is in use. This safety feature is built in to ensure that the user must press the OPERATE key to obtain a large change in output, which may be damaging to external circuitry or equipment connected to the 2720GS output terminals.

6.5 Modifying the Output Voltage by a "PPM" Offset

This is achieved in the 2720GS by simply entering the required ppm offset using the DATA ENTRY section keys in a similar manner to direct output voltage entry (see 6.3). The user should note that the output will be modified by the entered number of parts per million of the present output voltage, thus performing a positive correction followed by an identical negative correction will **not** provide the original output (for large corrections). For user convenience a conversion table from percent to ppm is given below:

100% = 1000000 ppm
10% = 100000 ppm
1% = 10000 ppm
0.1% = 1000 ppm
0.01% = 100 ppm
0.001% = 10 ppm
0.0001% = 1 ppm

6.6 Modifying the Output Voltage Using "STEP CONTROL"

The STEP CONTROL section of the keyboard provides a simple way to alter the output of the 2720GS while displaying the total amount that the output has been altered. This technique is usually used for the calibration of voltmeters and similar equipment.

a) Set the output of the 2720GS (as shown in 6.3) to the nominal voltage required.

b) Press the STEP CONTROL ON OFF key once. A display digit in the output voltage display will start flashing and the lower display will show that no deviation has taken place (the user should note that the accuracy of the deviation computation is 0.01ppm, thus a very small non-zero result is given for some output voltages).

c) Move the "flashing" digit to the required digit by pressing the Left or Right Arrow keys as required.

d) Increment or decrement the output voltage as required by the use of the Up or Down Arrow keys respectively. Note that the Up Arrow key will always increase the output voltage in a positive direction and the Down Arrow key will always decrease the output voltage in a negative direction, independent of the polarity of the output voltage. The deviation display in the lower or AUXILIARY display will show the total deviation from the output voltage present when the STEP CONTROL mode was initially selected. This deviation data may be presented in either voltage or ppm units by pressing the "uV", "mV", "V" or "PPM" keys.

e) The user may exit the STEP CONTROL mode by any of the following methods :

Press the STEP CONTROL ON OFF key (output remains unchanged)
OR
Press the DATA ENTRY NO key (output returns to the voltage present when the STEP CONTROL mode was entered)
OR
Manually entering a new output voltage or "ppm" offset
OR
Recalling an output voltage from a memory location
OR
Selecting the AUTO NULL mode of operation

f) While in STEP CONTROL mode the user may reset the "nominal" voltage (the voltage from which the deviation is calculated) to the present level by pressing the DATA ENTRY CLR key.

6.7 Setting the Required ERROR LIMIT

Whenever deviation data is displayed in the lower or AUXILIARY display, this data is compared with an error limit and a PASS or FAIL indication is given as shown in the examples below

PASS indication : Go DEV +1.12PPM
FAIL indication : FL DEV -100.56PPM

The error limit used for comparison may be entered by the user in voltage or ppm units, as required, by the use of the SET ERROR LIMIT key.

a) Press the SET ERROR LIMIT key, the 2720GS will display the present error limit either in volts or percent.

b) Using the DATA ENTRY section of the keyboard, enter the required error limit (in uV, mV, V or ppm as required). The actual error limit will not be updated until the ENTER key is pressed, thus the user may abort the entry and return to the original error limit by either pressing the SET ERROR LIMIT key again or by pressing the DATA ENTRY NO key.

6.8 Setting Current and/or Voltage Limits

The 2720GS gives the user the capability of entering individual current limits for each of its three output amplifiers (covering the +/-13V, +/-130V and +/-1200V ranges of output respectively) and of limiting the range of output voltages available.

a) Press the SET CURRENT LIMIT key. The unit will display the present 13V amplifier current limit in the AUXILIARY display.

b) If it is not required to change the current limit then press the DATA ENTRY ENTER key, otherwise enter the required current limit data in mA followed by the ENTER key. The user should note the following :

> Use of current limits of >15mA degrades the wideband noise specification of the 13V amplifier.
>
> Although the stated maximum current limit is 100mA, the user may enter current limits of up to 139mA (the 2720GS will typically provide 140mA).

c) The unit will now display the 130V amplifier current limit. The same procedure as for the 13V amplifier should be followed, however there is no wideband noise restriction.

d) The unit will now display the 1200V amplifier current limit. The same procedure as for the 130V amplifier should be followed, however the maximum specified current limit is 30mA with a maximum allowable entry of 39mA.

e) The unit will display the present upper voltage limit. If it is not required to alter either voltage limit then the user should abort further entry by pressing either the DATA ENTRY NO or SET CURRENT LIMIT key to deselect SET CURRENT LIMIT mode of operation. If it is not required to alter the present upper voltage limit, but it is wished to continue on to display or alter the lower voltage limit, the user should press the ENTER key. If the user wishes to alter the upper voltage limit then this is achieved by entering the required limit in uV, mV or V units as required. The upper voltage limit will not be altered until the ENTER key is pressed, when the present output voltage will be immediately compared to the new limit, and any adjustment to the output voltage required will be implemented.

f) The unit will now display the present lower voltage limit if the SET CURRENT LIMIT mode was not exited in the above step. The user may alter the lower voltage limit in a similar manner to the upper voltage limit if so desired.

The user should note the following features :

The unit actually has two independent current limit systems, one is the fail-safe current limit of the output amplifier in use and will operate immediately under severe overload conditions, the other is the user entered current limit which is achieved by the use of an internal ammeter and has a 500ms time-constant to enable the rejection of "spikes" and capacitor charging.

Should a current limit be exceeded then the 2720GS will select the zero voltage mode of STANDBY. If the current limit condition persists then the output terminals are automatically open circuited

to protect the 2720GS from the external source of current (this condition is automatically internally recorded and failure of the 2720GS due to repeated operation in this manner may affect your warranty).

If the output amplifiers' fail-safe current limit continually indicates a limit situation, while the ammeter does not, then that amplifier is automatically failed and deselected from further use until the failure condition is found to be no longer present during a SYSTEM CHECK.

The upper and lower voltage limits may be of either polarity and the output voltage is always set to the closer of the two limits if a voltage outside of these limits is attempted to be outputted. The voltage limit comparison is performed for all requested output voltages (including auto-null mode) except during External Calibration.

The 2720GS has an internal voltmeter which continuously compares the actual voltage at the output terminals with the requested output voltage and will automatically select the zero voltage STANDBY mode if the actual voltage is in disagreement by >10V, if this disagreement persists in zero voltage STANDBY then the output terminals are open circuited in a similar manner to a persisting current limit.

6.9 Using the Nullmeter Independently of the Output

The internal DIGITAL NULLMETER may be used as a stand alone meter, independently of the output generating section of the unit if desired (the only limitation being the dual use of the AUXILIARY DISPLAY and the 2000V common mode voltage limit on the nullmeter). This is achieved by pressing the DIGITAL NULLMETER ON/OFF key to select the nullmeter (the NULLMETER LED will illuminate to indicate the selection). The lower display will now indicate the nullmeter reading in the selected unit. The displayed unit may be changed by simply pressing the "uV", "mV", "V" or "PPM" key as required. The user should note that the ppm mode of display will be relative to the output voltage present at that time (or the nominal output voltage if step control is also being used). The nullmeter reading data is also compared with the error limit in the same manner as the step control deviation obtained in 6.6, with a similar display format (the DEV in the deviation display is replaced with NUL when displaying a nullmeter reading).

The nullmeter is fully auto-ranging and is protected for inputs of upto 2000V, however for user protection it is recommended that extreme caution be exercised when operating the nullmeter at high voltages.

The user is advised to use the highest quality, shielded, low thermal emf cables for the nullmeter connections whenever possible, as thermal emfs of several microvolts are easily obtainable with normal cabling. It is also advised that the output voltage low (black) terminal be used as a guard for this cabling, if possible, as this will significantly reduce any picked up noise from the

external environment.
Updated nullmeter readings (after range selection has been achieved) are made available every 2 seconds and have an effective filter time constant of 1 second.
Whenever a period of over 1 day, or large temperature changes, have occurred it is recommended that a **SET ZERO** operation be performed to ensure the zero accuracy of the nullmeter. Zeroing of the nullmeter is achieved by shorting the nullmeter inputs, waiting for the reading to settle and then pressing the SET ZERO key. The unit will automatically update its stored zero offset to the present unzeroed nullmeter reading and subtract this figure from all future nullmeter readings. The user should note that there is no limit on the range of values for this zero offset, thus this facility may also be used for drift measurements from a nominal offset if so desired, however the user is reminded to re-zero the nullmeter before attempting to use the nullmeter for normal use after using this facility.

6.10 Using the Nullmeter in Auto Null Mode

The nullmeter may also be used to automatically adjust the output voltage to obtain and then maintain a zero reading from the nullmeter. To use this mode of operation it is recommended that the nullmeter be zeroed (see 6.9) before using this facility.

a) Select STANDBY mode (press the OPERATE/STANDBY key if required).

b) Connect the 2720GS output and nullmeter terminals as shown in Figure 6-1 or 6-2 as required. The polarity of the nullmeter and output connections **must** be such that an increase in output voltage from the 2720GS will cause a positive indication on the nullmeter terminals.

c) Select operate on the external voltage source (if required).

d) Select the nominal required voltage from the 2720GS in the normal manner and select the OPERATE mode.

e) Press the AUTO NULL key on the 2720GS. The unit will prompt for the "DIVISION RATIO". The 2720GS will multiply all actual nullmeter readings by this number before subtracting the result from the output voltage, thus the entered number will directly affect both the settling time and stability of the 2720GS output voltage. It is recommended that, for best performance, half of the actual division ratio be entered (e.g. 0.5 if there is no divider, 5 if there is a 10:1 divider). For the fastest settling then the actual division ratio should entered or slightly higher (under no circumstances should a number of greater than two times the actual division ratio be entered, as positive feedback will result). The entry is achieved by the use of the DATA ENTRY numeric keys on the 2720GS followed by the ENTER key. For circumstances where it is not possible to achieve the correct polarity of the connections to the nullmeter terminals then a negative division

ratio entry will achieve the desired results.

f) The 2720GS will now continuously adjust its output to maintain a zero nullmeter reading and the lower or AUXILIARY display will display the offset from the original "nominal" output voltage in the desired units (operation is identical to the Step Control mode).

g) Auto Null mode may be deselected by any of the following methods:

Press the AUTO NULL or NULLMETER ON OFF key. The 2720GS will exit auto null mode with the output at the present voltage.
OR
Press the STANDBY key to enter STANDBY mode. The 2720GS will exit auto null mode and select the STANDBY mode.
OR
Press the DATA ENTRY NO key. The 2720GS will exit auto null mode and return the output voltage to the previous "nominal" value.

6.11 Storing Data into a Selected Memory Location

The 2720GS has over 550 memory locations for the storage of sets of output voltage, error limit and standby status data. This data may be stored into a selected memory location as follows:

a) Press the MEMORY CONTROL STO key. The 2720GS will display the next memory location (000 if the unit was not previously in memory control, i.e. LED off) in the lower or AUXILIARY display.

b) If this location is not the required location then enter the required address using the DATA ENTRY numeric keys followed by the ENTER key. If this was the required memory address then just press ENTER.

c) The AUXILIARY display will now show the present output voltage contents of this memory.

d) If this data is the required data then press ENTER, otherwise enter the required output voltage with units of "uV", "mV" or "V" and press ENTER.

e) The AUXILIARY display will now show the present error limit contents of this memory in either "V" or "%" units.

f) Leave this data unchanged or change it as required in a similar manner to the output voltage contents with units of "uV", "mV", "V" or "PPM" as required.

g) The 2720GS will now prompt the user if the unit is to automatically enter the STANDBY mode when this locations' contents are recalled. If the DATA ENTRY NO key is pressed then the OPERATE/STANDBY status when the contents are recalled will be unchanged. Otherwise, if the ENTER key is pressed then the STANDBY status will be forced

at that time. The user should note that this will be the only protection against adverse voltages, the vari-safe operation being disabled during memory recall operations.

h) The 2720GS will now return the displays to normal, entry of data being complete.

6.12 Recalling Data from a Selected Memory Location

Having placed data into any of the over 550 memory locations the user may recall that data into use by the following procedure.

a) Press the MEMORY CONTROL RCL key. The lower or AUXILIARY display will show the next location address (000 if not presently in memory control).

b) If this is the required address then press ENTER. Otherwise enter the required address using the DATA ENTRY numeric keys followed by pressing the ENTER key.

c) The lower or AUXILIARY display will now show the output voltage contents of the requested memory location.

d) If this data is not the required output voltage data then press the DATA ENTRY NO key to abort the procedure and restart this procedure. Otherwise press the ENTER key. The output voltage, error limit and STANDBY status data will be automatically updated from the requested memory location and memory control mode entered.

While in memory control mode (MEMORY CONTROL LED illuminated) the following features are enabled

a) MEMORY CONTROL CLR key. Pressing this key will cause the 2720GS to exit memory control mode, as will direct entry of an output voltage.

b) MEMORY CONTROL RCL LAST key. Pressing this key will cause the sequence of recalling the memory location preceding the currently used location to be executed. The lower display showing the output voltage data from that location awaiting the user pressing the ENTER or NO keys as required. This key enables the user to easily repeat the previous step in a calibration procedure or to quickly step back to an earlier step if the key is repeatedly used.

c) MEMORY CONTROL STEP TO NEXT key. Pressing this key will cause a similar event to pressing the RCL LAST key as described above, however, the next memory location after the present one is used. This key thus enables the user to easily step through a calibration procedure.

6.13 Performing Checks to Ensure Correct Operation

The 2720GS has many built in, fully user interactive, self checks which may be commanded at almost any time. The method of using these checks is described here. Should any faults be found during a procedure then the user is referred to the Maintenance section of this manual for further details.
It should be noted that the performance of the checks does not require any external equipment or connections.

6.13.1 Checking the Displays and LEDs on the Front Panel

This function is achieved by pressing the DSPL CHK key in the SYSTEM CONTROL section of the front panel. The 2720GS will now illuminate all segments of both displays and all of the LEDs including the lightning bolt.
This condition will remain until one of the following events occurs:

Any key is pressed (including the DSPL CHK key).
OR
The 2720GS requires to display an error or failure message.

6.13.2 Checking the Internal Circuitry of the 2720GS

This interactive procedure is started by pressing the SYS CHK key in the SYSTEM CONTROL section of the front panel.

a) The 2720GS will now prompt the user to remove any connections from the terminals of the unit. The 2720GS will actually open circuit the output terminals during the system check but it is recommended to remove the connections as a safety precaution.

b) The user should press the ENTER key to continue, or the NO key to abort the system check.

c) The unit will now prompt the user if it is to perform checks on the internal digital circuitry. This check will take approximately 5 seconds and checks all microprocessor and associated circuitry. The user should press the ENTER key to perform the check, or the NO key to skip the checks. If the user selects to perform the checks then the unit will return either a PASS or a diagnostic reply when the checks are completed.

d) The unit will now prompt the user if it is to perform checks of the internal Analog to Digital convertors. These checks will take approximately 20 seconds and will perform basic operation and accuracy checks on the internal voltmeter used to check the output voltage, the internal ammeter used to monitor the output current load and the internal high resolution AtoD used to monitor the reference system for OBRMS (see section VIII). The user should press the ENTER key to command the checks to be performed or should press the NO key to command them to be skipped. If the user selects to perform the checks then after each check the unit will return a PASS or FAIL message as required.

e) The unit will now prompt the user if it is to perform checks on the output amplifiers and feedback (sense) system. These checks will take approximately 45 seconds and will perform basic operation and accuracy checks on all three output amplifiers and the Digital to Analog convertor. The user should press the ENTER key to command the checks to be performed or should press the NO key to command them to be skipped. If the user selects to perform the checks then after each check the unit will return a PASS or FAIL message as required.

f) The unit will now prompt the user if it is to perform checks of the reference system, which will take approximately 30 seconds (20 seconds for option "54-4T", 40 seconds for option "HSR") and respond with a PASS or FAIL message as required.

g) The unit will now give a complete "listing" of the present status of each part of the 2720GS in the lower or AUXILIARY display. This feature may be disabled by one of the rear panel "configuration switch" sections (see section V).

6.14 Obtaining the Present Accuracy Specification

The 2720GS has built in methods of determining the actual specification, valid at any time. The result of this calculation may be obtained by pressing the DISPLAY TOLERANCE key on the front panel of the 2720GS. The unit will respond by illuminating the DISPLAY TOLERANCE LED and displaying the actual accuracy specification at the present output voltage level, ambient temperature, internal temperature, temperature difference from calibration(s), and time since last calibration data was obtained. The displayed accuracy specification may have any units the user requires in the same manner as a deviation or nullmeter display (see previous paragraphs). This accuracy data is automatically updated every 10 minutes if the DISPLAY TOLERANCE mode is still active (every 1 minute during warmup) to show the affects of any changes in the environment. DISPLAY TOLERANCE mode is exited by pressing any key. The user should note that the calculation of this data is dependent on many factors, including the accuracy of the date and temperature data at the time of external calibration and the present date information.

6.15 Setting the Time Information

The user may set the correct time (in 24 hour format only) by pressing the SET CLOCK key followed by the correct hours, minutes and seconds digits, followed by the ENTER key. The real time clock is updated at the instant that the ENTER key is pressed, thus this may be used to accurately set the time if desired.

6.16 Recovery from a Major Fault or Resetting the System
During a SYSTEM CHECK or at any other time the 2720GS may detect a "major fault", this will cause the unit to display a failure message and sound a long beep (as for any error or failure message). The unit will then stop operation and place itself in a safe condition with the output terminals being open circuited. This condition may be overcome and the failure retested by pressing the RESET key in the SYSTEM CONTROL section of the keyboard. This key may also be pressed at any other time if it is wished to quickly place the 2720GS and its output terminals in a safe condition. This will not cause any of the current settings or fault statii to be lost, it will only place the unit in open circuit standby and exit all operating modes.

6.17 Displaying the Time Since the Last Calibration
A useful "Quality Assurance" overcheck feature is the 2720GS' ability to display a listing of the number of days since the various parts of the 2720GS were previously calibrated. This is achieved by the following procedure

a) Press the LAST CAL key in the CALIBRATION CONTROL section of the keyboard.

b) The lower display will now show the number of days since the last calibration of the following items

Internal Reference (i.e. a 10V external calibration)
Reference Divider (i.e. a 1V external calibration)
Internal Calibration
Nullmeter calibration
Nullmeter Set zero operation
External Reference option calibration (if fitted)

6.18 GPIB STATUS Section of the Front Panel
The operation of the LEDs and keys in this section are fully described in section VII of this manual.

6.19 Setting the Date Information and External Calibration
This operation requires the use of the Calibration key and is described in section IX of this manual.

6.20 Using the External Reference (if fitted)
The external reference should first be checked to ensure compatibility with the fitted option. Option EXR1 requires a voltage of 0.95 to 1.05V, EXR7 requires 6.1 to 7.5V and EXR10 requires 9.5 to 10.5V. The user should also be aware that the external reference inputs are **not isolated from the output terminals** and will require that the load on the 2720GS' output terminals and the external reference be floating with respect to each other.

a) The user should connect the external reference to the external reference input terminals, ensuring that the correct polarity

is present. If standard cells (or similar) are to be directly connected then the user must ensure that the correct polarity is used before connecting to the terminals otherwise the cells may be damaged.

b) The user should now press the EXTERNAL REFERENCE ON/OFF key. The lower display will now prompt the user to check the connections after which the user should press the ENTER key.

c) The lower display will now prompt the user for the actual voltage of the external reference voltage present on the terminals. If this voltage is acceptable to the option which is fitted then the EXTERNAL REFERENCE LED will illuminate and the 2720GS will utilize this external reference source in place of its internal references.

d) Should the external reference voltage entered above be unacceptable then the 2720GS will display a message and then re-prompt for the actual voltage. The user may press the NO key to abort the operation entirely.

e) While the 2720GS is operating from an external reference source the unit may be switched back to using the internal reference system by any of the following

Pressing the EXTERNAL REFERENCE ON/OFF key again
OR
The 2720GS recognizing that the applied voltage has passed beyond the required range
OR
Pressing any SYSTEM CHECK key (other than DSPL CHK)
OR
Starting an external calibration

6.21 Performing an Internal Calibration

Prior to performing an Internal Calibration the user is advised to perform a System Check in order to ensure that all required circuitry is operational. If there is any faulty circuitry and an Internal Calibration is attempted then the 2720GS will only perform those portions of the sequence that are possible.
Pressing the INT CAL key in the SYSTEM CONTROL section of the front panel will initiate an internal calibration of the circuitry if the warm up time has elapsed. This procedure is a user interactive one and is split into four (or five if option EXR is fitted) sections. At the start of the Internal Calibration (as for a system check) the user is requested to remove all connections and the 2720GS waits until the ENTER key is pressed.

6.21.1 Reference System Calibration

This calibration is automatically performed at the beginning of the Internal calibration sequence and takes approximately 2 seconds. This step calibrates for any small error in the reference averaging system and will also bring back into use any unused references that have restabilized back to the correct value.

6.21.2 Calibration of Output Gain

The calibration of "Output Gain" is recommended to be performed at least every 30 days or whenever a large (>5C) change in temperature is suspected. The user should be aware that there is an uncertainty of approximately 0.5ppm associated with performing an internal calibration of "Output Gain" thus excessively frequent use will not give any improvement in performance.

This portion of the internal calibration procedure will calibrate the entire sense feedback system scaling (except for the 10:1 reference divider) if selected and will take approximately 45 seconds. Also included in this sequence is the calibration of the zero and scaling of the internal voltmeter and the zero of the ammeter. If any step returns a calibration constant which differs significantly from the previous result then that step is automatically recalibrated until either consistent results are obtained or an excessive number of retries have occurred. Thus the user may notice some variability in the time taken for this sequence. Execution of this sequence is commanded by pressing ENTER when the 2720GS prompts the user if it is to perform it. If the user wishes to skip this sequence then the user should press the NO key.

6.21.3 Calibration of the Nullmeter

The calibration of the nullmeter is recommended to be performed at least every 3 years (or if the accuracy is suspect or a component has been changed). The accuracy specification of the nullmeter is such that more frequent calibration is unnecessary.

This sequence will calibrate the basic scaling and higher range zeroes of the nullmeter and require the user to provide links from the SENSE terminals to the NULLMETER input terminals. The cable used need not be high quality but shielded cable is recommended.

Execution of this sequence is commanded by pressing the ENTER key. If it is wished to skip this sequence then the user should press the NO key.

The user is advised to rezero the nullmeter after the internal calibration sequence is completed.

6.21.4 Calibration of Output Zeroes

The calibration of the output system zero offsets is recommended to be performed every year or more regularly if desired. The sequence takes up to 10 minutes and requires the use of the internal nullmeter to measure and thus correct for any output system zero offsets. Because the nullmeter is used to its full specification for this calibration, this sequence **should never follow a calibration of the nullmeter, the nullmeter must have been zeroed immediately preceding the selection of Internal Calibration and the nullmeter must be connected to the SENSE terminals (Corresponding terminals) with the HIGHEST QUALITY, SHIELDED, LOW THERMAL EMF CABLES. The 2720GS must also be free from drafts (especially air-conditioning ducts).** It is further recommended that any movement of personnel or objects close to the 2720GS or cabling be kept to an absolute minimum. If this calibration is selected (by pressing the ENTER key when prompted) the unit will request that the connections be made. It is recommended that the connections actually be made before the Internal Calibration sequence is started in order that any thermal emfs from the heat of fingers, hands etc. have settled out (these connections will not affect the accuracy of the preceding calibration sequences). After confirming that the connections have been made (by pressing the ENTER key) the 2720GS will automatically select each range in turn and adjust its output voltage to obtain a zero reading from the nullmeter. The unit will execute this for each range for a minimum of 10 seconds until the nullmeter indicates that the output zero is well within the specifications for that range, if the output will not adjust within specification inside 60 seconds or yields a zero offset which is to large then that calibration step will give a FAIL message and a long beep sound.

6.21.5 Calibration of the External Reference Option (if fitted)

The final step in the Internal Calibration is that of the external reference if it is fitted. This step is recommended to be performed at least every 30 days. Execution of this calibration is commanded by pressing the ENTER key when prompted. The 2720GS will then prompt the user to provide connections between the SENSE terminals and the respective External Reference input terminals. These connections should be made with high quality, shielded, low thermal emf cable. After confirming that the connections have been made by pressing the ENTER key the 2720GS will automatically calibrate the external reference with the required voltage level.

The user should note that EXR1 will rely upon the maintenance of the 2720GS 1V range accuracy to perform this calibration. Thus if a high degree of accuracy is required from an option EXR1 it is recommended that the internal calibration calibration of the option only be performed immediately following an external calibration which includes the 1V calibration.

The above note does not apply to options EXR7 and EXR10 since the calibration of these is performed ratiometrically and does not rely on the accuracy of the 2720GS' output system.

If this step is not to be performed then the user should press

NO at either prompt mentioned above.

6.21.6 Aborting an Internal Calibration
If it is wished to abort an Internal Calibration without using any of the collected data this may be achieved at any time before the lower display shows END CAL by the user pressing the RESET key.

6.22 Performing the Calibration of a Voltmeter
This is achieved by connecting the Voltmeter to the 2720GS as shown in Figure 6-3. It is recommended that the 2720GS be placed in STANDBY before making the connections.

a) Select the required calibration voltage from the 2720GS by using the DATA ENTRY numeric keys followed by ENTER (see 6.3).

b) Set the accuracy specification of the voltmeter under test at this level as the error limit in the 2720GS (see 6.7). This data may be entered either in voltage or ppm units as desired.

c) Modify the output voltage from the 2720GS using step control until the voltmeter reads the required voltage (as entered into the 2720GS in step a). See 6.6 for details.

d) The actual error of the voltmeter (with the correct polarity sign) will be displayed in the lower or AUXILIARY display of the 2720GS. The units of this display may be changed as desired by the use of the "uV", "mV", "V" or "PPM" keys.

e) Also in the lower display will be the pass or fail status of the voltmeter under test. If the voltmeter error is within the entered error limit then the first two characters will be "GO", if the error is to large then they will be "FL".

f) Further calibration points may be checked by repeating this procedure. Further voltmeters may be checked at this same voltage level by pressing the NO key. This will return the 2720GS to the "nominal" voltage output.

The use of the above procedure with a 2720GS will yield typical accuracies of 2ppm+0.1uV when used in this manner. Thus it is suitable for the direct calibration of almost all DVMs with good ratio of accuracies.

6.23 Performing the Calibration of a DC Voltage Source

This is achieved by connecting the DC Voltage source to the 2720GS as shown in Figure 6-4. It is recommended that both the 2720GS and the DC Voltage source be in STANDBY mode while connecting them.

It is further recommended that the 2720GS nullmeter be zeroed prior to performing this procedure (see 6.9).

a) Select the required voltage output level to perform the calibration on both the 2720GS and the DC Voltage Source. Select OPERATE on both units.

b) It is recommended that the upper and lower voltage limits for the 2720GS be set such as to limit the possible excursion of the output to safe limits (see 6.8).

c) Set the error limit in the 2720GS to the accuracy specification of the DC Voltage source at the set output voltage level. This may be in either voltage or ppm units (see 6.7).

d) Press the AUTO NULL key on the 2720GS. The lower display will prompt the user to enter the division ratio. Since no divider is used in this application, a numerical value of 0.5 is entered to obtain the best results. Use the numeric keys in the DATA ENTRY section followed by ENTER (i.e. "0" "." "5" "ENTER").

e) The lower display will (after a delay) be updated every 2 seconds with the actual error of the DC Voltage source. The units of this display may be altered by the use of the "uV", "mV", "V" or "PPM" keys.

f) Also in the lower display will be pass or fail status of the DC Voltage source under test. If the error of the DC Voltage source is within the accuracy entered in c) then the first two characters in the lower display will be "GO", otherwise it will be "FL".

g) Further calibration voltage levels can be checked as desired by deselecting auto null (press the AUTO NULL key) and repeating the above procedure.

The use of the above procedure with a 2720GS will yield accuracies of typically 2ppm+0.2uV and thus is suitable for the calibration of most DC Voltage sources directly with good ratio of accuracies.

6.24 Using the 2720GS as a "Tracking" Source

A further use of the Auto Null function in the 2720GS is to use the 2720GS as a "tracking" voltage source.

In the standards laboratory it is a common requirement to compare the divided output of a voltage source with a standard cell and to continuously alter the voltage to maintain a null between the output of the divider and the standard cell. This is the usual

method by which very high accuracy 100 and 1000V levels are generated. While the 2720GS has excellent accuracy at these levels even this specification may not be adequate, thus the above method is used. A brief glance at the operation of the 2720GS Auto Null function shows that this is exactly the same procedure as that shown above. It is recommended that the 2720GS nullmeter be zeroed prior to performing this procedure (see 6.9).

a) Connect the 2720GS and divider as shown in Figure 6-5. Ensure that the standard cell is not connected at this time.

b) Select the required output voltage from the 2720GS (see 6.3) and select OPERATE.

c) Select the required division ratio on the divider (if selectable).

d) Connect the 2720GS nullmeter, divider output and standard cell (or other reference voltage) as shown in Figure 6-5.

e) Press the AUTO NULL key on the 2720GS. The lower display will now prompt the user for the division ratio. The ratio of the divider, divided by two (or more), should be entered (e.g. if the divider is 100:1 then enter 50 or less).

f) The 2720GS will now automatically alter its output to maintain a zero reading on the nullmeter, thus ensuring that its output voltage is exactly the required voltage.

The use of the above procedure with a 2720GS will yield an overall accuracy (with respect to the voltage reference) of typically 0.2ppm+0.1uV plus the inaccuracy of the divider (typically less than 0.5ppm). Thus overall accuracies can be maintained below 1ppm by using this method.

6.25 Using the 2720GS for Standard Cell Inter-Comparison

Inspection of the specifications for the digital nullmeter in the 2720GS will show that this nullmeter is ideally suitable for the "round robin" type of standard cell inter-comparison.
The very high input impedance ensures that there is negligible load on the standard cells, and the good 0.1%+100nV accuracy ensures the best results.
The connections shown in Figure 6-6 are recommended and the procedure for using the 2720GS nullmeter is shown in 6.9.
The typical accuracy of cell to cell comparison utilizing a 2720GS is 0.1ppm.

6.26 Using the 2720GS as a Transfer Standard.

The 2720GS' good short term stability enables it to be used as a transfer standard for transferring from high impedance standards (such as standard cells) to other equipment (such as other standard cells if the "round robin" method above is not used). Another good use is to transfer the output voltage of a standard cell

to drive the input of a voltage divider (e.g. to generate a 1V level). The method used is basically the same as shown in 6.23 except that the divider is not usually used. The auto null mode can be maintained and the output of the 2720GS used directly as a tracking output (with low impedance), or the auto null mode can be deselected (by pressing the AUTO NULL key) when settled and the output of the 2720GS used independently of the original source. If option "BAT" is used and the power interruption is not very long (preferably less than 2 minutes) then the 2720GS can be removed from the AC power source and transferred to another room (or building) to achieve inter laboratory comparison.
Typical transfer accuracies obtainable with a 2720GS used as described above are better than 0.4ppm from a single standard cell, or 0.25ppm from a 10V standard.

6.27 Using a Pair of 2720GS for Divider Comparison
A pair of 2720GS may be used for the comparison of two voltage dividers (e.g. for the calibration of a secondary ratio standard against the primary standard) eliminating all errors associated with lead resistances in an automatic manner as shown in Figure 6-7. Using the method shown in this figure accuracies of better than 0.00000002 with 10V applied to each divider.
Referring to Figure 6-7, the following procedure should be used:

a) Zero the nullmeters of both 2720GSs (see 6.9)

b) Connect the two 2720GSs, the reference divider (divider #1), and the divider under test (divider #2) as shown in Figure 6-7.

c) Select the required drive voltage for both dividers (the same voltage on each) as output from both 2720GS.

d) Set both dividers to the same ratio. The ratio used should be the ratio at which the dividers are to be compared.

e) Select AUTO NULL operation on the 2720GS #2 with a division ratio entered as between 0.1 and 0.5. This will ensure that both dividers have the same drive voltage across them at all times and eliminates the effect of lead resistances.

f) Select normal Nullmeter use in 2720GS #1 and select for the nullmeter data to be displayed in "PPM" format. This data will be the actual difference in the division ratios of the two dividers expressed in ppm of unity.

g) To check at further division ratios the user should select the required ratio on both dividers. The 2720GSs will automatically adjust for any change in lead resistance errors and 2720GS #1 will always show the error expressed in ppm of unity (the normal method of expressing error for dividers).

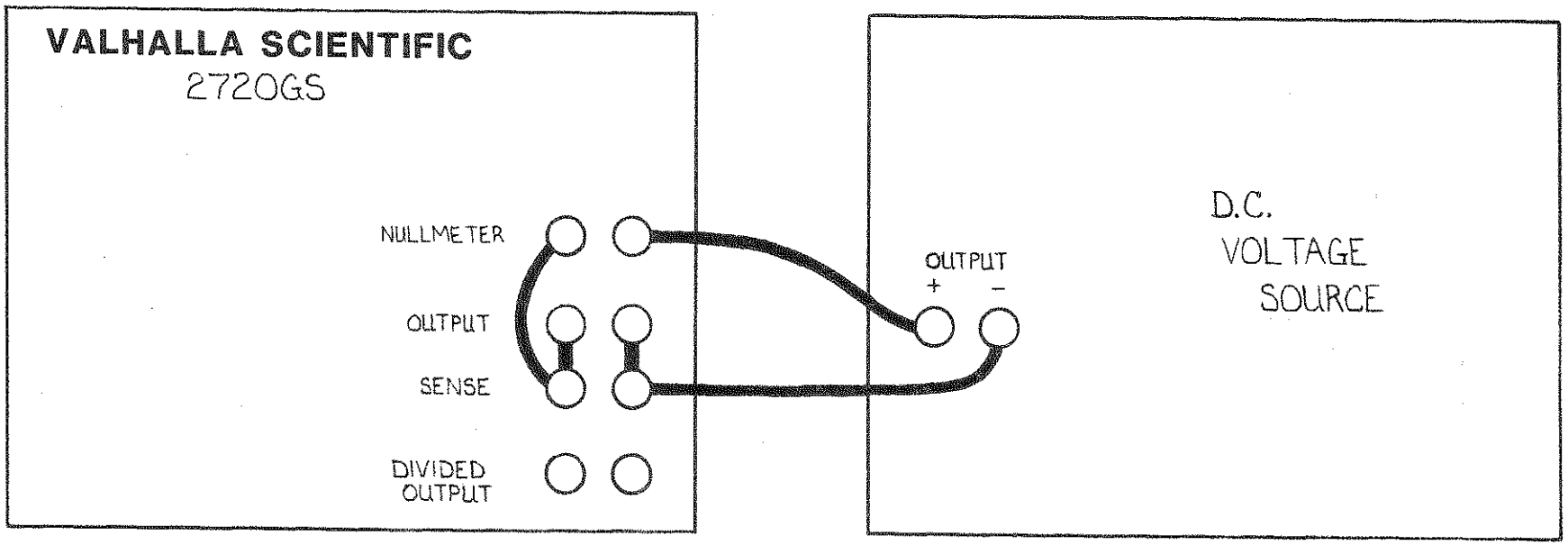


FIGURE 6-1

USING AUTO NULL WITHOUT A DIVIDER

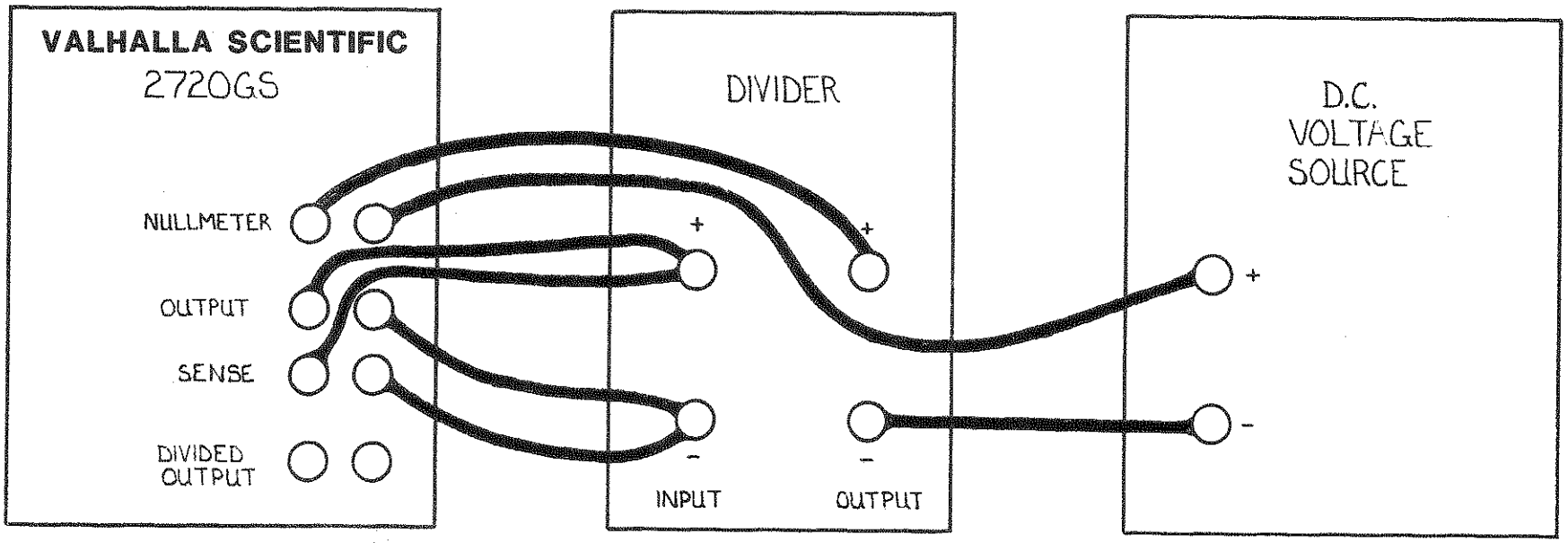


FIGURE 6-2

USING AUTO NULL WITH A DIVIDER

ON THE 2720GS OUTPUT

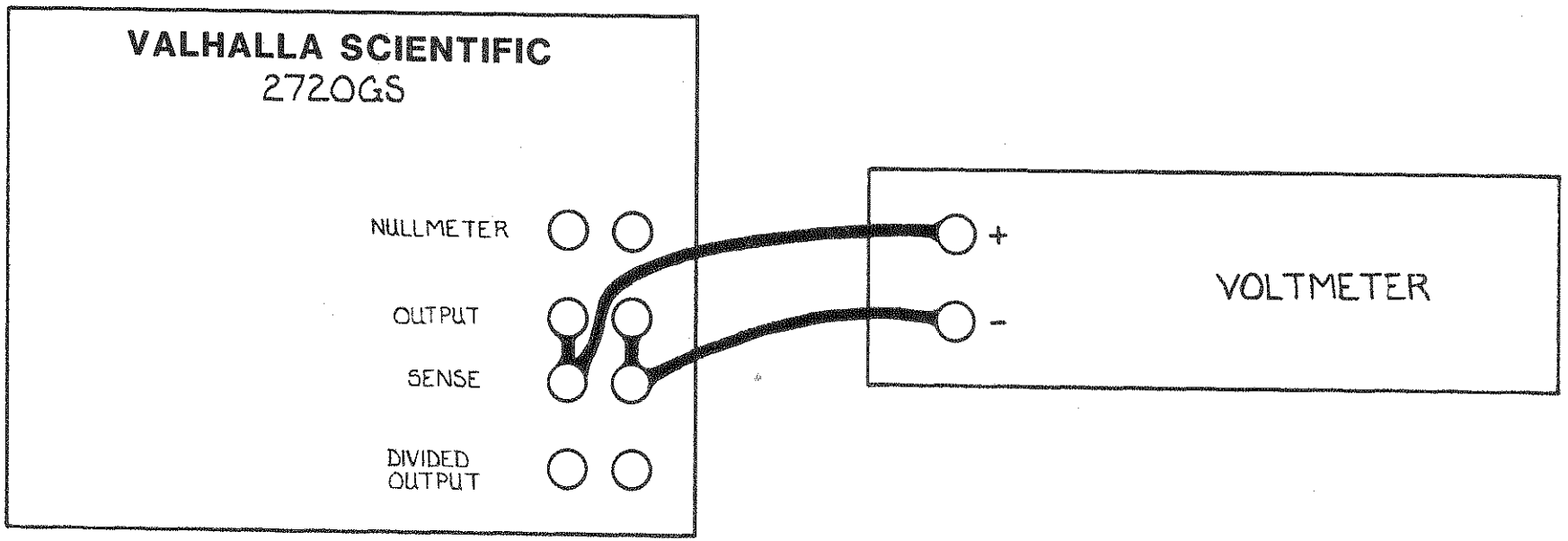


FIGURE 6-3
CALIBRATION OF A VOLTMETER

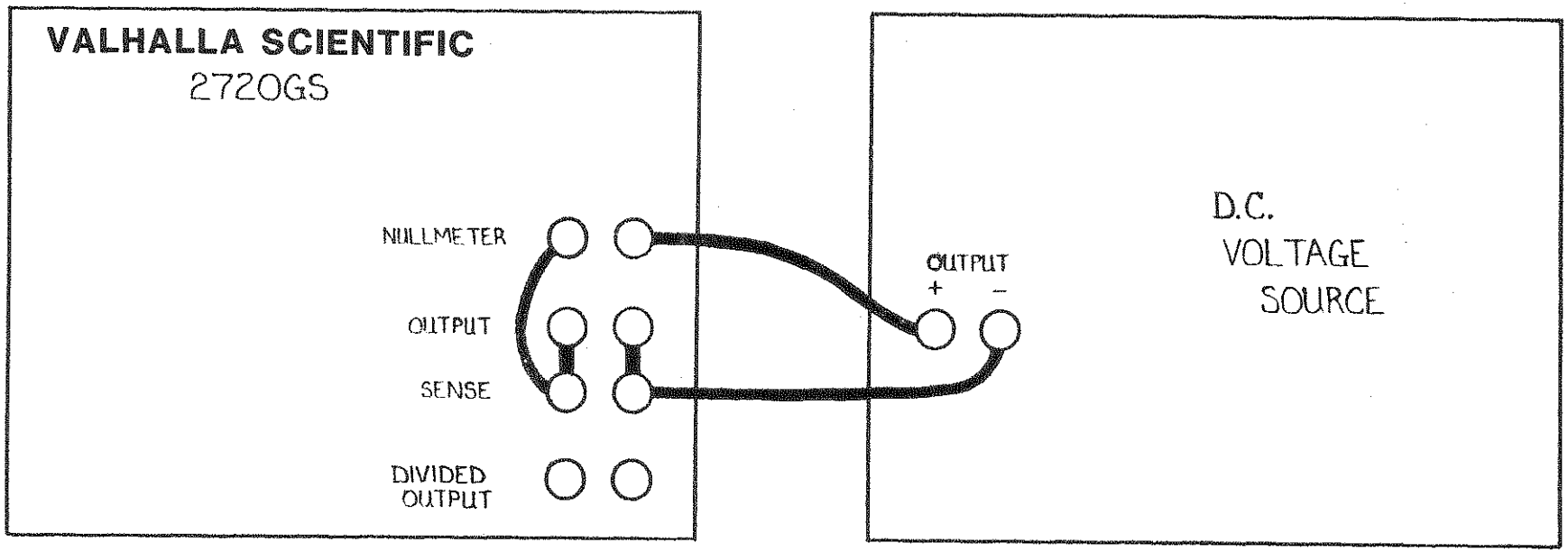


FIGURE 6-4
CALIBRATION OF A D.C. VOLTAGE SOURCE

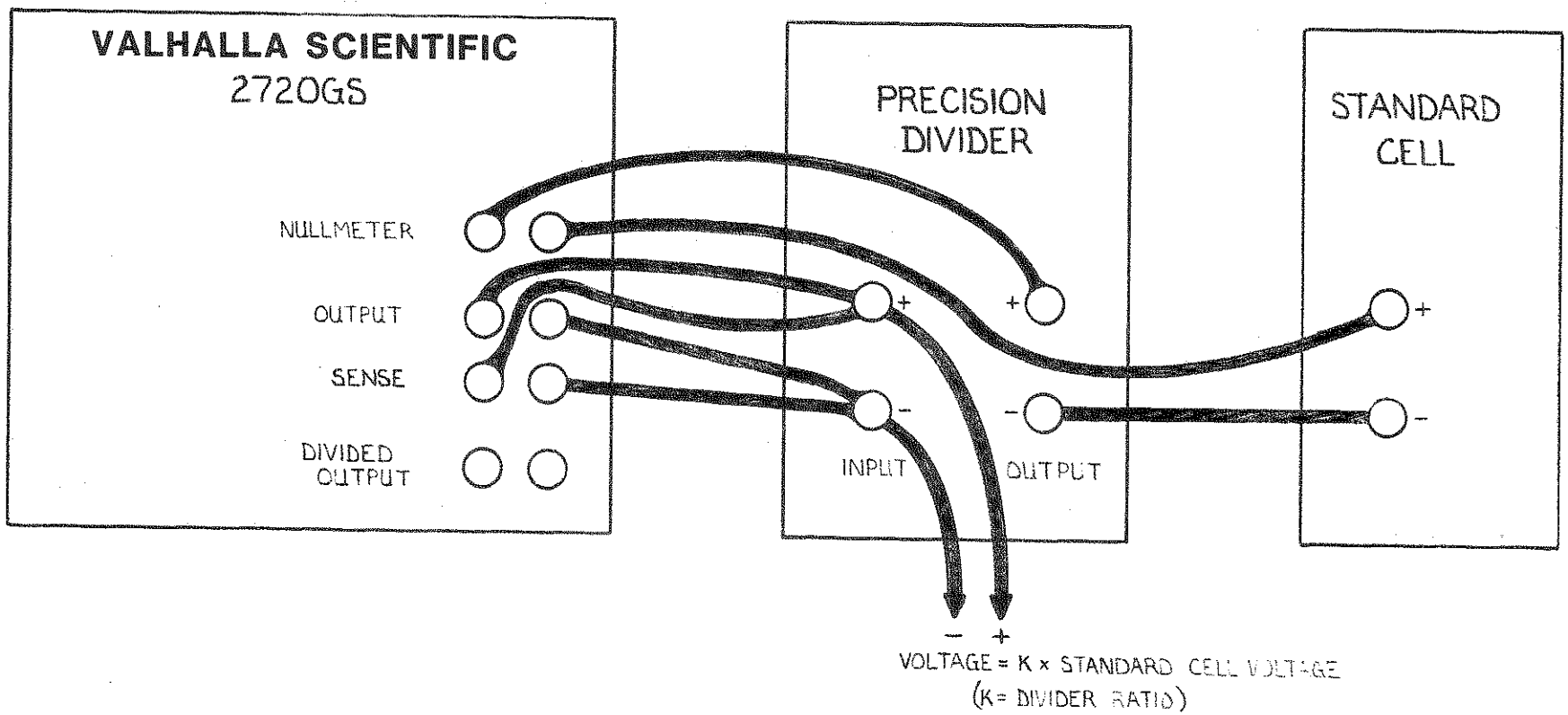
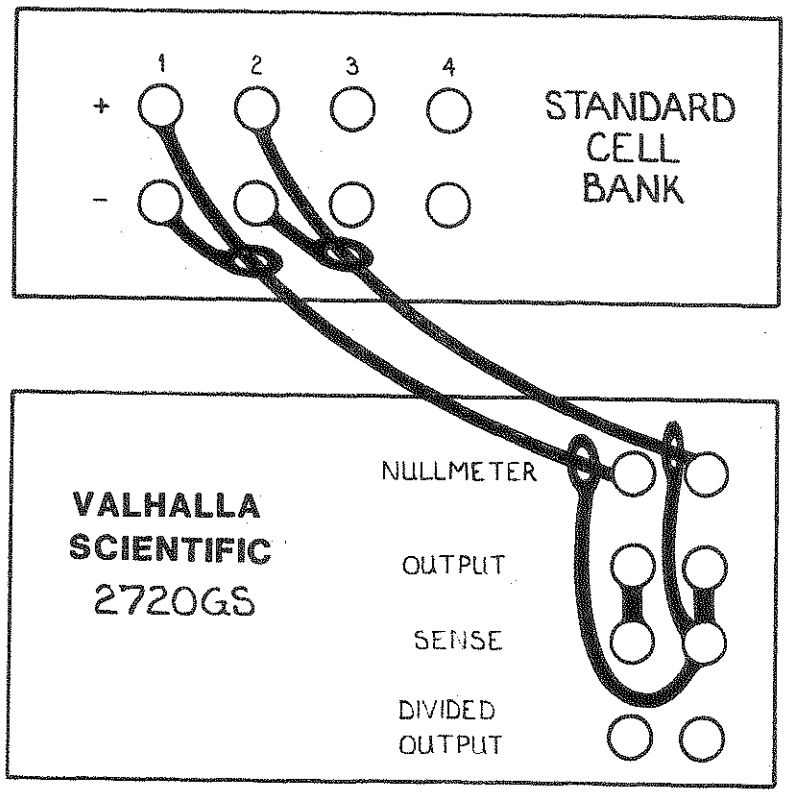


FIGURE 6-5
USING THE 2720GS AS A TRACKING SOURCE

METHOD A : DIRECT NULLMETER READING OF CELL TO CELL VOLTAGE DIFFERENCE.

REPEAT FOR EACH PAIR OF CELLS.
(EXAMPLE : 1-2, 2-3, 3-4, 1-3, 1-4, 2-4)



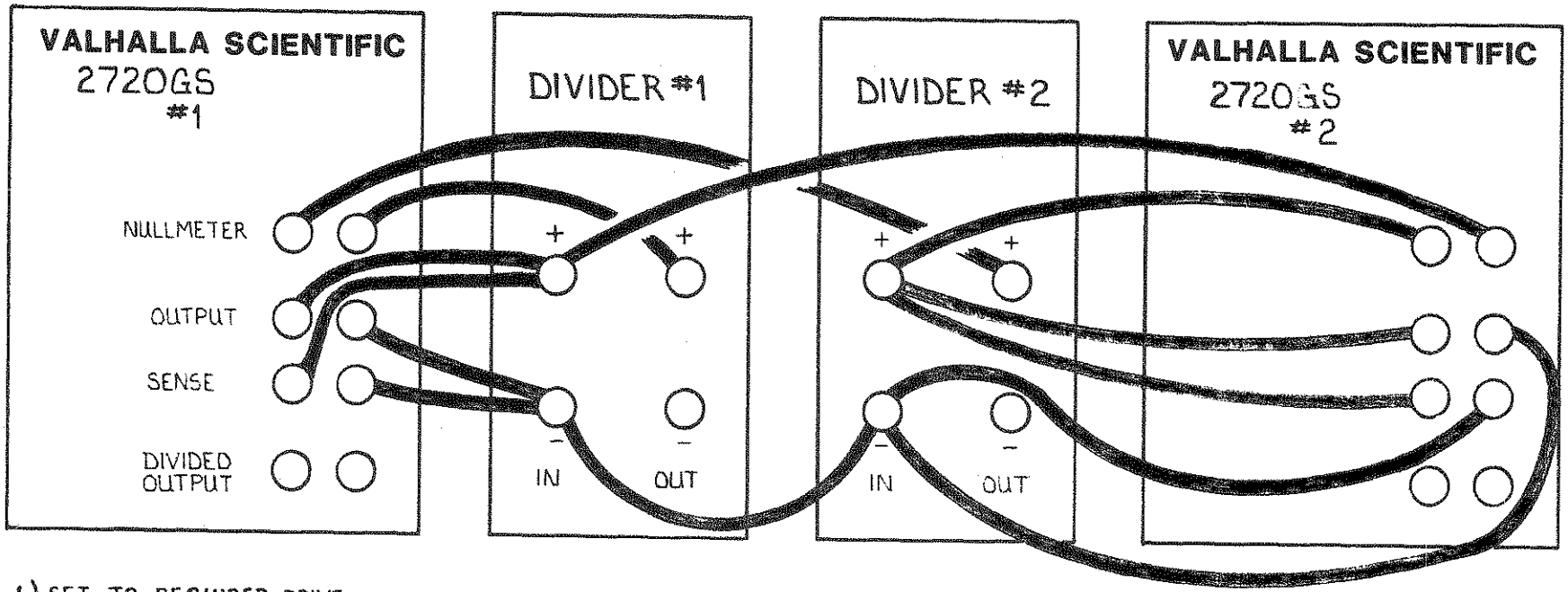
METHOD B : USING THE 2720GS AS A TRANSFER DEVICE.

1.) USE CONNECTIONS SHOWN IN FIGURE 6-5.
2.) AUTO NULL TO FIRST CELL VOLTAGE.
3.) DESELECT AUTO NULL. (PRESS AUTO NULL)
4.) RECONNECT SECOND CELL VOLTAGE.
5.) RESELECT AUTO NULL. (PRESS AUTO NULL)
6.) PRESS PPM.
7.) LOWER DISPLAY SHOWS PPM DEVIATION OF CELL 2 FROM CELL 1.
8.) REPEAT FOR EACH CELL.

NOTE : IF ACCURACIES OF < 0.5PPM ARE NOT REQUIRED THEN THE USE OF THE DIVIDER IS NOT REQUIRED.

FIGURE 6-6

STANDARD CELL INTERCOMPARISON



1.) SET TO REQUIRED DRIVE VOLTAGE.
2.) TURN ON NULLMETER.
3.) SELECT PPM DISPLAY OF NULLMETER READING.
4.) DISPLAYS DIVIDER #2 ERROR REFERRED TO DIVIDER #1.

MAINTAIN SAME DIVISION RATIO ON BOTH DIVIDERS.

1.) SELECT REQUIRED DRIVE VOLTAGE.
2. SELECT AUTO NULL WITH A DIVISION RATIO ENTRY OF 0.5. OUTPUT VOLTAGE WILL TRACK THAT OF 2720GS #1.

FIGURE 6-7

DIVIDER COMPARISON

SECTION VII

REMOTE OPERATION

7.1 General

This section contains a description of the IEEE 488 bus and how to use this interface to control and operate the 2720GS. It is assumed throughout this section that the user has read Sections IV and VI, and is familiar with the manual operation of the 2720GS.

7.2 Definitions

The following are definitions of the terms used in describing the IEEE 488 interface and its operation in the 2720GS.

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 between to devices, with input and output data being carried on the same wires.

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

Byte : A group of data bits (usually 8) which are 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 : A unit or controller connected to the bus.

Device dependent message : A message containing information or commands having meaning only to the recipient device (usually refers to commands which are not included in the IEEE 488 (1978) standard).

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

Interface message : A message intended for interface or bus management.

Local operation : Operation of a device by its front panel controls or other form of manual operation.

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

7.3 Basic Description of the IEEE 488 (1978) Bus

This chapter gives a basic description of the general principles of the IEEE 488 (1978) bus (also known as GPIB, HP-IB, IEC DTC-66, ANSI MC1-1 etc.). The user is recommended to read the full IEEE-488 standard for more details if required.

7.3.1 The Purpose of the IEEE 488 Standard

The purpose of the standard is to allow for interconnection of programmable instruments with a minimum of engineering. Its intent is to remove the need for adaptors and numerous types of patching cables often encountered with other forms of interfaces. The IEEE 488 standard allows system configurations using programmable instruments, calculators and other types of peripheral devices produced by different manufacturers, providing a set of rules for establishing an unambiguous communications link with a high degree of compatibility yet maintaining flexibility between independently manufactured products.
The IEEE 488 (1978) standard defines the :

Electrical characteristics - driver and receiver circuit parameters, electrical signal levels, loading requirements and grounding requirements.

Mechanical characteristics - connector type, contact assignments and cable assembly.

Functional characteristics - the complete repertoire and precise definition of each of the signal lines, the protocol and timing relationships and the response to each message.

The IEEE 488 (1978) standard does not define the :

Way in which information (device dependent messages) will be interpreted by the receiving device.

Maximum amount of time for a full handshake of data to occur (it does define the minimums however).

7.3.2 Basic IEEE 488 Standard Defined Parameters

The IEEE 488 standard defines a bi-directional bus carrying bit parallel, byte serial data. The most basic of its definitions are as follows :

All bus data is digital

A maximum of 15 devices may be interconnected on a single bus

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

The maximum data transmission rate is 1 megabyte per second

Of all the devices on the bus only one may be the controller at any time. The controller exercises control over all other devices on the bus. The other devices may be listeners (only able to receive data), talkers (only able to transmit data) or both (as is the 2720GS, capable of both transmitting and receiving data). The controller is the only device capable of addressing other devices on the bus and commanding them to talk or listen as required. Only one device may talk at any one time.

The interconnecting cable consists of 16 signal wires and eight ground returns linking devices into a complete system (the user is cautioned to be careful of generating ground loops when interconnecting devices via the bus). Each cable connector is a plug and socket combination to permit the "daisy chaining" of devices.

The 16 signal wires are as follows :

8 data wires (DIO0 through DIO7 inclusive)
5 management wires (ATN, EOI, SRQ, IFC and REN)
3 handshake wires (DAV, NRFD and NDAC)

It should be noted that all of these wires use "inverse logic", i.e. a low voltage level indicates the "true" state (also called "asserted") while the high voltage level indicates the "false" state.

DIO0 to 7 - These wires are the bi-directional data bus

ATN - This wire may be asserted by the controller to indicate that an address or command is present on the bus.

EOI - This wire may be asserted by the controller or the talker. If ATN is also asserted then EOI being asserted indicates that the controller is polling devices. If ATN if false then it may be asserted by the talker to indicate the end of a message (see 7.5.1.3).

SRQ - This wire may be asserted by any device to indicate that it requires attention (e.g. a fault has occurred or data is ready). Usually the controller will respond by polling the devices to determine which requires service.

IFC - This wire is asserted by the controller to reset the bus (note that only the bus is affected) to an idle state.

REN - This wire is asserted by the controller to indicate to all devices that they may enter the REMOTE state. The user should note that for a device to enter REMOTE the REN wire must be asserted and the device must subsequently receive its listen address. If this wire is not asserted then all devices will be in the LOCAL state.

DAV - This wire is asserted by the talker and indicates that a valid data byte has been placed on the DIO0 to 7 wires.

NRFD - This wire may be asserted by any listener and indicates that it is not yet ready to receive further data.

NDAC - this wire may be asserted by any listener and indicates that it has not yet completed reading the data byte present on the DIO wires.

7.4 Device Independent Messages

This paragraph describes all of the IEEE 488 defined commands and their affect upon the operation of the 2720GS.
In this paragraph (as in all further paragraphs) examples are given for the HP85 computer and it is assumed that the 2720GS has its address set to 15.

7.4.1 Device Clear (DCL)

This command will cause all of the devices to enter the reset state (both interface and instrument functions). The 2720GS will perform a power on reset cycle when this is received, however the normal display sequence is not followed.
The user should note that this command can cause "peculiar" activity by the devices on the bus. This is because the device clear itself will cause the interface to reset, as soon as the interface is again ready to read the bus it may re-read the device clear command, if a slower device has not yet released the handshake, and thus restart a further device clear. This will be visible as a complete bus lock-out with all of the devices continuously performing a device clear. Although every precaution has been taken in the 2720GS to eliminate this problem with the IEEE 488 standard it cannot be entirely overcome. If possible the user is recommended to use the Selective Device Clear command (7.4.2).
This command is implemented with the HP85 by the statement **CLEAR7**

7.4.2 Selective Device Clear (SDC)

This command will cause the addressed device to individually enter the reset state. This command will perform the same function as the DCL command in 7.4.1 but only on one unit at a time, thus overcoming the problem inherent with the DCL command.
This command is implemented with the HP85 by the statement **CLEAR715**

7.4.3 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. When received by the 2720GS it will be handshaked and will not cause an error but will be ignored.
The user should note that only the addressed form of this command is covered 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 2720GS is not defined and may cause bus errors if used.

This command is implemented in the HP85 by the statement **TRIGGER715** for the addressed form, and **TRIGGER7** for the unaddressed, "unofficial" form.

7.4.4 Go To Local (GTL)

This addressed command will command the individual addressed device to enter the LOCAL state (i.e. enables manual operation of the device). This command is fully implemented in the 2720GS and is commanded by the HP85 statement **LOCAL715**
The user should note that many computers also have a similar unaddressed version of this command (**LOCAL7** for the HP85). This command actually is quite different from the addressed command (it unasserts the REN line) but will cause all of the devices, including the 2720GS to enter the LOCAL state.

7.4.5 Interface Clear (IFC)

This command will cause all of the interfaces of the devices to enter an idle state. This is fully implemented in the 2720GS and may be commanded with an HP85 by the statement **RESET7**

7.4.6 Identify (IDY)

This command is also called "parallel poll".
This command will cause all devices to respond by simultaneously placing their parallel poll response byte onto the DIO bus wires. The 2720GS fully implements this command which is commanded with an HP85 by the statement **PPOLL7**

7.4.7 Local Lock Out (LLO)

This command will cause all of the devices to enter either the LOCAL WITH LOCK OUT or REMOTE WITH LOCK OUT state (depending whether they were in LOCAL or REMOTE states respectively). The function of this command is to disable the manually operated LOCAL key or control on the devices. The 2720GS fully implements this command which may be commanded with an HP85 by the statement **LOCKOUT7**

7.4.8 Parallel Poll Configure(PPC), Enable(PPE), Disable(PPD) and Unconfigure(PPU)

These commands are used to set the Parallel Poll response byte and to dis/en-able the parallel poll response. These commands are not implemented in the 2720GS and are ignored if received.

7.4.9 Remote Enable (REN)

This command (the assertion of the REN wire) enables all devices to enter the REMOTE state when they next receive their listen address. The 2720GS fully implements this command which may be commanded with an HP85 by the statement **REMOTE7**
Many computers also have a command which includes the sending of the listen address which will immediately place the addressed device into the REMOTE (or REMOTE WITH LOCK OUT,see 7.4.7) state. With an HP85 this is accomplished by the statement **REMOTE715**

7.4.10 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 b) or send SPD to end the serial poll

The 2720GS fully implements this function and may be commanded to send its serial poll response byte with an HP85 by the statement **SPOLL(715).** This statement will implement the entire sequence once.

7.4.11 Take Control (TCT)

This command from the controller to another potential controller will request the other to take over as controller. The 2720GS does not have the capability of becoming a controller thus this command is not implemented but will be ignored.

7.5 IEEE Commands for the 2720GS (Device Dependent)

The command set for the 2720GS is described in the following paragraphs. For each command examples are given and, as for the previous paragraphs, they assume the 2720GS has an address of 15 and that an HP85 computer is used.

7.5.1 REMOTE and LOCAL States

Although not device dependent commands, a full explanation of the implementation of the LOCAL and REMOTE states is explained here.

7.5.1.1 LOCAL

When the 2720GS is in the LOCAL or the LOCAL WITH LOCK OUT states the REMOTE LED on the front panel is extinguish and full manual control of the 2720GS as described in section IV and VI may be performed. The user should note that it is not possible to enter the REMOTE state manually other than via the controller.
Although they are separate states there is no difference apparent to the user between the LOCAL and LOCAL WITH LOCK OUT states.
The user should note that the 2720GS will accept data/commands from the IEEE 488 bus while in LOCAL but they will be discarded, the unit may however be read at any time.

7.5.1.2 REMOTE

As mentioned previously, after the 2720GS has received its listen address, while the REN line is asserted, it will enter the REMOTE (or REMOTE WITH LOCK OUT state,see 7.5.1.3) state. In this state the REMOTE LED on the front panel is illuminated and all keys on the front panel are ignored except for the following :

a) The LOCAL key - pressing this will return the 2720GS to the LOCAL state and reactivate the keys.

b) The ADDR key - pressing this will cause the 2720GS to display the present address for approximately 1 second.

c) The DSPL CHK key - pressing this will cause all display elements and LEDs to illuminate until any key is pressed. This does not affect the operation of the 2720GS in any way,

7.5.1.3 REMOTE WITH LOCK OUT

This state is entered either from the REMOTE or LOCAL WITH LOCK OUT states, dependent on the order in which the commands were given. While in this state the 2720GS will operate as in the REMOTE state, however all keys on the 2720GS front panel are ignored without exception.

7.5.2 Data Format Used in the 2720GS

These paragraphs describe the data formats used by the 2720GS for data read from the unit and for numeric data sent to the 2720GS.

7.5.2.1 Command/Data Format from the Controller to the 2720GS

All commands from the controller take the form of four alpha characters which may be upper or lower (or mixed) as desired. Embedded spaces within commands or data are discarded and thus ignored, the user may freely use spaces to format commands and/or data into easily readable form.
Many of the commands require data with the command, this data is required in one of the following formats, as identified in the paragraph dealing with each individual command :

a) Integer Format - This may be a 1,2 or 3 digit number in the range 0 to 255. No sign or decimal point may be present.

b) Free Format Numeric Format - This may be any number of characters in any of the following general forms -

```
e.g.  10          : Sign and/or decimal point not required
e.g.  -1.567      : Normal numeric quantity
e.g.  1.4E-3      : Normal exponential format
e.g.  1.4e-3      : Lower case and upper case are the same.
e.g.  .01E3       : Sign before exponent not required
e.g.  1.23456E+03 : Exponent may have any number of digits.
e.g.  0000.45     : Leading zeroes are discarded.
```

If desired, more than one command may be transmitted on the same line by separating the commands by the desired separator (see SSEP command, 7.6.1.2). The user should note that the 2720GS will except any number of characters on the same line (i.e. upto the terminator) with a maximum limit of 128 characters. If more than 128 characters are sent to the 2720GS without a terminator then the 2720GS will discard the characters and will generate an error condition.
The commands are not actioned until a terminator is received (either "Line feed" character or EOI asserted with the last character, or both) when any valid commands are executed in the order received. If an erroneous command is received then an error message is generated and the remaining portion of the line is discarded.

7.5.2.2 Data Format from the 2720GS
Data read from the 2720GS is controlled by the use of the various "Gxxx" commands. This data may be read any number of times and reflects the status of the data at the time read (not necessarily at the time of the "Gxxx" command) and is sent in the same order as the set of "Gxxx" commands were received.
Each command line containing one or more (upto a maximum of 8) "Gxxx" commands will "reset" the list of data required to be read and start a new list from the "Gxxx" commands on that line. The user should note that the transmission of one (or more) "Gxxx" command(s) immediately followed by a read of the 2720GS may cause undefined results if the controller is faster than the 2720GS. It is recommended that the user ensure that at least 500ms occurs between the "Gxxx" command and the read of the 2720GS. The user should also note that the data to be read will not be updated until the previous data has been completely read (if it has started to be read), thus controllers performing actions in real-time or not having exact compatibility with the set terminator may occasionally read the wrong data after commanding "Gxxx", this may be overcome by reading the 2720GS twice and discarding the first data read.
The first character sent by the 2720GS when read is always a space, followed by the requested list of data defined by the last received set of "Gxxx" commands.
Data read from the 2720GS will be in one of the following formats depending on the data type :

a) Integer data - this is always three digit numeric data with no decimal point or sign. The total field width is 3 characters.

b) Numeric data - this will be a 9 digit number preceded by the sign and with a decimal point in the required position (e.g. +1.23456789, -1000.05672 or +0.00000102 etc.). The total field width is always 11 characters.

c) Date and time data - this will be exactly as displayed in the AUXILIARY display of the 2720GS. The total field width is always 18 characters.

d) Days from calibration update - this will as the integer format but with 4 digits instead of 3. The field width is always 4 characters.

7.5.3 Power on Default Values

Although many of the IEEE 488 parameters are maintained by battery back up, for user convenience the 2720GS will initialize some of the operating parameters at power up or after receipt of a reset command. These parameters are as follows :

a) Data read from the 2720GS is set as if GERR, GDNG commands were received (see 7.6.1.11 and 7.6.1.13).

b) Lower display is set to show the date and time data when in REMOTE as if the SLOW0 command were received (see 7.6.1.5).

c) The input data buffer is cleared (thus any commands not yet actioned are discarded).

7.5.4 Percentage Data

All data requested which are a percentage value will be referred to the current "nominal" output voltage value set by the SREF command (see 7.6.2.2). The only exception to this is the GCAL command (see 7.6.1.6) which will return percentage data referred to the constants actual ratio value.

7.5.5 Deviation and Nullmeter Reading Data.

The 2720GS provides the user with the capability of reading the deviation of the output voltage referred to a "nominal" value or alternately the actual nullmeter reading data. Both data are read by the same commands, which data is read is described below

a) If the Nullmeter is off - the user will receive the deviation between the present output voltage setting and the previously set "nominal" output. This data will be a negative quantity if the output is higher than nominal giving the correct polarity for the error of the connected measuring device being calibrated.

b) If the nullmeter is on for normal (or stand alone) use - the user will receive the actual nullmeter reading.

c) If the 2720GS is in Auto Null mode - the user receives the deviation between the present output voltage and the previously set "nominal" voltage. This data will be a positive quantity if the output voltage is higher than "nominal" giving the correct polarity for the error of the connected voltage source being calibrated.

7.5.6 Post RESET Delay

To ensure that all wires are settled following a device clear or RESE command (see 7.6.1.2) it is recommended that a 100ms minimum delay is forced prior to performing any bus operation with the 2720GS following either of the above actions. The user should also note that the 2720GS will not operate the IEEE 488 bus until the complete set of status messages have been displayed following a power up. Any bus activity with the 2720GS during either of the above periods of time will cause undefined results.

7.6 Commands and Examples

This set of paragraphs list each command, its exact operation and one (or more) example which may be used with an HP85 computer and with the 2720GS set to address 15. The actual statement for the HP85 is printed in bold.

7.6.1 Commands That are ALWAYS Executed

These paragraphs contain the commands which are always executed independent of the activity currently being performed by the 2720GS.

7.6.1.1 "RESE" - RESEt

This command will cause a device clear of the 2720GS (as the IEEE-488 device clear function). The user should note that any commands following this command will be discarded and a 100ms minimum delay before any bus activity with the 2720GS should be forced.

EXAMPLES :

OUTPUT715;"RESE"
or
OUTPUT715;"RESET"

7.6.1.2 "SSEP" - Set SEParator

This command will cause the data input/output separator to be changed to the desired character(s). This command requires an integer value to follow it. Once set, the commanded separator character is stored in non-volatile (battery backed up) memory and thus it is not necessary to reset it following a power outage.

SSEP0 - will select a "," (comma) to be used
SSEP1 - will select a ";" (semi-colon) to be used
SSEP2 - will select a " " (space) to be used
SSEP3 - will select a ":" (colon) to be used
SSEP4 - will select a "/" (slash) to be used

The user should note that if the SSEPn command is to be followed by another command, then the SSEPn command must be followed by the previously set separator while the following commands must be separated by the newly set separator. If the user is unsure as to the previously set separator then the use of commands following the SSEPn command is not recommended.

EXAMPLE :

OUTPUT715;"SSEP0" - will cause a comma to separate read data and to be expected between commands.

7.6.1.3 "STRM" - Set TeRMinator
This command will set the terminator, sent after the required data has been read, to be set to the required value. The command requires an integer value to follow it. The commanded terminator is stored in non-volatile (battery backup-up) memory, thus it is not necessary to reset this following a power outage.
In the list below (CR) indicates the carriage return character and (LF) indicates the line feed character.

STRM0 - will select for the 2720GS to assert EOI with the last data character.
STRM1 - will select for (CR)(LF) to be sent after the last data character, EOI being asserted with the (LF) character.
STRM2 - will select for (LF) with EOI asserted to be sent following the last data character.
STRM3 - will select for (CR)(LF) to be sent after the last data character.
STRM4 - will select for (LF) to be sent after the last data character.

EXAMPLE

OUTPUT715;"STRM1" - will select the required terminator for the HP85 (and most other computers).

7.6.1.4 "SSRQ" - Set SRQ generation mode
This command allows the user to select the reasons for the 2720GS to be able to generate a service request (SRQ) to the controller. One or more reasons may be selected to cause an SRQ by the use of this command followed by an integer equal to the addition of the value for each reason listed below :

2 - New nullmeter/deviation data available due to an updated nullmeter reading. This enables the controller to proceed with other activities and read the new data as available on a real-time basis.

4 - Change in major activity status (see 7.6.1.13). This enables the controller to proceed with other activities returning to the 2720GS function when the commanded activity has been completed.

8 - The requested change in data to be read has been actioned. i.e. following one (or more) "Gxxx" commands. This enables the controller to ensure that the data read is the data requested by synchronizing both 2720GS and controller.

16- When the output has settled following a change in output voltage command (only given if the change is greater than 0.25V). This enables the controller to time when to read any device connected

to the 2720GS. The SRQ is given when the output has settled to within 10ppm of the change.

32- Any error condition. This enables the 2720GS to interrupt any controller activity when an error condition occurs.

The integer defining the reason which will cause the 2720GS to generate an SRQ is stored in non-volatile memory (battery backed-up) thus the user need not reset the required number following a power outage.
The user is strongly recommended to fully read the manual for the controller and understand the operating principles of both the controller and 2720GS before attempting to operate a "real-time" SRQ interrupt driven system.

EXAMPLE :

OUTPUT715;"SSRQ48" - will cause the 2720GS to generate an SRQ whenever an error occurs and whenever the output settles due to a commanded change in output voltage.

OUTPUT715;"SSRQ0" - will cause the 2720GS not to generate an SRQ for any reason.

When any of the enabled reasons shown above occur the 2720GS will respond by asserting the SRQ wire in the IEEE 488 bus and will set up its serial poll response byte. This response byte may then be read by the controller either by a serial poll (which will also clear the SRQ wire) or by reading data made available by the "GSPB" command (see 7.6.1.8). Either method will clear the serial poll response byte. The contents of the serial poll response byte are as follows:

SPB	Serial poll bit
1	Bit 0 - Not used (undefined)
2	Bit 1 - Set if a new nullmeter reading is available
4	Bit 2 - Set if a change in major activity has occurred
8	Bit 3 - set if a newly commanded message is ready
16	Bit 4 - Set if the output has settled following a change
32	Bit 5 - Set if an error has occurred
64	Bit 6 - Set if the 2720GS is requesting service (asserting-SRQ)
128	Bit 7 - Not used (set to zero)

The user should note that the serial poll response byte bits always reflect the current conditions, the SRQ wire assertion being generated if the bit is set in the response byte and also the corresponding "SSRQ" command data.

7.6.1.5 "SLOW" - Set LOWer display contents

This command enables the user to control the contents of the lower or AUXILIARY display while the 2720GS in REMOTE. The command should be followed by an integer which will command the required source of data for the lower display (see below). The integer is stored in non-volatile memory (battery backed-up) thus it is not necessary to reset the required data following a power outage.

SLOW0 - will cause the lower display to show the date and time.
SLOW1 - will cause the lower display to show the deviation or nullmeter data in voltage units.
SLOW2 - will cause the lower display to show the deviation or nullmeter data in percentage units.
SLOW3 - will cause the lower display to show the "nominal" output voltage (see 7.6.2.2).

EXAMPLE :

OUTPUT715;"SLOW1" - will cause the 2720GS lower display to show the nullmeter or deviation data.

7.6.1.6 "GCAL" - Get CALibration constant

This command will cause the selected calibration constant data to be retrieved from the non-volatile calibration memory of the 2720GS and made available for the next time(s) the controller reads the 2720GS. The user should note that a delay of greater than 500ms is required to ensure that this command has been implemented prior to attempting to read the requested data or that the relevant SSRQ command (see 7.6.1.4) be used. If the user attempts to read the data before this time has been allowed then it is possible that the previous data will be read.
The user should note that the calibration data is only retrieved from memory at the time of receipt of the "GCAL" command, thus successive reads will always return the same result even if the constant has been updated since the "GCAL" command.
The user should also note that the use of multiple GCAL commands will not yield the expected result, actually all returned quantities will be the data for the last quantity requested.

This command should be followed by an integer data describing the calibration constant it is wished to read. The list of integers is given below :

0 through 7 - Reference 1 through 8 voltage at the time of the latest calibration (in volts).

8 - Reference Divider ratio (divider used for 0.65V,1.3V,650mV and 1300mV ranges). The data in nominally 100% and is the data at the time of the latest 1V external calibration.

9 - Nullmeter scaling coefficient (1.073% nominal)

10 - Nullmeter high range zero offset (1.19% nominal)

11 - External reference scaling coefficient (14.39/100/143.9% nominal for the EXR1/7/10 respectively).

12,13 - Internal DVM scaling and zero coefficients respectively (0.119% and 0.085% nominal resp.)

14,15 - Internal ammeter zero and scaling resp. (0.119% and 0.098% nominal resp.)

16 - Reference averaging coefficient (100% nominal)

17 - 2:1 sense buffer scaling (for 1300mV,1.3V,13V,26V,130V and 1200V ranges) (100% nominal)

18 - 2:1 sense attenuator scaling (for 26V range) (100% nominal)

19,20 - 10:1 and 100:1 sense attenuator scaling resp. (100% nominal)

21 - Negative polarity DtoA convertor offset (0% nominal)

22 through 32 - 650mV,1300mV,0.65V,1.3V,6.5V,13V,26V,65V,130V,600V and 1200V range zero offsets in voltage units

33,35,37,39,41 - Voltages of reference 1 at the times of previous calibrations (earliest to latest but one resp.)

34,36,38,40,42 - As above for reference 2

43,45,47,49,51 - As above for reference 3

44,46,48,50,52 - As above for reference 4

53,55,57,59,61 - As above for reference 5

54,56,58,60,62 - As above for reference 6

63,65,67,69,71 - As above for reference 7

64,66,68,70,72 - As above for reference 8

73 through 77 - Reference Divider ratios at the time of previous calibrations (earliest through latest but one resp.)

78 - User set Nullmeter zero offset (by SET ZERO command) in volts.

79 through 86 - Presently measured reference voltages (as obtained by the OBRMS system) in volts

87 - Presently measured reference averaging system error (as obtained by the OBRMS system) in %

EXAMPLE :

```
OUTPUT715;"GCAL0" - will command read of reference 1 voltage
WAIT1000          - will ensure that sufficient time is allowed
ENTER715;A          - controller reads voltage data into variable
```

7.6.1.7 "GLST" - Get days from LaST calibration

This command is similar to the "GCAL" command (7.6.1.6) but will cause the days since the data was last updated to be read instead of the data itself. The command should be followed by an integer, which has the same meaning as the integer used for the GCAL command (see 7.6.1.5).

EXAMPLE :

```
OUTPUT715;"GLST25" - will command read of days since 1.3V range
                     zero was obtained.
WAIT1000
ENTER715;A          - controller reads data (0000 to 9999 days)
```

7.6.1.8 "GSRQ" - Get SRQ reason command data
"GSPB" - Get Serial Poll response Byte
"GOUT" - Get voltage OUTput
"GREF" - Get nominal (or REFerence) output voltage
"GFLR" - Get error limit in volts (or FLooR)
"GPRF" - Get error limit in PeRcent of reFerence
"GPCT" - Get PeRcenTage deviation/nullmeter data
"GVOL" - Get deviation/nullmeter data in VOLtage units
"GCLK" - Get CLocK data
"GMEU" - Get MEmory in Use location address number

These commands all request that the 2720GS make available the requested data for the controller to read. The user should note that either a minimum of 300ms delay or the SRQ should be used to ensure that the command has been actioned prior to attempting to read the requested data.

EXAMPLES :

```
OUTPUT715;"GOUT" - request to read output voltage
WAIT500
ENTER715;A       - controller reads output voltage into variable
```

or

```
OUTPUT715;"SSEP0"      - sets separator to a comma
OUTPUT715;"GOUT,GREF" - requests to read output and nominal
WAIT500
ENTER715;A,B           - reads data into separate variables
```

7.6.1.9 "GSTS" - Get output STatuS

This command will request that the 2720GS make the current output status available for read by the controller. The data will be the numeric addition of the following integers for each state that is true plus 209.

8 - If the divided output mode is active
32 - The output is in OPERATE mode

EXAMPLE :

```
OUTPUT715;"GSTS" - commands future read of output status
WAIT500          - ensures command has been completed
ENTER715;A       - will read present status of the output
.
.
.
ENTER715;A       - will read the present status of the output
```

7.6.1.10 "GEPF" - GEt deviation/nullmeter Pass/Fail status

This command will cause the 2720GS to make the Pass or fail status of the comparison of the error limit and the deviation or nullmeter data. The data read will be the single digit "0" if the comparison yields a Pass (within error limit) or a "1" if the comparison Fails (exceeds error limit). This data is continuously updated by the 2720GS and this updated status is read each time, thus it is not necessary to continually send the "GEPF" command.
The 2720GS always knows which form of error limit entry was used (voltage or percentage) and will always update the other form of error limit to correspond with the current output voltage. The comparison is always done in voltage units.

7.6.1.11 "GERR" - Get ERRor status

This command will cause the 2720GS to make available the last occurring error code to be read by the controller. After the data is read the code read will be "000" until a further error occurs. The available error codes and causes are listed below:

001 - Battery backed-up data lost
002 - Real time clock failure
003 - Front Panel Microprocessor failure
004 - Front panel main RAM failure
005 - Front panel main ROM failure
007 - Incompatible software fitted
009 - Not yet warmed up,cannot action command
010 - Unspecified main system failure
020 - Serial link between uPs failure
040 - Attempted more than 8 read variables (see 7.5)
050 - Command not possible except in external calibration
051 - Command at an unexpected time - ignored
052 - Command not possible during external calibration
152 - IEEE 488 interface failure

153 - Terminator expected and not found, or not expected
154 - Separator expected and not found, or not expected
155 - Not possible to action command (not fitted, faulty or unknown)
156 - Numeric data entry out of range for command
157 - Too many characters in input string
168 - Manually entered voltage data out of range
169 - Voltage limits exceeded
170 - Manually entered limit data out of range
175 - Memory location address number out of range

7.6.1.12 "GVRS" - Get software VeRSion

This command will cause the 2720GS to make available the software revision to the controller to read. The version is of the format **nn.nn** where n is a numeric digit.

7.6.1.13 "GDNG" - Get DoiNG status

This command will cause the 2720GS to make the present major activity status available to the controller for read. The user should note that only the lengthy procedures are included. The data read by the controller is continuously updated by the 2720GS and is a 3-digit integer with the following meanings :

000 - No major activity
010 - Krefav internal calibration
011 - Kb2 internal calibration
012 - Ka2 internal calibration
013 - Kal0 internal calibration
014 - Kal00 internal calibration
015 - DVM zero calibration
016 - DVM scaling calibration
017 - Ammeter zero calibration
018 - Nullmeter high range zero calibration
019 - Nullmeter scaling calibration
020 - 6.5V range zero calibration
021 - negative polarity zero offset calibration
022 - 650mV range zero calibration
023 - 1300mV range zero calibration
024 - 0.65V range zero calibration
025 - 1.3V range zero calibration
026 - 13V range zero calibration
027 - 26V range zero calibration
028 - 65V range zero calibration
029 - 130V range zero calibration
030 - 600V range zero calibration
031 - 1200V range zero calibration
032 - External reference calibration
064 - Waiting for 10V external calibration standard voltage
066 - Waiting for 100V external calibration standard voltage
067 - Waiting for 1000V external calibration standard voltage
068 - Waiting for 1V external calibration standard voltage
080 - Waiting for 10V external calibration step "CNUL" or "CSKP"
082 - Waiting for 100V external calibration step "CNUL" or "CSKP"

083 - Waiting for 1000V external cal. step "CNUL" or "CSKP"
084 - Waiting for 1V external calibration step "CNUL" or "CSKP"
112 - Digital system check of front panel uP.
113 - Digital system check of main uP.
128 - System check of analog to digital convertors
129 - System check of the output system
130 - System check of the internal reference system
132 - System check of the external reference input.

7.6.1.14 "GSTA" - Get overall STAtus

This command will cause the 2720GS to make the overall unit status data available for the controller to read. The 2720GS continually updates this data such that it is always valid at the time read and may be read any number of times.
The data read by the controller will be a 22 character alpha-numeric string where each character position describes the status of the various portions of the 2720GS and options as follows :

1st character : Reference 1 status
"0" - Not fitted
"1" - No calibration data
"2" - Faulty
"3" - Medium error detected
"4" - Latest calibration data lost
"5" - Noisy
"6" - Oven over temperature
"7" - Early calibration data lost
"8" - In use
2nd through 8th: Reference 2 through 8 status resp.
9th character : Average in use reference grade
10th character : Average reference grade fitted
11th character : External Reference status
"0" - Not fitted
"1" - No calibration data or faulty
"2" - Not in use
"3" - In use
12th character : External reference type (0=EXR1,1=EXR7,2=EXR10)
13th character : AtoD convertor statii
"0" - All convertors operational
"1" - DVM faulty
"2" - Ammeter faulty
"4" - Main AtoD faulty
Other numbers are combinations of above codes.
14th character : "BAT" or "EBU" status
"0" - not fitted
"1" - Low voltage/charge
"2" - OK
15th character : Output voltage/current safety status
"0" - Below 30V and below current limit
"1" - Above 30V and below current limit
"2" - Below 30V and above current limit
"3" - Above 30V and above current limit

16th character : Output status
"0" - Open circuit standby
"1" - zero volt standby
"2" - Operate

17th character : Output range in use
"0" to "8" - 650mV,1300mV,0.65V,1.3V etc.

18th character : Amplifier in use
"0" - Divided output
"1" - 13V
"2" - 130V
"3" - 1200V

19th character : Amplifier fault status
"0" - All amplifiers
"1" - 13V amplifier faulty
"2" - 130V amplifier faulty
"4" - 1200V amplifier faulty
Other numbers are combinations of the above

20th character : Nullmeter status
"0" - Not fitted
"1" - Faulty
"2" - Not in use
"3" - In use (normal operation)
"4" - In use (auto null)

21st character : Divider status
"0" - Faulty data
"1" - Oven over temperature
"2" - No fault

22nd character : Internal calibration data
"0" - faulty
"1" - OK

7.6.2 Commands which cannot be executed during external calibration

7.6.2.1 "SLOC" - Select LOCal

This command has the same effect as pressing the front panel LOCAL key, i.e. it will return the 2720GS to the LOCAL state if the unit is not in the LOCK OUT state.

7.6.2.2 "SREF" - Set REFerence (or nominal) voltage

This command will cause the existing output voltage setting to be used as the new nominal output voltage.

7.6.2.3 "OPER" - select OPERate mode
"STBY" - select STandBY mode (zero volts)
"OPEN" - select OPEN circuit standby

These commands will set the status of the output system to the required status.

7.6.2.4 "DIVY" - DIVider Yes
"DIVN" - DIVider No

These commands will select or deselect the divided output modes respectively. If the output voltage is over 1.3V and "DIVY" is commanded then the 2720GS will generate an error.

7.6.2.5 "CALI" - CALibrate,Internal

This command will cause the 2720GS to execute an Internal Calibration of the Reference system, Output gain and External Reference (if fitted). It is recommended that any external connections be removed during this sequence. In order for the 2720GS to implement this command the warm up time since power was applied must have expired. The user should note that this command implements only those internal calibrations which are recommended at regular intervals (30 days is sufficient) and is recommended to read section VI of this manual before attempting this command.
It is imperative that the REMOTE/LOCAL status of the 2720GS not be altered during an internal calibration and the user should note that no commands can be actioned during the sequence which takes approximately 1.5 minutes). It is recommended that the controller sets the 2720GS, using the "GDNG" command, such that it may read the current activity to determine when the 2720GS becomes available for use following the "CALI" command.

7.6.2.6 "TSTS" - TeST System

This command will cause a full system check to be performed by the 2720GS. The sequence is the same as a manually commanded SYS CHK with all of the user prompts automatically answered YES. As for the CALI command in 7.6.2.5 it is imperative that the REMOTE LOCAL status of the 2720GS not be changed during the sequence, and that no commands will be actioned during the execution (it takes approximately 2 minutes).

7.6.2.7 "SCLK" - Set CLocK

This command allows the controller to set the hours, minutes and seconds data in the real time clock of the 2720GS. The required format is as shown below (note that all 6 digits must be present)

EXAMPLE :

OUTPUT715;"SCLK154320" - sets the clock to 15 hours, 43 minutes and 20 seconds.

7.6.2.8 "MEMN" - MEMory, No

This command is similar to pressing the MEMORY CONTROL CLR key in manual operation (see 6.11) in that it removes the 2720GS from the MEMORY CONTROL mode.

7.6.2.9 "CLRM" - CLeaR all Memories

This command will initialize all memory location contents in the 2720GS to 0 volt output, 1200V error limit and no automatic standby.

7.6.2.10 "SINR" - Select INternal Reference
"SEXR" - Select EXternal Reference

These commands are for the 2720GS to select either the Internal References or the external reference input (if fitted) respectively. If the SEXR command is received and no option is fitted then the 2720GS will raise an error and ignore the command.
The SINR command requires no numeric data to be performed, however the SEXR command must be followed by numeric data as to the actual external reference voltage (in Volts) and if this voltage is not acceptable the 2720GS will raise an error and ignore the command.

EXAMPLE :

OUTPUT715;"SINR" - will select the internal references

OUTPUT715;"SEXR1.01814567" - will select a 1.01814567V external reference to an option EXR1

7.6.2.11 "SNUL" - Select NULlmeter on
"SNOF" - Select Nullmeter OFf
"SETZ" - SET Zero

These commands are used to control the normal operation of the 2720GS nullmeter. The SNUL and SNOF commands select or deselect resp. the nullmeter for normal use. The SETZ command will operate in the same manner as pressing the SET ZERO key in manual operation (see 6.9 for a description of the use of the nullmeter). The user is recommended to read the section on the manual use of the nullmeter (6.9) prior to using it remotely.
The 2720GS may be set to generate an SRQ every time that a nullmeter reading is made available (see 7.6.1.4) or the user may "randomly" read the nullmeter data in either voltage (GVOL command) or percentage (GPCT command) forms.

EXAMPLE :

```
OUTPUT715;"SNUL,GVOL"  - select nullmeter on and to read the
                         readings in voltage form
WAIT3000
ENTER715;A             - fetch nullmeter reading from 2720GS
.
.
ENTER715;A             - fetch another nullmeter reading
OUTPUT715;"SETZ"       - zero the nullmeter (ensure zero input)
.
.
.
.
OUTPUT715;"SNOF"       - turn off the nullmeter
```

7.6.2.12 "SOUT" - Set OUTput voltage
"SANL" - Select Auto NulL mode

These commands are used to control the 2720GS output voltage. The numeric data following either command is used as the new output voltage requirement (note that neither command updates the "nominal", or reference, output voltage, see SREF 7.6.2.2) and does not affect the present output STANDBY/OPERATE status. If the SANL version of this command is used then this will also automatically select the auto null mode if the 2720GS is in OPERATE or placed into OPERATE within 2 seconds. Neither of these commands will place the 2720GS into the STANDBY mode even if the "Vari-safe" limit is exceeded, since this feature is only active when operating under manual control.

EXAMPLES :

To select an output of 10 volts (not auto-null)
OUTPUT715;"SOUT10"

To set the output voltage to the value of variable "A"
This example demonstrates the usefulness of discarding spaces
OUTPUT715;"SOUT",A

To select auto null mode from an initial output of 1.01814 volts and read the percentage change from this voltage.
Note that although the SRQ facility is used to synchronize, the SRQ interrupt capability of the computer need not be used, the loop formed by lines 30 and 40 merely waits for a service request to be generated by the 2720GS.
The user should note that the first reading is not available for approximately 10 seconds to allow the nullmeter to settle.

```
10 OUTPUT715;"SSRQ2,SANL+1.01814,SREF,GPCT"
20 A=SPOLL(715) - dummy read to clear any pending service request
30 A=SPOLL(715)
40 IF A < 64 THEN 30 - wait for nullmeter reading
50 ENTER715;A - read percentage deviation from initial value
60 DISP A;"% Deviation"
70 GOTO 30
```

7.6.2.13 "INCR" - INCRement output voltage by a voltage
"INCP" - INCrement output voltage by a Percentage

These commands are used to alter the output voltage by the amount specified by the numeric quantity following the command. The user should note that for the INCR command the output voltage will increase in a positive direction for a positive numeric data and the output voltage will increase numerically for a positive numeric data in the case if the INCP command (i.e. the command follows normal mathematical practice for addition and multiplication). As for the SOUT command (7.6.2.12), these commands do not affect the STANDBY/OPERATE status under any circumstances, neither do they affect the stored "nominal", or reference, output voltage.

7.6.2.14 "SVLM" - Set Voltage LiMit

This command will set the upper (positive numeric data) or lower (negative numeric data) voltage limit to the desired voltage level defined by the numeric data following the command. The user should note that, unlike when manually set, the upper and lower voltage limits must be of opposite polarities to be set remotely. The manually entered voltage limits may remain in effect while the 2720GS is under REMOTE control however.

7.6.2.15 "SCLM" - Set Current LiMit

This command will set the presently used amplifiers' current limit to the value of the numeric data following the command in the units of milliamps. This is unlike the manual capability of individually setting each current limit. The user may still individually set each amplifiers' current limit remotely by setting an output voltage, followed by the current limit, for each amplifier (the user is recommended to place the 2720GS in STANDBY output mode before doing this). The user should note that the 2720GS must be allowed time to select the required amplifier (400ms is sufficient) before programming a current limit, otherwise the incorrect amplifiers' current limit will be affected. The user is also reminded to ensure that the output voltage selected is within the allowed limits set by the SVLM command (see 7.6.2.14).
Although the controller may give the 2720GS data with any resolution the unit will truncate the numeric data into milliamps.

EXAMPLE :

To set the 13V amplifier limit to 10mA, 130V to 100mA, and 1200V to 30mA.

```
OUTPUT715;"STBY,SOUT10"
WAIT500
OUTPUT715;"SCLM10"
OUTPUT715;"SOUT100"
WAIT500
OUTPUT715;"SCLM100"
OUTPUT715;"SOUT1000"
WAIT500
OUTPUT715;"SCLM30"
```

7.6.2.16 "SFLR" - Set FLooR (error limit in voltage units)
"SPRF" - Set PeRcent Floor (error limit in percent)

These commands will cause the error limit to be set to the required numeric value. If the user sets the error limit in voltage units (SFLR command) then the percentage data will automatically be updated to reflect any changes in the "nominal" output voltage and vice versa. The user should note that the 2720GS always performs error limit comparison in voltage units.

EXAMPLES :

To set an error limit of 10 microvolts

OUTPUT715;"SFLR10E-6"

To set an error limit of 10ppm (0.001%)
OUTPUT715;"SPRF10E-4"

7.6.2.17 "MEMY" - Use MEMorY location data

This command will cause the 2720GS to automatically recall and use the data contained in the memory location address specified by the numeric data following the command. If the contents of the memory contain the command to enter the STANDBY output mode then the 2720GS will do so, otherwise the output mode will remain unchanged.

If a memory location address outside of the allowable range (presently 000 through 557 inclusive) then the command will be ignored and an error generated.

EXAMPLE :

To recall into use the contents of memory 001
OUTPUT715;"MEMY1" - note that leading zeroes need not be present

7.6.2.18 "SMEM" - Set MEMory contents

This command will cause the 2720GS to set the contents of the specified memory location to the the specified quantities.
The format of this command is as follows :

SMEMa...a,v....v,e....e,x

where a...a is the memory location address (0 to 557)
v...v is the required output voltage contents
e...e is the required error limit contents in percent
x is the letter "O" if the 2720GS is not to automatically enter the STANDBY output mode when the memory is recalled

EXAMPLE :

To set memory 1 to 10.45 volts, with an error limit of 5ppm and not to enter standby
OUTPUT715;"SMEM1,10.45,.0005,O"

7.6.2.19 "GMEM" - Get MEMory contents

This command will cause the 2720GS to make the entire contents of the specified memory available for the controller to read. The same format as used to define the memory contents in the SMEM

command (7.6.2.18) is used for the read data, the output voltage and error limit fields being normal numeric data and the select standby command field being as entered. The user should note that selecting this command uses 3 of the available 8 "Gxxx" commands allowed at any one time.

EXAMPLE :

If the data written into memory 1 in the example in 7.6.2.18 is to be read back into the controller.

```
OUTPUT715;"GMEM1"
WAIT500
ENTER715;A,B,A$
```

7.6.2.20 "GVLM" - Get Voltage LiMit

This command will cause the 2720GS to make both the upper and lower voltage limits available for the controller to read. The user should note that the use of this command uses 2 of the allowable 8 "Gxxx" commands. The 2720GS will output the data upper voltage limit followed by the lower voltage limit.

7.6.2.21 "GCLM" - Get Current LiMit

This command will cause the 2720GS to make the current limit in use, at the time the command is received, available for the controller to read. The data is output as a three digit unsigned integer without decimal point and is in the units of milliamps.

7.6.2.22 "GTOL" - Get unit TOLerance

This command will cause the 2720GS to calculate and make available the actual specification, at the time and environmental conditions upon receipt of the command, for the controller to read. The data is made available in voltage units only and although it may be read any number of times it is only calculated once.

7.6.3 Commands Which May Only be Executed in EXTERNAL CALIBRATION

EXTERNAL CALIBRATION CAN ONLY BE ACCOMPLISHED WHILE THE FRONT PANEL KEYSWITCH IS IN THE "CALIBRATE" POSITION.

The commands listed in these paragraphs can only be executed after this switch has been manually placed into this position.

THE USER IS STRONGLY RECOMMENDED TO PERFORM AND BECOME CONVERSANT WITH THE MANUAL METHOD OF EXTERNAL CALIBRATION BEFORE ATTEMPTING TO REMOTELY (OR AUTOMATICALLY) PERFORMING AN EXTERNAL CALIBRATION.

THE FOLLOWING SEQUENCE IS RECOMMENDED FOR REMOTE EXTERNAL CALIBRATION

7.6.3.1 Initial Preparation

The user should disconnect all leads from the 2720GS after first ensuring that all functions of the 2720GS are operational and that the nullmeter has been correctly zeroed. It is recommended that the user perform an output gain internal calibration (**CALI** is the remote command for this, see 7.6.2.5) prior to performing an external calibration. The equipment required and operating sequence for a manual external calibration are found in section IX of this manual.

The user is recommended to set the 2720GS to send the major activity status and the percent deviation data when read by the use of the **GDNG** command (see 7.6.1.13) and the **GPCT** command (see 7.6.1.8). When the user is ready to begin an external calibration the keyswitch should be placed in the CALIBRATE position after first ensuring that the 2720GS is in the REMOTE state.

7.6.3.2 Sequence Control

The calibration sequence is controlled by the 2720GS automatically, thus the user must be aware of this sequence prior to performing an external calibration. The front panel displays are still used (as they are for a manual external calibration) for informing the user of the present calibration step in progress.

Remote external calibration uses the first four steps only of the fuller manual calibration :

First step : 10V calibration
Second step : 1V calibration
Third step : 100V calibration
Fourth step : 1000V calibration

The user should note that any (or all!) of the above steps may be skipped and is recommended to read section IX for the recommended calibration intervals for each of these steps.

7.6.3.3 Performing an External Calibration

Each of the steps shown in 7.6.3.2 is started automatically by the 2720GS and each performed in the same manner. The entire sequence may be started by sending the 2720GS the command "**CALE**", if desired, however this is unnecessary.

a) At the start of each step, the output of the 2720GS is set to 1V (approximately) and the unit will await entry of the voltage of the external standard (see section IX for the allowable range of entries for each step). This voltage is entered from the controller by the use of the command "**CSTD**" followed by the voltage data (e.g. **CSTD10.000053**). If the step is to be skipped then the controller should send the command "**CSKP**" at this time instead of the **CSTD** command.

b) After receiving and checking the validity of the voltage of

the standard the 2720GS will output the required voltage for calibration automatically and will use a special form of the auto null mode to correct for any calibration error which is present. The amount of the error corrected for should be monitored by the controller through the use of the data read from the use of the **GPCT** command issued before the calibration sequence was started. It is recommended that the controller should check this data and if the data appears invalid it should inform the user that the calibration should be aborted. When this data has settled to within acceptable limits the controller may send the command "**CNUL**" to indicate to the 2720GS that this correction should be applied to the respective calibration constants. The command "**CSKP**" may be issued instead if the user wishes to skip this step but had not done so at the entry of the standard voltage.

c) The 2720GS will repeat steps a) and b) for each of the four calibration steps.

After completion of all of the calibration steps the 2720GS will store the collected calibration corrections and will request that the calibration key be returned to the OPERATE position. The external calibration procedure is completed when this has been done. The controller may (if the user desires) restart the entire procedure at any time prior to the keyswitch being returned to the OPERATE position by sending the 2720GS the command "**CALE**".

7.6.4 Summary of Commands

Command Format	Paragraph	Description
CALE	7.6.3.3	Start External Calibration
CALI	7.6.2.5	Start Intercal Calibration
CLRM	7.6.2.9	Clear all memories
CNUL	7.6.3.3	Calibration step completion
CSKP	7.6.3.3	Skip calibration step
CSTD<number>	7.6.3.3	Inform about voltage of standard
DIVN	7.6.2.4	Select Active output
DIVY	7.6.2.4	Select divided output
GCAL<integer>	7.6.1.6	Read Calibration constant
GCLK	7.6.1.8	Read date/time
GCLM	7.6.2.21	Read current limit
GDNG	7.6.1.13	Read activity in progress
GEPF	7.6.1.10	Read deviation pass/fail
GERR	7.6.1.11	Read previous error
GFLR	7.6.1.8	Read error limit in Volts
GLST<integer>	7.6.1.7	Read days from last calibration
GMEM<number>	7.6.2.19	Read memory contents
GMEU	7.6.1.8	Read memory in use
GOUT	7.6.1.8	Read output voltage
GPCT	7.6.1.8	Read percentage deviation
GPRF	7.6.1.8	Read error limit in %
GREF	7.6.1.8	Read nominal output voltage
GSPB	7.6.1.8	Read Serial Poll response
GSRQ	7.6.1.8	Read SRQ Mask
GSTA	7.6.1.14	Read overall status
GSTS	7.6.1.9	Read output status
GTOL	7.6.2.22	Read tolerance of 2720GS
GVLM	7.6.2.20	Read voltage limits
GVOL	7.6.1.8	Read deviation/nullmeter (Volts)
GVRS	7.6.1.12	Read software versions
INCP<number>	7.6.2.13	Add percentage to output
INCR<number>	7.6.2.13	Add voltage to output
MEMN	7.6.2.8	Exit memory control
MEMY<number>	7.6.2.17	Use memory contents
OPEN	7.6.2.3	Select STANDBY (Open)
OPER	7.6.2.3	Select OPERATE
RESE	7.6.1.1	Perform Device Clear
SANL<number>	7.6.2.12	Select auto null
SCLKhhmmss	7.6.2.7	Set time
SCLM<number>	7.6.2.15	Set current limit
SETZ	7.6.2.11	Zero nullmeter
SEXR<number>	7.6.2.10	Select External Reference
SFLR<number>	7.6.2.16	Set error limit in Volts
SLOC	7.6.2.1	Select LOCAL state
SLOW<integer>	7.6.1.5	Select lower display contents
SINR	7.6.2.10	Select Internal Reference
SMEM<number>,<output>,<error limit>,<O>	7.6.2.18	Set memory contents
SNOF	7.6.2.11	Turn off nullmeter

SNUL	7.6.2.11	Turn on nullmeter
SOUT<number>	7.6.2.12	Set output voltage
SPRF<number>	7.6.2.16	Set error limit in %
SREF	7.6.2.2	Set nominal to present output
SSEP<integer>	7.6.1.2	Set required seperator
SSRQ<integer>	7.6.1.4	Set SRQ Mask
STBY	7.6.2.3	Select STANDBY (0V)
STRM<integer>	7.6.1.3	Set required terminator
SVLM<number>	7.6.2.14	Set voltage limit
TSTS	7.6.2.6	Start System Check

SECTION VIII

THE OBRMS SYSTEM

8.1 General

This section gives a brief description of the On Board Reference Monitoring System utilized in the 2720GS.

8.1.1 The Use of OBRMS

The OBRMS system is incorporated into the design of the 2720GS in order to maintain the overall specifications of the 2720GS even if a fault should occur in one (or more) of the references. In basic terms the system is designed to continuously monitor all of the internal references and eliminate from use any that should exhibit any abnormal deviation from the average reference. This enables the 2720GS to maintain its specification even under adverse conditions.

8.1.2 The Operating Principles of OBRMS

The basic concept behind the OBRMS system is the same as that used in standards laboratories for many years for monitoring standard cells. Since no absolute voltage standard is available, each references' value is compared with the average measured value, the deviation from nominal is closely monitored for changes and any reference which has changed significantly is not used as a primary reference from that point forward (until restabilized back to its original value, or recalibrated). In this manner any reference which changes its' value by more than preset limits is no longer used.

In practice (as in the standards laboratory) cross-checks are performed to ensure that an apparent deviation was not caused by line interference or similar event. In the 2720GS this is achieved by comparing the average measured value of the in-use references with the measured average value of the in-use references (which should be the same). Any interference effects will cause these values to become significantly unequal and thus the results of the measurements will be ignored.

8.1.3 OBRMS limits

At the time of an external calibration (the 10V calibration point) the current deviations of each reference are recorded and the absolute value of each reference calculated. These values are stored in memory in each reference module. From this time forwards the actual measured deviations from the average is compared with these calibrated deviations and any change above the limits in the table below will cause the action shown.

Deviation	Action
<3ppm	If not in use - Brought back into use at time of INT-CAL or at midnight if still within limit.
	If in use - No action.
<7ppm	If not in use - No action.
	If in use - No action.
<50ppm	If not in use - No action.
	If in use - "NOISY" status set.
<150ppm	If not in use - No action.
	If in use - "DRIFTY" status set.
>150ppm	"FAULTY" status set.

8.1.4 Allowable Reference Phenomenae

As can be seen from the above data the correct operation of the OBRMS system is central to the performance of the 2720GS. Semi-conductor references (as do to Weston cells) will suffer occasional shifts in value (especially due to power on/off cycles or temperature shock) thus it should not be considered abnormal for a reference to be not in use. Even fully aged references can (and will) change value in a step manner randomly. Valhalla Scientific Inc does warranty that no more than one reference will become "NOISY" during the first year and that none will become "DRIFTY" or "FAULTY" during this period.

In order than a faulty OBRMS system cannot fault "good" references the system is automatically cross-checked every 10 minutes and a full operational check is performed during a commanded SYSTEM CHECK.

8.1.5 Drift Analysis

After the 2720GS has been in use for some time (typically 3 to 6 months) the references and divider resistor networks will have fully stabilized to the environment and any remaining drift rate will be both small and also linear with time. Thus the calibrator of the 2720GS can select for the change in calibration from the previous data to be used for "drift analysis" (only if more than

90 days has elapsed since the previous calibration was performed). With this enabled the drift rate is calculated and the value updated every day to reflect the expected data at that time. If more than one pair of data points are available for drift analysis then a multi-order curve fit routine is used to forward extrapolate the data in time. The resultant value of this is the value used by OBRMS to compare each references' deviation from the average thus even if a reference is consistently drifty then the 2720GS will "learn" its' drift rate and automatically correct for it.

8.1.6 Reference Status Messages

Following a system check or a Reset the 2720GS will display the status of all the references (only the not in use references following a Reset).The list below gives the list of status messages and their cause.

BEING USED - A reference which is in use.

LOST DATA - A reference which has had earlier calibration data corrupted, but still has valid data from the most recent calibration.

OVEN FAULT - A reference whose oven has lost control, this may occur if the ambient temperature is above 40C or due to a failure of the oven control circuitry.

NOISY - OBRMS has detected an error of greater than 7ppm, but less than 50ppm. If present error has returned to less than 3.5ppm then this reference may be returned to use at midnight, or by performing an Internal Calibration.

BAD DATA - A reference which has its latest calibration data corrupted, but still has valid earlier calibration data.

MED ERROR - OBRMS has detected an error of greater than 50ppm, but less than 150ppm. If error reduces to less than 50ppm then will automatically be changed to NOISY status.

FAULTY - OBRMS has detected an error of greater than 150ppm or a system check has determined that the reference averaging of this reference will yield an error. This condition will not be automatically reset if the condition is not found later, but may only be reset by an External Calibration.

NO CALDATA - A reference which has no valid calibration data.

NOT FITTED - A reference which is not fitted. This may also be caused by the reference having a faulty NOVRAM which will not accept calibration data (see Section X for details).

SECTION IX

CALIBRATION

9.1 General

The following paragraphs describe the overall calibration requirements for the 2720GS and the method of performing the external calibration of the unit. It is assumed that the user is familiar with the operation of the 2720GS and that section VI has been read.

9.2 Calibration Philosophy

The maintenance of the specifications of the 2720GS is achieved by the combined use of three "styles" of calibration :

a) Internal "factory" adjustments - the internal adjustments do not require periodic adjustment, only being needed following component replacement. If any of these "factory" adjustments are adjusted then a full internal calibration must be performed followed by an external calibration.

b) Automatic internal calibration - these automatic calibration sequences are fully described in section 6.21 and are used to correct for drift in the resistive attenuators used for the various ranges, and any zero offsets. Internal calibration is also used to perform the primary calibration on the nullmeter and external reference inputs and the various internal Analog to Digital convertor monitoring systems within the 2720GS. The sequences performed by the Internal calibration do not require user skill and the recommended intervals are :

Output Gain - every 30 days or greater than 5C change
Nullmeter - every 3 years
Output zeroes - every year
External Reference - every 30 days or greater than 5C change

c) External calibration - the user interactive external calibration is performed without the need to remove any covers etc. and is employed to maintain the absolute calibration of the output voltage and the internal reference division ratio. The recommended calibration interval for performing an external calibration is dependent on the accuracy required by the user. The user is referred to the accuracy specifications in section 2.2 to determine the number of days between external calibrations in order to maintain the desired accuracy. If the 2720GS should drop two references out of use, then this should also be used to indicate that an external calibration is necessary. The user will also find that the older the 2720GS is, the less frequent the calibrations are required, this is particularly true if the user is able to use the drift analysis package in the 2720GS (the use of this facility is not relied upon for the accuracy specifications in 2.2). Valhalla Scientific recommends that, for best results, an external calibration interval of 60 days during the first year, 90 days in the second,

and 180 days thereafter be used. The five portions of an external calibration and their affect on the 2720GS are shown below in the order in which they are performed :

10V calibration - 2720GS "learns" the absolute volt
1V calibration - Used with the 10V step to "learn" voltage ratio
100V calibration - Used to "learn" any abnormal 100V requirements
1000V calibration - Used to "learn" any abnormal 1000V requirements
Ammeter Calibration - calibrates the internal ammeter (required every 3 years)

The user should note that the only "required" calibrations are that of 10V, 1V and the ammeter. The 100V and 1000V calibrations are only included to "align" the 2720GS' high voltage output to the users own standards, the periodic calibration of these ranges being achieved by the Internal calibration procedure and thus it is unnecessary to periodically calibrate externally these ranges.

9.3 External Calibration Procedure
The following paragraphs describe the procedure to follow to perform a full external calibration. The user should note (as noted in 9.2) that it is not necessary to perform all of the following steps.

9.3.1 Preparation
It is highly recommended that the 2720GS be powered and operational for at least 2 hours continuously prior to performing an external calibration and that the user fully read all of the following paragraphs in this section before starting the external calibration sequence.
Immediately prior to performing an external calibration the user should perform an Internal calibration of "Output Gain" (see 6.21) followed by zeroing the nullmeter (see 6.9).

9.3.2 Initial External Calibration Steps
The external calibration sequence is started by the user turning the key operated CALIBRATION switch (mounted on the front panel) to the CALIBRATE position. The 2720GS will respond by requesting if the user requires to correct the Date information. If the user requires to alter the date information then this may be achieved by the utilization of the STEP CONTROL arrow keys (to adjust the date) followed by ENTER. If the user does not require to alter the date information then this is achieved by pressing either the ENTER or NO keys when requested.
The 2720GS will now request the user enters the calibration temperature (in degrees Celsius). The user must enter the actual ambient temperature using the numeric keys followed by the ENTER key or press the NO key if the temperature is unknown. The accuracy of the temperature entered need only be +/- 2C.

9.3.3 10V Calibration Step

After completing (or skipping) the temperature entry the 2720GS will request the user provide the connections for the 10V calibration step. If desired, the user may skip the 10V calibration step by pressing the NO key at this point in the sequence. The user has two alternative methods of achieving the 10V calibration:

9.3.3.1 10V Calibration Using a 6 to 11V Standard

The 2720GS and the 6-11V source are connected as shown in Figure 9-1. The user should take care with the polarity of the connections ensuring that the nullmeter will see a positive voltage if the 2720GS has an output which is higher than that of the standard. When the user has made the required connections the ENTER key should be pressed. The 2720GS will now prompt the user for the actual voltage of the 6-11V standard, this should be entered by the user using the DATA ENTRY numeric keys followed by ENTER. The 2720GS will now alter its output to achieve a null between its output voltage and the standard, and will display the correction required in the lower display in ppm. When this has settled the user should check that the correction is within expected limits and press the ENTER key to inform the 2720GS to accept the calibration data. If the displayed correction appears larger than expected then the user should carefully check the connections and the standard. If these are as expected then the calibration should be aborted by turning the calibration keyswitch to the OPERATE position, and the 2720GS checked to determine if maintenance is required.

9.3.3.2 10V Calibration Using a 0.6 to 1.1V Standard

The 2720GS and the 0.6-1.1V standard should be connected as shown in Figure 9-2 using a 10:1 voltage divider with an accuracy of better than 0.5ppm. The user should take care with the polarity of the connections ensuring that the nullmeter will see a positive voltage if the 2720GS has a divided output which is higher than that of the standard. When the user has made the required connections the ENTER key should be pressed. The 2720GS will now prompt the user for the actual voltage of the standard, this should be entered by the user using the DATA ENTRY numeric keys followed by ENTER. The 2720GS will now "know", from the fact that only 0.6 to 1.1V were entered, that its output is connected to a 10:1 divider.
The 2720GS will now alter its output to achieve a null between its divided output voltage and the standard, and will display the correction required in the lower display in ppm. When this has settled, the user should check that the correction is within expected limits and press the ENTER key to inform the 2720GS to accept the calibration data. If the displayed correction appears larger than expected then the user should carefully check the connections and the standard. If these are as expected then the calibration should be aborted by turning the calibration keyswitch to the OPERATE position, and the 2720GS checked to determine if maintenance is required.

9.3.4 1V Calibration Step

After completing (or skipping) the 10V calibration step the 2720GS will request the user to provide the connections for the 1V calibration step. If desired, the user may skip the 1V calibration step by pressing the NO key at this point in the sequence. The user has two alternative methods of achieving the 1V calibration:

9.3.4.1 1V Calibration Using a 6 to 11V Standard

The 2720GS and the 6-11V standard should be connected as shown in Figure 9-3 using a divider with an accuracy of better than 0.5ppm. The user should take care with the polarity of the connections ensuring that the nullmeter will see a positive voltage if the 2720GS has an output which is higher than that of the divided standard. When the user has made the required connections the ENTER key should be pressed. The 2720GS will now prompt the user for the actual voltage at the divider output (i.e. a tenth of the standard), this should be entered by the user using the DATA ENTRY numeric keys followed by ENTER. The 2720GS will now alter its output to achieve a null between its output voltage and the divider output, and will display the correction required in the lower display in ppm. When this has settled, the user should check that the correction is within expected limits and press the ENTER key to inform the 2720GS to accept the calibration data. If the displayed correction appears larger than expected then the user should carefully check the connections and the standard, if these are as expected then the calibration should be aborted by turning the calibration keyswitch to the OPERATE position, and the 2720GS checked to determine if maintenance is required.

9.3.4.2 1V Calibration Using a 0.6 to 1.1V Standard

The 2720GS and the 0.6-1.1V standard should be connected as shown in Figure 9-1. The user should take care with the polarity of the connections ensuring that the nullmeter will see a positive voltage if the 2720GS has an output which is higher than that of the standard. When the user has made the required connections the ENTER key should be pressed. The 2720GS will now prompt the user for the actual voltage of the 0.6-1.1V standard, this should be entered by the user using the DATA ENTRY numeric keys followed by ENTER. The 2720GS will now alter its output to achieve a null between its output voltage and the standard and will display the correction required in the lower display in ppm. When this has settled, the user should check that the correction is within expected limits and press the ENTER key to inform the 2720GS to accept the calibration data. If the displayed correction appears larger than expected then the user should carefully check the connections and the standard, if these are as expected then the calibration should be aborted by turning the calibration keyswitch to the OPERATE position, and the 2720GS checked to determine if maintenance is required.

9.3.5 100V Calibration Step

After completing (or skipping) the 1V calibration step the 2720GS will request the user to provide the connections for the 100V calibration step. If desired, the user may skip the 100V calibration step by pressing the NO key at this point in the sequence. The user has two alternative methods of achieving the 100V calibration:

9.3.5.1 100V Calibration Using a 6-11V or 0.6-1.1V Standard

The 2720GS and the standard should be connected as shown in Figure 9-2 using a divider (either 10:1 or 100:1 for a 6-11 or 0.6-1.1V standard resp.) with an accuracy of better than 0.5ppm. The user should take care with the polarity of the connections ensuring that the nullmeter will see a positive voltage if the 2720GS has an output which is higher than that of the divided standard. When the user has made the required connections the ENTER key should be pressed. The 2720GS will now prompt the user for the actual voltage of the standard, this should be entered by the user using the DATA ENTRY numeric keys followed by ENTER. The 2720GS will now "know", from the fact that only 6-11V or 0.6-1.1V were entered, that its output is connected to a 10:1 or 100:1 divider. The 2720GS will now alter its output to achieve a null between its divided output voltage and the standard, and will display the correction required in the lower display in ppm. When this has settled, the user should check that the correction is within expected limits and press the ENTER key to inform the 2720GS to accept the calibration data. If the displayed correction appears larger than expected then the user should carefully check the connections and the standard, if these are as expected then the calibration should be aborted by turning the calibration keyswitch to the OPERATE position, and the 2720GS checked to determine if maintenance is required.

9.3.5.2 100V Calibration Using a 60 to 110V Standard

The 2720GS and the 60-110V standard should be connected as shown in Figure 9-1. The user should take care with the polarity of the connections ensuring that the nullmeter will see a positive voltage if the 2720GS has an output which is higher than that of the standard. When the user has made the required connections the ENTER key should be pressed. The 2720GS will now prompt the user for the actual voltage of the 60-110V standard, this should be entered by the user using the DATA ENTRY numeric keys followed by ENTER. The 2720GS will now alter its output to achieve a null between its output voltage and the standard, and will display the correction required in the lower display in ppm. When this has settled, the user should check that the correction is within expected limits and press the ENTER key to inform the 2720GS to accept the calibration data. If the displayed correction appears larger than expected then the user should carefully check the connections and the standard, if these are as expected then the calibration should be aborted by turning the calibration keyswitch to the OPERATE position, and the 2720GS checked to determine if maintenance is required.

9.3.6 1000V Calibration Step

After completing (or skipping) the 100V calibration step the 2720GS will request the user to provide the connections for the 1000V calibration step. If desired, the user may skip the 1000V calibration step by pressing the NO key at this point in the sequence. The user has two alternative methods of achieving the 1000V calibration:

9.3.6.1 1000V Calibration Using a 60-110,6-11V or 0.6-1.1V Standard

The 2720GS and the standard should be connected as shown in Figure 9-2 using a divider (either 10:1,100:1 or 1000:1 for 60-110,6-11 or 0.6-1.1V standard resp.) with an accuracy of better than 0.5ppm. The user should take care with the polarity of the connections ensuring that the nullmeter will see a positive voltage if the 2720GS has an output which is higher than that of the divided standard. When the user has made the required connections the ENTER key should be pressed. The 2720GS will now prompt the user for the actual voltage of the standard, this should be entered by the user using the DATA ENTRY numeric keys followed by ENTER. The 2720GS will now "know", from the fact that only 60-110V, 6-11V or 0.6-1.1V were entered, that its output is connected to a 10:1, 100:1 or 1000:1 divider. The 2720GS will now alter its output to achieve a null between its divided output voltage and the standard, and will display the correction required in the lower display in ppm. When this has settled, the user should check that the correction is within expected limits and press the ENTER key to inform the 2720GS to accept the calibration data. If the displayed correction appears larger than expected then the user should carefully check the connections and the standard, if these are as expected then the calibration should be aborted by turning the calibration keyswitch to the OPERATE position, and the 2720GS checked to determine if maintenance is required.

9.3.6.2 1000V Calibration Using a 600 to 1100V Standard

The 2720GS and the 600-1100V standard should be connected as shown in Figure 9-1. The user should take care with the polarity of the connections ensuring that the nullmeter will see a positive voltage if the 2720GS has an output which is higher than that of the standard. When the user has made the required connections the ENTER key should be pressed. The 2720GS will now prompt the user for the actual voltage of the 600-1100V standard, this should be entered by the user using the DATA ENTRY numeric keys followed by ENTER. The 2720GS will now alter its output to achieve a null between its output voltage and the standard, and will display the correction required in the lower display in ppm. When this has settled, the user should check that the correction is within expected limits and press the ENTER key to inform the 2720GS to accept the calibration data. If the displayed correction appears larger than expected then the user should carefully check the connections and the standard, if these are as expected then the calibration should be aborted by turning the calibration keyswitch to the OPERATE position, and the 2720GS checked to determine if maintenance is required.

9.3.7 Ammeter Calibration

After the 1000V calibration step has been completed (or skipped) the 2720GS will prompt the user if it is to calibrate the ammeter. The user may answer by pressing either the ENTER(YES) or NO keys. If the NO key is pressed then the 2720GS will automatically skip the ammeter calibration procedure.
If the ENTER(YES) key was pressed then the 2720GS will prompt the user to make the required connections to a 100 ohm 0.1% resistor (capable of handling 100mA) as shown in Figure 9-4. The user should make the connections and then press the ENTER key (or press the NO key to abort the ammeter calibration step). The 2720GS will now automatically calibrate the internal ammeter (displaying an error condition if it fails) and continue to the next step.

9.3.8 Request if to Use Drift Analysis

If the previous calibration was performed over 90 days previously and the temperature was within 3C of the present temperature, then the 2720GS can, if desired, perform drift analysis between these data, and forward extrapolate this drift rate into the future. The 2720GS will always request if the user wishes to perform this activity. The user is not advised to utilize this facility in any of the following circumstances :

a) If the 2720GS is under a year old.

b) If the previous calibration was obtained on different equipment

c) If either calibration is known to contain errors.

d) If the previous calibration was obtained by a different procedure

e) If any component in the 2720GS has been changed or altered since the previous calibration

9.3.9 Completion of Calibration

After either denying or allowing the drift analysis facility, the 2720GS has completed the external calibration procedure and will request that the user return the calibration keyswitch to the OPERATE position. The user **MUST RETURN THIS SWITCH TO THE OPERATE POSITION TO COMPLETE THE CALIBRATION.**
It is advised that the user perform an Internal Calibration of "Output Gain" (see 6.21) after the external calibration.

9.3.10 Recommended Path(s) Through the Above Procedure

The 2720GS "learns" voltage ratio from the ratio between the 1V and 10V calibration points. In order for the accuracy specification of the 2720GS to be maintained, this ratio must be known to within 0.5ppm or better. It is due to this that it is recommended that only a 10V or 1V (nominal) reference standard be used and all other calibration points be obtained by the use of dividers.

9.3.10.1 Using a 6 to 11V Reference Standard
This is the recommended method for calibrating the 2720GS, the best possible accuracy being obtained from a standard of between 6 and 6.5 volts or 9.5 and 11 volts. The calibration techniques shown in 9.3.3.1 and 9.3.4.1 are used with the recommended equipment listed below:

a) 6 to 11V standard (e.g. Valhalla 2732A or SRL Transcell IV)

b) 10:1 voltage divider with <0.5ppm accuracy (e.g. Fluke 752)

9.3.10.2 Using a 0.6 to 1.1V Reference Standard
This technique offers the advantage of being able to use the users' standard cells directly, thus it offers better traceability than using a 6 to 11V standard, but will offer slightly degraded accuracy (0.1 to 0.2ppm typically) due to performing the null at only a 1V level. The calibration techniques shown in 9.3.3.2 and 9.3.4.2 being used with the recommended equipment listed below:

a) Standard cell (or similar)

b) 10:1 voltage divider with <0.5ppm accuracy (e.g. Fluke 752)

9.4 Internal "Factory" Adjustments
The internal adjustments provided in the 2720GS are provided to accommodate internal component tolerances and thus it is not necessary to routinely adjust them, adjustment only being required following component replacement.
For all of the adjustments listed below it is necessary to remove the top cover of the 2720GS. This may be achieved by removing the four #6-32 x 3/8" flat head screws holding the top, rear bezel and the two #4-40 x 1/4" flat head screws holding the top cover. The top cover and rear bezel may now be removed for access to the 2720GS.

9.4.1 "Bootstrap" Offset Adjustment
This adjustment is only required following replacement of IC7 or RV1 on the OUTPUT SYSTEM PCB (right hand side of 2720GS from the front).

a) Ensure that the 2720GS has been powered, with the POWER switch in the ON position for at least ten minutes, before making this adjustment.

b) Select 5V output.

c) Select STANDBY

d) Monitor the voltage between the cathodes of D3 and D4 (on the OUTPUT SYSTEM PCB) with a voltmeter having 100uV (or better) resolution at zero DC.

e) Adjust RV1 on the OUTPUT SYSTEM PCB for a voltmeter reading of less than +/- 500uV DC.

9.4.2 Standby Power Supply Adjustment

This adjustment is only required following replacement of any of the components associated with IC2, or IC2 itself, on the LOW VOLTAGE POWER SUPPLY PCB (center of the 2720GS).
The use of the LOW VOLTAGE POWER SUPPLY EXTENDER PCB (part of option "XB20") is recommended.

a) Remove option "BAT" or "EBU" (if fitted)

b) Ensure 2720GS has AC power applied with the power switch in the STBY position for at least 30 minutes.

c) Monitor the voltage between the anode of D14 and the top (-) lead of C5 on the LOW VOLTAGE POWER SUPPLY PCB with a voltmeter having an accuracy of better than 0.01V at 21.25V DC.

d) Adjust RV1 on the LOW VOLTAGE POWER SUPPLY PCB for a voltage of 21.25V +/- 0.1V DC.

9.4.3 Reference Oven Temperature Adjustments

This adjustment is only required following component replacement in the oven control circuitry on the REFERENCE MODULE PCB.
Note : 2720GS with serial numbers prior to 20-127 only have one adjustment and no test point connector - contact Valhalla Scientific for details if an early reference module requires adjustment.

a) Remove option "BAT" or "EBU" (if fitted) and the AC power. Allow 2720GS to fully cool for at least 8 hours with the top cover and the REFERENCE SYSTEM COVER removed.

b) Remove the shorting link from all reference PCB test connectors and the test connector at the rear top edge of the OUTPUT SYSTEM PCB.

c) Apply AC power with the POWER switch in the STBY position.

d) Monitor the voltage between pins 5 (+) and 6 (-) on the respective PCBs' test connector (front top edge) with a voltmeter with an accuracy of better than 0.01V at 0.5V DC.

e) Adjust RV1 for a reading of 0.5 +/- 0.05V DC on the voltmeter. Note that if the ambient temperature is not 20C then this voltage should be decreased by 0.02V per degree C above 20C. The user should also note that the "HEATING" LED on the reference PCB should be illuminated at this time.

f) Monitor the voltage between pins 3 (+) and 8 (-) on the test connector with the above voltmeter.

g) Adjust RV2 for a reading of 0.1V more than that obtained in step e) above.

h) When all required adjustments have been completed then the user should replace the shorting links and the REFERENCE SYSTEM COVER unless the Divider Oven temperature adjustments are also to be carried out.

9.4.4 Divider Oven Temperature Adjustments

This adjustment is only required following component replacement in the oven control circuitry on the OUTPUT SYSTEM PCB.
Note : 2720GS with serial numbers prior to 20-127 only have one adjustment and no test point connector - contact Valhalla Scientific for details if an early output system requires adjustment.

a) Remove option "BAT" or "EBU" (if fitted) and the AC power. Allow 2720GS to fully cool for at least 8 hours with the top cover and the REFERENCE SYSTEM COVER removed.

b) Remove the shorting link from all reference PCB test connectors and the test connector at the rear top edge of the OUTPUT SYSTEM PCB.

c) Apply AC power with the POWER switch in the STBY position.

d) Monitor the voltage between pins 3 (+) and 4 (-) on the test connector (rear top edge) with a voltmeter with an accuracy of better than 0.01V at 0.5V DC.

e) Adjust RV301 for a reading of 0.5 +/- 0.05V DC on the voltmeter. Note that if the ambient temperature is not 20C then this voltage should be decreased by 0.02V per degree C above 20C. The user should also note that the "HEATING" LED on the output system PCB should be illuminated at this time.

f) Monitor the voltage between pins 2 (+) and 1 (-) on the test connector with the above voltmeter.

g) Adjust RV302 for a reading of 0.1V more than that obtained in step e) above.

h) When the adjustments have been completed then the user should replace the shorting links and the REFERENCE SYSTEM COVER.

9.4.5 DAC Zero Adjustment

This adjustment should only be made following replacement of components in the Digital To Analog convertor.

a) Ensure that the 2720GS has been powered for at least one hour with the POWER switch in the ON position and the top cover in place.

b) Select 5V output voltage with the output in the zero volt STANDBY state (if the user is unsure then selecting OPERATE followed by STANDBY will achieve this).

c) Monitor the voltage on the output SENSE terminals with a voltmeter (or the internal nullmeter) having a resolution of 1uV DC.

d) Adjust RV301 on the MAIN MICROPROCESSOR PCB (center of unit) for a voltmeter reading of less than +/- 25uV DC.

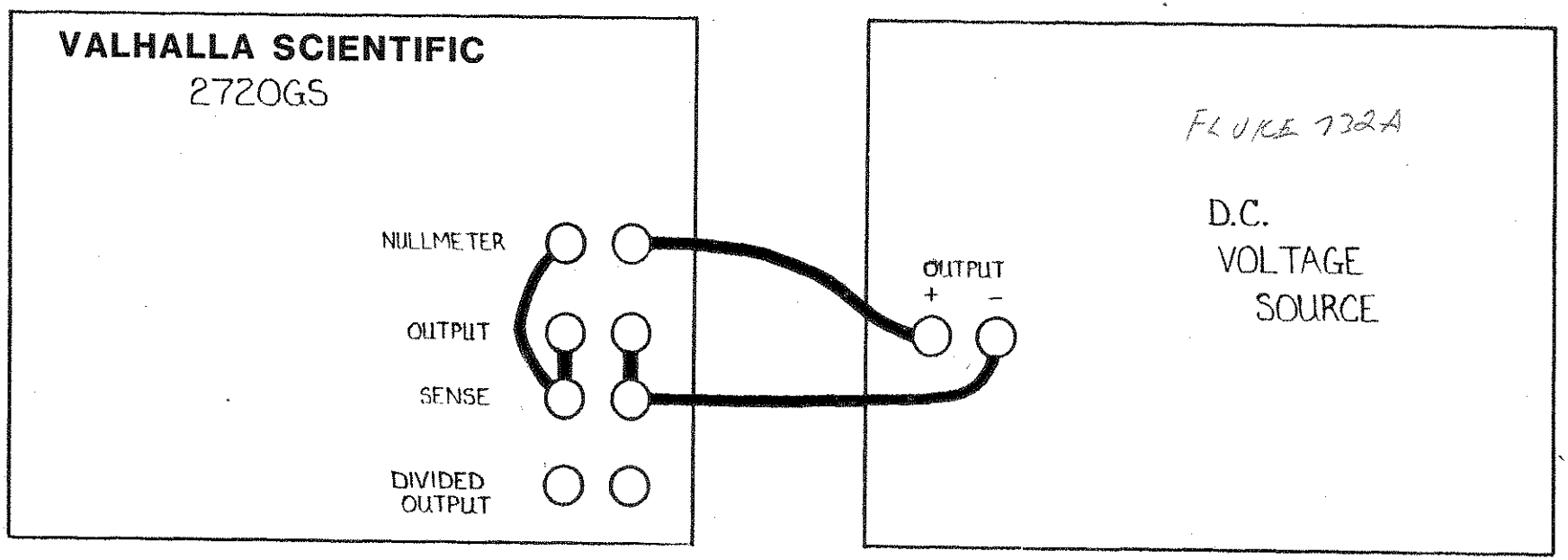


FIGURE 9-1
CALIBRATION WITHOUT A DIVIDER

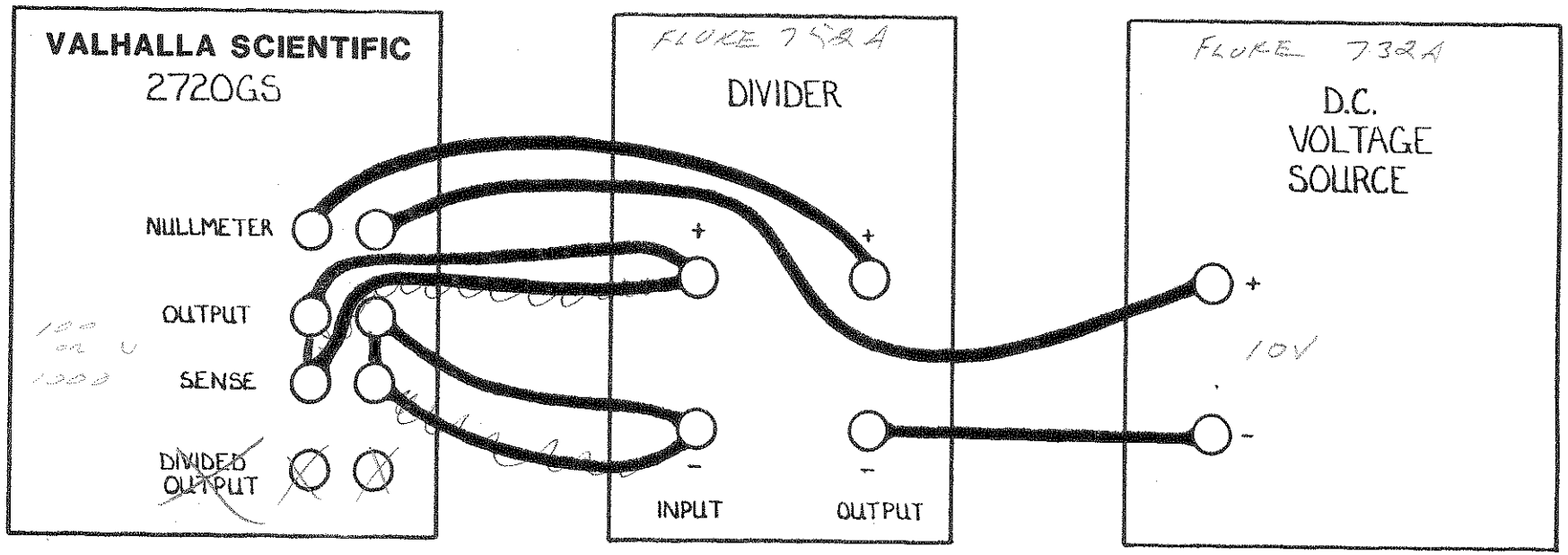


FIGURE 9-2
CALIBRATION USING A DIVIDER

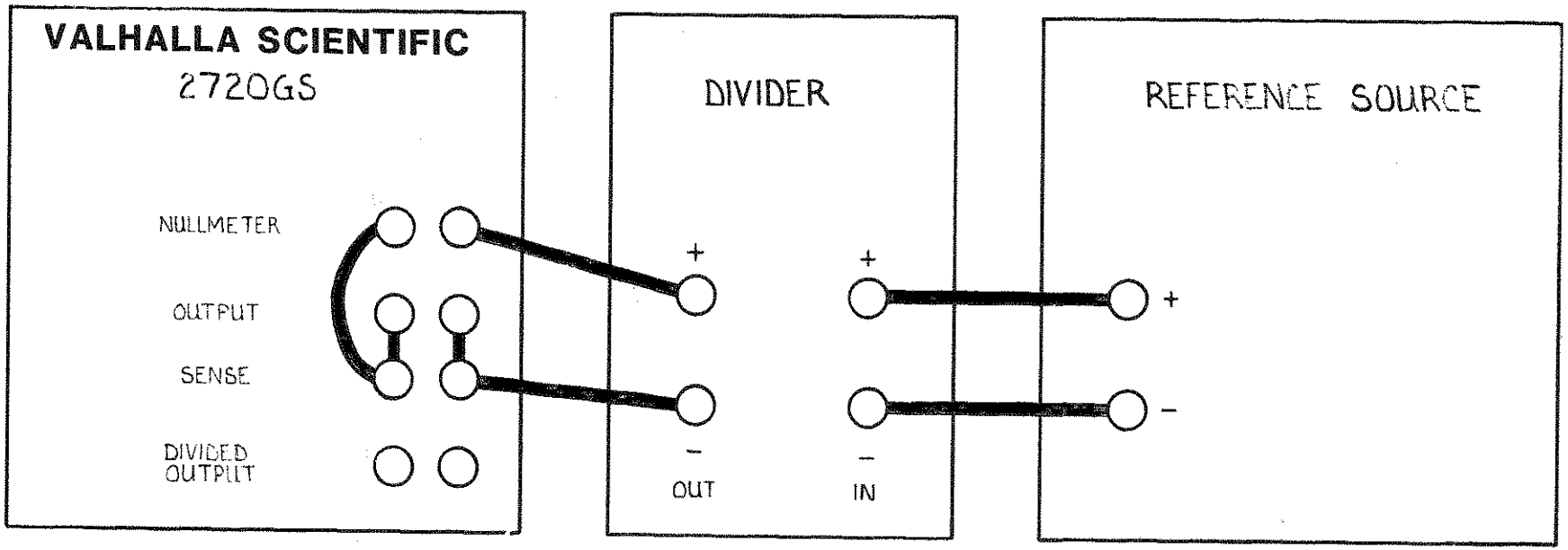


FIGURE 9-3

CALIBRATION WITH A DIVIDED REFERENCE

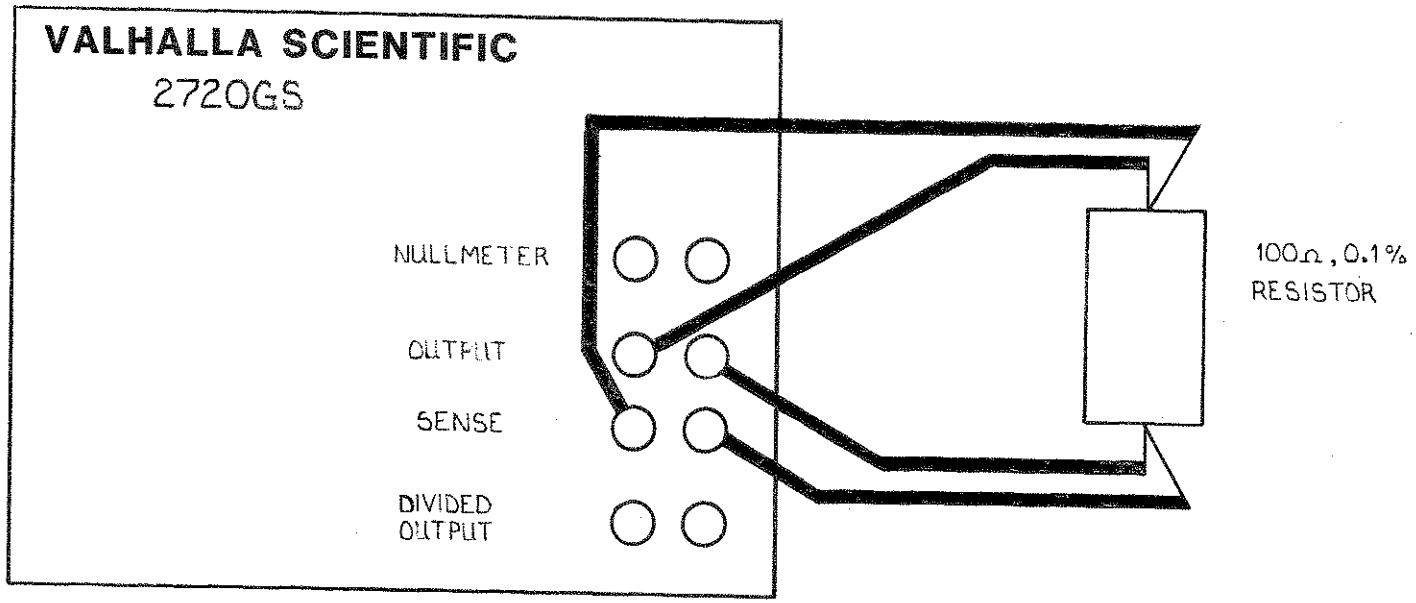


FIGURE 9-4

AMMETER CALIBRATION

SECTION X

MAINTENANCE AND TROUBLESHOOTING

10.1 General

The following paragraphs provide the information required to perform the required periodic maintenance and basic guidelines on trouble-shooting the 2720GS.

10.2 Periodic Maintenance

The 2720GS requires little periodic maintenance, that which is required is discussed in the following paragraphs.

10.2.1 Cleaning

It is recommended that the 2720GS be operated in a clean environment, however if the environment is "dusty" then periodic cleaning of the unit will be required.

The fan (on the rear panel) has a cleanable filter element which should be taken out and blown clean with compressed air (note that units prior to serial number 20-127 may not have this filter fitted, one may be ordered from Valhalla Scientific under part number 5-10491). The replaceable element may be ordered from Valhalla Scientific under part number 5-10492.

Loose dirt or dust, which is collected on the exterior surfaces of the 2720GS, 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 2720GS interior may be cleaned by blowing with dry compressed air.

If the 2720GS has become "heavily" contaminated with dirt or by other contaminant(s) then it is recommended that the unit be completely overhauled (contact your local Valhalla Scientific Service Center for details).

10.2.2 Battery Replacement

10.2.2.1 Internal Battery Replacement

The real time clock and non-volatile (non-calibration) data memory are maintained by an internal non-rechargeable battery located on the front-panel assembly. This battery has an expected life of five years, and a low voltage condition is indicated by the LOW BATT LED on the front panel (SYSTEM CONTROL section) being illuminated. Replacement of this battery is recommended at five year intervals and may be ordered from Valhalla Scientific under part number 5-10458.

a) Remove all power sources from the 2720GS.

b) Remove the top cover and top bezels by the removal of the eight 6-32 x 3/8" and the two 4-40 x 1/4" screws retaining them.

c) Remove the bezel on the POWER switch by carefully unscrewing it.

d) Place the 2720GS on its side and remove the two front feet from the bottom of the 2720GS.

e) Remove the two 6-32 x 1/2" black screws retaining the front panel assembly.

f) Remove the front, lower bezel by the removal of the remaining two 6-32 x 3/8" screws retaining it and pulling it slightly forward.

g) Carefully remove the front panel assembly away from the unit, unplugging the 24-way ribbon cable from it while doing so.

h) Place the front panel assembly face down on a soft, clean work surface and remove the PCB containing the battery.
On units prior to serial number 20-127 this will be the REAL TIME CLOCK PCB and the battery is notated as B1. The PCB is removed by unscrewing the four retaining screws and carefully pulling away the PCB from the remaining assembly.
On later units this will be the I/O PROCESSOR PCB and the battery is notated as B101. The PCB is removed by unscrewing the six nuts and carefully pulling away this PCB from the rest of the assembly.
After replacement the old battery should not be disposed of by fire and under no circumstances should an attempt to recharge it be made.

i) Reassembly is the reverse of the above procedure taking care to ensure that the correct screws and nuts are used and that each item is correctly seated.

10.2.2.2 Option "BAT" Battery Replacement
The batteries used in this option are of the sealed lead-acid type and are fully rechargeable. The 2720GS is equipped with the required charging circuitry to maintain these batteries. These batteries should last the entire life of the 2720GS, however if replacement does become necessary then the following procedure should be followed.

a) Remove the option "BAT" from the 2720GS and place on a clean work surface.

b) Remove the four 8-32 screws retaining the battery strap to the external "box" and remove the strap.

c) Carefully unplug the connections to each battery and remove the batteries.

d) Reassembly with new batteries is the reverse of the above procedure. The user is warned to take extreme care with the polarity of each battery as explosion could result from extended use with one or more reversed battery.
The option "BAT" will require a full 24 hour charge to initially obtain the specified period for maintenance of the 2720GS internal circuitry power.

10.2.3 System Check
It is recommended that a periodic check of the internal circuitry be performed every 30 days, or whenever the correct performance of the 2720GS is suspect. This may be achieved by performing a system check (see 6.12). A list of all the messages displayed by the 2720GS and their meanings is included at the end of this section.

10.2.4 Internal Calibration
This periodic "maintenance" has been discussed in sections VI and IX and the user should refer to these sections.

10.3 Troubleshooting
The following paragraphs give basic procedures for troubleshooting and component replacement in the 2720GS.

10.3.1 Component Replacement
The 2720GS accuracy and reliability can only be maintained if the following precautions are taken when changing a component:

a) Only use the specified component or exact equivalents. Spare parts can be ordered from your nearest Valhalla Scientific Service Center by the Valhalla part number listed in the parts list in section XV of this manual. Please provide the type and serial number of the unit with your order.

b) Only use 63/37 rosin core electronic grade solder with a 50W (or lower) maximum power soldering iron.

c) Always use extreme care when removing or inserting components.

d) The MAIN MICROPROCESSOR PCB located down the center of the 2720GS is a four layer PCB, thus extreme care must be taken not to damage any plated-through holes when removing components from this PCB.

e) Most of the semiconductor devices used in the 2720GS can be damaged by static discharges. Thus the user should follow strict static free procedures to ensure that damage does not occur.
The user should :
Minimize handling of components and assemblies to a minimum.
Transport and store components in the original containers.
Discharge any static build up on the user (or 2720GS) prior to handling components or assemblies.

Handle the components such that all (or many as possible) of the leads are in contact with the user.
Never slide a component over a surface.
Use a grounded tip soldering iron and ensure that the assembly being (de)soldered is also grounded.

f) When soldering leads to the terminals the user must ensure that the highest possible quality soldering is used. A dry joint may cause the 2720GS to exceed its specification limits.

10.3.2 Assembly Replacement
The user may order complete replacement assemblies (on an exchange basis) from the nearest Valhalla Scientific Service Center under the following numbers :

2720-601 : I/O PROCESSOR PCB ASSEMBLY
2720-602 : LOW VOLTAGE POWER SUPPLY PCB ASSEMBLY
2720-603 : MAIN MICROPROCESSOR PCB ASSEMBLY
2720-604 : REFERENCE MODULE PCB ASSEMBLY
2720-606 : DISPLAY PCB ASSEMBLY
2720-607 : NULLMETER PCB ASSEMBLY
2720-609 : OUTPUT SYSTEM PCB ASSEMBLY
2720-613 : HIGH VOLTAGE POWER SUPPLY ASSEMBLY
2720-614 : REAL TIME CLOCK PCB ASSEMBLY (20-127 and earlier-units)
2720-401 : FRONT PANEL ASSEMBLY (complete assembly inc. PCBs)
2720-403 : AMPLIFIER ASSEMBLY (complete inc. PCBs)

The physical location of each of these assemblies and PCBs is shown in Figure 10-1.
The serial number and list of fitted options fitted in the 2720GS must given at the time of order.

10.3.3 Finding the Faulty Assembly or Component
The internal system check of the 2720GS will generally obtain the assembly on which a fault lies. The indicated fault will often allow the user to directly obtain the area on the assembly in which to start troubleshooting down to the component level if required. In order to troubleshoot the 2720Gs down to component level the user must have a grasp of the operating principles of the 2720GS, which are explained fully in section XI of this manual.

10.3.3.1 Displayed Informative, Warning and Error Messages.
A list of all of the possible display messages for the 2720GS is given below, along with an explanation of the cause of the message ("x" is used to indicate that a numeric quantity will appear in this position):

"ILIM 13V xxxmA "
"ILIM 130V xxxmA "
"ILIM1200V xxxmA "
Requesting current limit for amplifier

"-- 100mA MAX ---"
"--- 30mA MAX ---"
Entered current limit beyond limitation, 2720GS will set limit to maximum allowed

"UPPER VOLT LIMIT"
"LOWER VOLT LIMIT"
Request for voltage limits

"SETTING DEFAULTS"
Indicates that non-volatile battery maintained data has been lost. If occurs often, then replace FRONT PANEL ASSEMBLY after checking rear-panel configuration switch (see 5.1.2.2)

"INT REF xxxxDAYS"
"DIVIDER xxxxDAYS"
"INT CAL xxxxDAYS"
"NULLMTR xxxxDAYS"
"SETZERO xxxxDAYS"
"EXT REF xxxxDAYS"
Response to "LAST CAL" key

"- VERSION xx.xx -"
Displayed as part of the power on cycle.

"I/O ROM FAILURE "
IC25 on I/O PROCESSOR PCB has failed

" CLOCK FAILURE "
Real time clock on I/O PROCESSOR PCB has failed

" I/O uP FAILURE "
I/O PROCESSOR PCB failure (probably IC10)

"I/O RAM FAILURE "
I/O PROCESSOR PCB failure (probably IC8)

"- IEEE FAILURE -"
I/O PROCESSOR PCB failure (probably IC2)

" INPUT VOLTAGE? "
Request for external reference input voltage

"DATA ENTRY ERROR"
Incorrect external reference voltage entered

"NOT WARM xx MINS"
2720GS has not been powered long enough to perform the required operation.

" DIVISION RATIO?"
Request for ratio of external divider

"- CHANGE DATE? -"
Request if date data is correct

" TEMPERATURE ? "
"TEMPERATURE xxC"
Request for temperature of calibration

"- CAL ABORTED "
Keyswitch returned to the OPERATE position. Calibration is aborted

"-- CONNECTIONS (NO TO ABORT) "
Request for user to provide the required connections during External calibration

"- AMMETER CAL -"
"-- AMMETER CAL? (YESorNO) "
Request if user wishes to calibrate the internal ammeter.

"- CAL FAILURE -"
Failure to calibrate ammeter. The user should carefully check his connections and 100 ohm resistor. If connections OK, then OUTPUT SYSTEM PCB is faulty.

" DRIFT ANALYSIS "
"-- USE DATA FOR DRIFT ANALYSIS? (YESorNO) "
Request if user wishes to use this calibration data for automatic drift analysis

"CALIBRATION END"
"TURN OFF CAL KEY"
Calibration complete, request to return the CALIBRATION keyswitch to the OPERATE position.

" ENTER 10V STD "
" ENTER 1V STD "
" ENTER 100V STD "
" ENTER 1000V STD"
Request for user to enter value of standard

"IEEE ADDRESS xx "
Display of present IEEE address

"NO A-D CONVERTOR"
Cannot perform requested activity due to faulty A-to-D convertor

"- INTERNAL CAL -"
Performing Internal Calibration

" OUTPUT GAIN ? "
" OUTPUT ZEROES? "
"-- NULLMETER? --"
Request if to internally calibrate the indicated section

"INT CAL COMPLETE"
Internal calibration completed

"----- PASS -----"
"----- FAIL -----"
Test/calibration result

"- CAL - KREFAV -"
Calibration of reference averaging system. If fails then check REFERENCE MODULE PCBs and MAIN MICROPROCESSOR PCB.

"-- CAL -- KB2 --"
"-- CAL -- KA2 --"
"-- CAL - KA10 --"
"-- CAL KA100 --"
Performing calibration of OUTPUT SYSTEM PCB dividers. If fails then check OUTPUT SYSTEM PCB.

" CAL - DVM ZERO "
" CAL DVM SCALING"
Performing calibration of internal DVM. If fails then check OUTPUT SYSTEM PCB and AMPLIFIERS.

" CAL - DAM ZERO "
Performing calibration of ammeter zero. If fails then check OUTPUT SYSTEM PCB.

"CAL - NULL ZERO "
"CAL - NULLMETER "
Performing calibration of nullmeter. If fails then check user connections and then NULLMETER PCB

" CAL 6.5V ZERO "
" CAL -MDAC ZERO "
" CAL 650mV ZERO "
"CAL 1300mV ZERO "
" CAL 0.65V ZERO "
" CAL 1.3V ZERO "
" CAL 13V ZERO "
" CAL 26V ZERO "
" CAL 65V ZERO "
" CAL 130V ZERO "
" CAL 600V ZERO "
" CAL 1200V ZERO "
Performing calibration of the zero of the indicated range. If fails then check OUTPUT SYSTEM PCB and AMPLIFIERS.

" CAL - EXT REF "
Performing calibration of option EXR1/7/10. If fails then check option.

" NO SUCH MEMORY "
User entry of memory location number out of range (000 to 557)

"--MEMORY--xxx---"
Request for user entry of memory location number.

"- ERROR LIMIT? -"
Request for user entry of error limit to use in memory contents.

"--- STANDBY? ---"
Request if user wishes 2720GS to enter standby when memory contents are recalled.

"--- HI THERE ---"
Greeting from 2720GS to user when power applied.

"MAIN uP FAILURE "
Failure of MAIN PROCESSOR PCB detected. Probably IC9 or associated circuitry.

"REF x NOT FITTED"
"REF x NO CALDATA"
"REF x FAULTY "
"REF x MED ERROR "
"REF x BAD DATA "
"REF x NOISY "
"REF x OVEN FAULT"
"REF x LOST DATA "
"REF x BEING USED"
Display of status of reference x. See section VIII for details.

"EXREF NOT FITTED"
"- EXREF FAULTY -"
"--- EXREF OK ---"
Display of option EXR1/7/10 status.

"- OPTION EXR1 --"
"- OPTION EXR7 --"
"- OPTION EXR10 -"
Display of type of EXR option which is fitted.

"---- DVM OK ----"
"-- DVM FAULTY --"
Display of DVM status. DVM is located on the OUTPUT SYSTEM PCB

"-- AMMETER OK --"
" AMMETER FAULTY "
Display of ammeter status. Ammeter is located on the OUTPUT SYSTEM PCB.

"--- AtoD OK ----"
"-- AtoD FAULTY -"
Display of Analog to Digital convertor status. The AtoD is located on the MAIN MICROPROCESSOR PCB.

"NO OPTn BAT/EBU "
" BAT/EBU FITTED "
"LOW VOLT BAT/EBU"
Display of option BAT or EBU status.

"- NO NULLMETER -"
"FAULTY NULLMETER"
"- NULLMETER OK -"
Display of nullmeter status. The NULLMETER PCB should be checked if not OK.

" 13V AMP OK "
" 13V AMP FAULT "
" 130V AMP OK "
" 130V AMP FAULT "
" 1200V AMP OK "
"1200V AMP FAULT "
Display of amplifier statii. Check HIGH VOLTAGE POWER SUPPLY PCB and AMPLIFIER ASSEMBLY if not OK.

"- SYSTEM CHECK -"
Presently performing a system check.

"--- DIGITAL? ---"
"---- AtoD's? ---"
"--- OUTPUT ? ---"
"--- EXT REF? ---"
Request if to check the indicated portion of the 2720GS.

"CHECKING DIGITAL"
" CHECKING DVM "
"CHECKING AMMETER"
" CHECKING AtoD "
"CHECKING 13V AMP"
"CHECKING 130VAMP"
"CHECKING1200VAMP"
"CHECKING REF SYS"
"CHECKING EXT REF"
Display of the portion of the 2720GS presently being checked.

" NOVRAM FAULTY "
A faulty NOVRAM has been detected. Check REFERENCE MODULEs, OUTPUT SYSTEM PCB, NULLMETER PCB and EXR1/7/10 option. The status display at the end of system check will determine which has failed. This failure can also be caused by a failure of the Main uP IC9 or associated circuitry.

" OUTSIDE LIMITS "
Attempted to obtain output voltage outside of entered voltage limits.

"CHECKS COMPLETED"
System check completed.

"-- REMOVE CONNECTIONS (NO TO ABORT) "
Request user remove connections to terminals.

"NO FAULTY PARTS "
Result of power on test if no faulty portions of the 2720GS are detected.

"NO DIVIDER DATA "
2720GS cannot be operated due to the lack of 1V external calibration data. Contact your nearest Valhalla Scientific Service Center for details.

"DIVIDER OVEN BAD"
Fault in the oven control portion of the OUTPUT SYSTEM PCB.

"NO INT CAL DATA "
Internal Calibration data has been lost. Perform INT CAL to obtain new data. If persists then check OUTPUT SYSTEM PCB.

"INT CAL DATA OK "
Internal Calibration data is valid.

"WARMUP IS xxMINS"
Display of warm up time after application of power.

"SYSTEM ERR- MATH"
A mathematics overflow has occurred. Usually caused by bad internal calibration data. Contact your nearest Valhalla Scientific Service Center if condition persists.

"OUTPUT OVER MAX "
Requested output voltage cannot be obtained. Probably due to failure of an output amplifier.

"- OUTPUT SLOW -"
Output cannot be taken below 30V and 3mA in order to change relays. Unit will continue after 3 seconds and ignore condition.
If output voltage/current cannot be controlled when correct range selected then further messages will be displayed.

"-- NO REFERENCES --"
2720GS cannot be operated due to there being no usable reference modules.

"-- OVER TEMP --"
Unit cannot be operated due to excessive operating temperature. If temperature is OK then check for internal overheating and MAIN MICROPROCESSOR PCB.

" CANNOT CAL YET "
Due to insufficient OBRMS data (see section VIII), the 2720GS cannot be calibrated at this time. If condition persists then check MAIN MICROPROCESSOR PCB.

"-- UNDEFINED SYSTEM ERROR "
Unknown source of error. Contact nearest Valhalla Scientific Service Center and supply fullest possible details as to when malfunction occurred. This error should never occur, but "catches" errors which should have been already discovered by other checks.

" ENTER PASSWORD "
Requests user enters password for data repair function.

" WRONG PASSWORD "
Incorrect password has been entered.

"-- NO DIVIDER NOVRAM "
"-- NO INT CAL NOVRAM "
2720GS cannot operate due to IC201, 202, 203 or 204 not being fitted on the OUTPUT SYSTEM PCB. If ICs are fitted then suspect IC indicated or possibly IC209.

"--UNDER TEMP --"
Warning message that the ambient temperature is below specified temperature limit for operating

"--- CHANGES ---"
Warning message that an item (shown in lower display) has changed its status.

"-- SELF TEST --"
Performing power on self test routines.

" SERIAL NUMBER ?"
Request for 2720GS serial number.

"----------------"
Indicates that an attempt was made by the 2720GS to display an unknown error message. This indicates a failure of the 2720GS, contact nearest Valhalla Scientific Service Center for details.

The above list of messages are those in the 2720GS at the time of writing. At each revision of the 2720GS the number of messages is extended to provide more and improved error, warning and informational messages. Should a message occur which the user requires help in understanding then he should contact the nearest Valhalla Scientific Service Center.

10.3.3.2 Non-Reported Failure Diagnostics

Although most of the possible failures are detected by the microprocessors in the 2720GS, there are some failures that either cannot be detected or cannot be displayed. These failures are listed here.

a) Unit provided with AC power, POWER switch in ON position but no display.
Check fuse, if OK then check LOW VOLTAGE POWER SUPPLY PCB, if OK then replace FRONT PANEL ASSEMBLY.

b) Power applied, POWER switch in STBY position but fan does not operate.
Check fuse, if OK then check LOW VOLTAGE POWER SUPPLY PCB, if OK then check fan.

c) Displays functional but "garbage" displayed.
Replace FRONT PANEL assembly.

d) Unit passes system check on all amplifiers but no voltages available on output terminals.
Check wiring to terminals, if OK replace OUTPUT SYSTEM PCB.

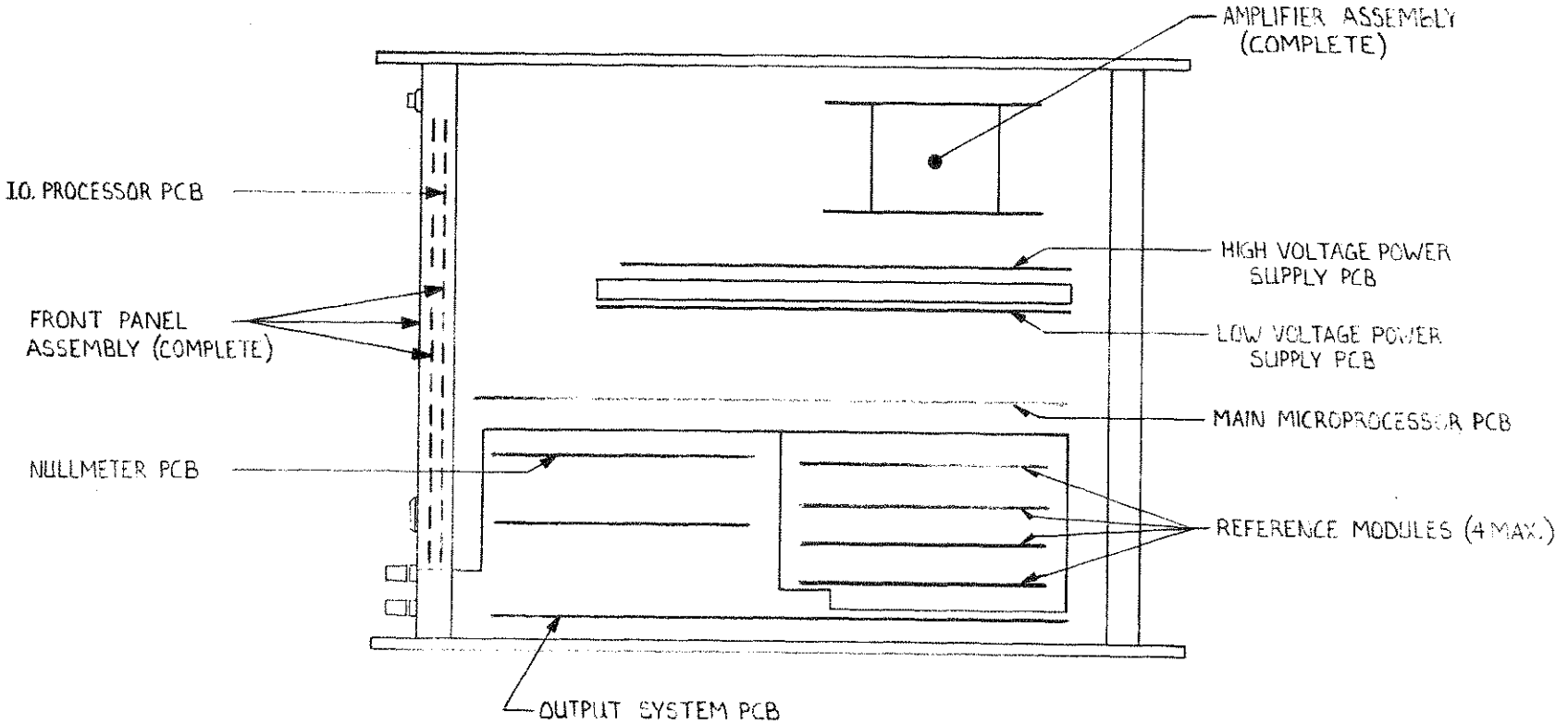


FIGURE 10-1

INTERNAL ASSEMBLY

SECTION XI

THEORY OF OPERATION

11.1 General

This section gives the theory of operation of the circuitry used in the 2720GS, and is divided into two parts. The first part is a functional description referring to the block diagram shown in Figure 11-1, the second being a detailed description referring to the schematic diagrams found at the end of this manual.

11.2 Functional Description

This section describes the general operation of each section of the 2720GS. The paragraph titles refer to the block diagram shown in Figure 11-1.

11.2.1 Earthy Section (Keyboard, Display, IEEE, Real Time Clock and I/O uP)

This section contains all of the circuitry required to interface to the user, both via the front panel and the IEEE 488 interface. The central item in this section is the I/O microprocessor which responds to commands from the user and from the main microprocessor, and issues data via the displays, IEEE 488 interface and to the main microprocessor.

11.2.2 Floating/Earthy Interface.

The main microprocessor and the I/O microprocessor communicate through this section, which provides optical isolation between the two sections.

11.2.3 Main Microprocessor

This uP section controls all of the analog circuitry in the 2720GS and operates under the control of the I/O uP. It generally performs "housekeeping" duties such as status checking and OBRMS while there is no activity commanded by the I/O uP.

11.2.4 Dual Reference Module

Each reference module contains two nominally 6.95V references. Each of these references has its own ovened enclosure and own constant current source for its supply. The pair of references, ovens and current sources are enclosed in a single oven on each reference module PCB. The main oven has circuitry to protect it from failure and consequent damage due to overheating. Each module contains a non-volatile memory (NOVRAM) which contains the actual voltage (and other data) for the latest six calibrations of the references.

The pair of reference outputs are multiplexed onto a common "reference average" line and also onto the main Analog to Digital convertor input.

11.2.5 Reference Generator
The reference generator section contains the main Analog to Digital convertor which is used by the main uP to check the references during OBRMS cycles (see section VIII), and during system check to check the output system, and during Internal Calibration of the 2720GS. This section also contains a buffer amplifier to supply the main Digital to Analog convertor with the average reference voltage.

11.2.6 Main Digital to Analog Convertor
This section provides an extremely linear output voltage controlled by digital data from the main uP and referenced to the reference voltage supplied by the reference generator.

11.2.7 Polarity Selection
This relay section provides polarity switching at the output of the main DtoA convertor.

11.2.8 Error Amplifier
This section compares the output of the DtoA convertor (via the polarity selection) and the main attenuator output, thus maintaining the voltage at the sense terminals (divided or amplified as required) at a fixed relationship to the output of the DtoA convertor.

11.2.9 13V, 130V and 1200V Amplifiers
These are the main high power amplifiers used to drive the output terminals. The amplifier in use is selected by the main uP from the output voltage required and the current limit required. The 2720GS will automatically utilize the next highest capability amplifier, if possible, should one fail.

11.2.10 Main Attenuator
This section senses and attenuates or amplifies the voltage at the sense terminals in order to provide the required scaling and to correct for scaling errors in the amplifiers or any external voltage drops in the cabling etc.. It is this section which controls the accuracy of all ranges of the 2720GS except the 6.5V range.

11.2.11 Nullmeter
The nullmeter is a separate high-resolution, auto-ranging digital voltmeter operating under the control of the main uP directly. It provides full opto- and transformer isolation from the rest of the 2720GS.

11.2.12 External Reference
The output of this section may be selected, by the main uP, to replace the internal references in driving the input to the reference generator and thus the rest of the 2720GS.

11.3 Detailed Description

The paragraphs that follow use the same functional blocks as that used in 11.2, but give full detail on their operation down to individual component level. Throughout this section it is assumed that the reader has a knowledge of electronics and is conversant with the operation of the 2720GS from the front panel.

11.3.1 Earthy Section

This section is described in its five functional parts and is physically located in the Front Panel Assembly.

11.3.1.1 Keyboard

The keyboard used in the 2720GS is of the "membrane" panel type and is fully sealed and integrated into one package yielding a single metal-backed front panel switch assembly.
The switches are arranged in a matrix which is shown in sheet 2 of drawing 2720-071. The I/O uP scans the switches periodically to check if any new switches are pressed and that the previous switch has been released. It does this by sequentially pulsing each "keyboard drive" line low (to 0V) and reading the "keyboard return" lines to see if this has pulled any of these lines low. As can be seen, each switch will produce a unique combination, allowing the I/O uP to determine the exact key which has been pressed.

11.3.1.2 Display

The circuitry for this section is shown in the schematic diagram 2720-076.
The display comprises of two distinct systems :

a) The main displays. These consist of two 16-character, 16-segment vacuum flourescent displays driven by IC1 and IC2. These are 32 bit shift registers operating under the control of the I/O uP. The displays are each multiplexed at 2048Hz by the I/O uP shifting the driver for each character (IC2) at this rate. At the time of each change the I/O uP loads the segment drive shift register (IC1) with the two sets (one for each display) of 16 bar data for the next display window, having latched the previous contents onto the outputs of the drivers. The displays are fully sealed units and require various voltage levels for their signals (+45V DC and two anti-phase 2.7V AC supplies at a DC voltage of approximately 8.5V DC) with the AC supplies being generated via a potentiometer to adjust the display brightness (RV1 on the I/O PROCESSOR PCB).

b) The LEDs. These consist of several discrete and one package of red LEDs driven in common anode configuration by seven current limiting, six bit latches (IC3 through 9). The LEDs are not multiplexed and the operating current (and thus brightness) is controlled by the adjusting resistor R1. The state of each latch is directly controlled by the I/O uP "writing" a six bit byte of data into the respective latch.

11.3.1.3 IEEE Interface

The control and operation of this interface is directly under the control of the I/O uP in conjunction with IC1, 2 and 15 (2720-071). An explanation of the interface is given in section VII of this manual and a full explanation of the functions of these integrated circuits is beyond the scope of this manual (the reader is referred to the manufacturers handbook on the MC68488 for full details).

11.3.1.4 Real Time Clock

The real time clock functions are generated within IC102 (2720-084 or 2720-071). This is a CMOS IC supplied from the supply labelled "+B" on the schematic, this is generated either from the battery or from the +5V supply whichever is higher. This selection is performed by the diodes D2 and 3 with C3 providing a smooth transition during changes in the power supply.
The real time clock is provided with a 32.768KHz reference clock by the crystal Y1 and is adjusted by means of C8 (the 32.768KHz should be monitored between TP1 and TP2 (GND)).

11.3.1.5 I/O Microprocessor

This section controls all front panel and IEEE portions of the 2720GS, providing commands to the Main Microprocessor to perform the action required by the user.
There are several parts that make up this section :

a) Microprocessor. A MC6803 (IC10) single-chip microcomputer is used in this section. A full description of this IC is beyond the scope of this manual and the user is referred to the manufacturers data on this part. The busses (Address and Data) are partially multiplexed out of IC10 (D0-7 are combined with A0-7 resp.) and are demultiplexed by the latch IC9. The microprocessor obtains its clock from an internal oscillator controlled by the 4MHz crystal Y1 and the capacitors C2 and C3.

b) Address Decode. The address map of the microprocessor is split up into the required portions by this section which consists of IC4 (74LS138) and IC3 (74154). These ICs provide the required selection signals for the various devices which are connected to the busses.

c) ROM. As standard the 2720GS has one ROM (IC25) with the provision for an extra ROM to accommodate user special user requirements. The standard ROM is a UV erasable 128K bit (16K x 8) device, which is factory programmed with the software required to operate the 2720GS.

d) RAM. The 2720GS stores all of its operating variables (e.g. the required output voltage, current limits, memory locations etc.) in a 64K bit (8k x 8) static RAM (IC8). This device is powered from the same supply as the Real Time Clock and thus its data contents are maintained by the battery during power down.

e) RESET control. This circuitry (consisting of IC103, TR101 and associated components) detects the absence of the main 5V supply to the I/O uP section. Whenever this supply is below 4.6V (approx.) the RESET line will be made high (and the "not RESET" line low), holding the microprocessor and associated components in a predetermined state which will protect the contents of the Real Time Clock and RAM.

11.3.2 Floating/Earthy Interface

This section is shown on Schematic 2720-071 and is located on the Front Panel Assembly.
The I/O microprocessor controls the activity of the rest of the 2720GS via this section. This is required because the I/O microprocessor and associated circuitry is ground referenced while the rest of the 2720GS is floating, thus opto-isolation is required in the digital data paths.
This is accomplished by the isolators IC23, 13, 12 and 11 and the associated circuitry. Data is transferred between the two microprocessor sections in one of two ways.

a) Static parallel data. There are three static control lines.
CAL is normally held low by the I/O uP until the Main microprocessor has requested permission to store non-volatile calibration data when it is released.
Not MRESET is normally released (high) by the I/O Microprocessor until a faulty Main Microprocessor (or a requirement for a fast transition to a safe condition is required) is detected when it is held low.
Not I/O RESET is normally released by the Main Microprocessor until it determines that the I/O Microprocessor is not functioning when it is pulsed low to attempt to restart the I/O Microprocessor.

b) Serial data with handshake. The lines Not GRANT, DATA RECEIVE, CLK, REC, TRT and DATA SEND are used for the transmission of commands and data between the two microprocessors. The user should note that the Not GRANT line is "bi-directional". The sequence used to transfer data/commands is outlined below:

The "dormant" state of these signals are :
Not GRANT - High
DATA RECEIVE - Low
CLK - Square wave at a 120us period (approx.)
REC - Low
TRT - Low
DATA SEND - Low

Data transfer from I/O to Main uP sections :

i) I/O uP releases DATA RECEIVE to a high state.
ii) If available, the Main uP pulls the Not GRANT line to a low state.

iii) After recognition of the GRANT line the I/O uP starts to transmit serial data on the REC line, clocked by the CLK signal.
iv) After the complete message has been transmitted the I/O uP pulls the DATA RECEIVE line low.
v) The Main uP releases the Not GRANT line to a high state.

Data transfer from Main to I/O uP sections :

i) Main uP releases DATA SEND to a high state.
ii) If available, the I/O uP pulls the Not GRANT line to a low state.
iii) After recognition of the Not GRANT line the main uP starts to transmit serial data on the TRT line, clocked by the CLK signal from the I/O uP.
iv) After the complete message has been transmitted the main uP pulls the DATA SEND line low.
v) The I/O uP releases the Not GRANT line to a high state.

11.3.3 Main Microprocessor

This section is shown on Schematic 2720-073 sheets 1 and 2 and is physically located on the Main Microprocessor PCB assembly.

11.3.3.1 Microprocessor

The main microprocessor itself is a MC68A09 (IC9) operating from a clock of 4.2MHz (approx.). An explanation of the operation of the microprocessor is beyond the scope of this manual and the user is referred to the manufacturers data sheet for this device. An outline of the signals used by the microprocessor is given below :

A0 through 15 - Address bus. Used to address the source/destination element for the data bus.
D0 through 7 - The data bus.
E - the microprocessor bus clock (1.05MHz approx.)
R - Read.High indicates a read operation is in progress, low indicates a write operation.

11.3.3.2 ROM and RAM

The main microprocessor has its software factory programmed into a 16K x 8 UV erasable ROM (IC8) and stores temporary data in a 2K x 8 static RAM (IC7).

11.3.3.3 Address Decode

The address map of the microprocessor is divided into the required portions by the address decode circuitry consisting of IC1, 2, 3 and 4. These devices decode the top few address bus lines to perform this task, thus enabling the various devices on the busses one at a time.

11.3.3.4 Serial Link Control

The control of data reception/transmission between the two microprocessors is performed by a MC68A50 ACIA (IC10) with buffering for the interface lines provided by IC11. The operation of this device is beyond the scope of this manual and the user is referred to the manufacturers data sheet.

11.3.3.5 Frequency Counters

The nullmeter, ammeter and DVM in the 2720GS produce a frequency output. These signals are measured by the triple frequency counter device MC68A40 (IC12). This device measures these frequencies using the microprocessor clock (E) as the reference.

11.3.3.6 RESET and SAFE Control

This portion of circuitry, consisting of IC13 and associated components, controls the action of the microprocessor during power up and down, and also places the relays in the 2720Gs in a safe condition when required.

11.3.3.7 Calibration Data "Write" Control

The output of the address decode circuitry which commands the non-volatile memories in the 2720GS to store the data, is protected by IC6 from "unwanted" write actions. In order for the Main microprocessor to command this action it must obtain "permission" from the I/O processor, which will respond by releasing the CAL line high, which enables IC6 to pass this line through to the non-volatile memories.

11.3.3.8 Interface

The circuitry shown on sheet 2 of 2720-073 consists of the circuitry required to interface the microprocessor to the relays, FET switches and static lines to the I/O processor. These consist of four MC6821s (IC101, 102, 103 and 104). These ICs have lines which may be inputs or outputs (as determined by the microprocessor software). The operation of these ICs is beyond the scope of this manual and the user is referred to the manufacturers data sheet on this device. Several of the outputs of these ICs are level shifted by a number of NPN transistors (TR101-116).

11.3.4 Dual Reference Module

The circuitry for the dual reference module is shown in Schematic 2720-574. The user should note that there are **NO USER REPLACEABLE PARTS within the oven enclosure.** Under no circumstances should this cover be removed. Should a fault be traced to one of the reference modules in the 2720GS then it should be returned to Valhalla Scientific or one of its' Service Centers for replacement.

11.3.5 Reference Generator

The circuitry associated with this block is shown in the Schematic 2720-073 sheet 3 and is split into three functional portions.

11.3.5.1 Reference Averaging Buffer

The combined output of all selected references is buffered from the main D to A convertor by IC202 and associated components C203, 204, 205, 206 and R213. These components are configured as a non-inverting, unity gain buffer.

11.3.5.2 A to D Input Multiplex

The input to the main AtoD in the 2720GS is multiplexed between various points in the 2720GS by this circuitry. This is achieved by the use of FET switches (under the control of the Main Microprocessor) in series with 10Kohm resistors (to reduce transients). The input switches are TR201, 202, 203, 210 and 211 (plus FETs on the Dual reference Module(s)) and resistors R203, 204, 207, 208, 234 and 236. Any high-frequency noise present is filtered by capacitor C202. The output of the multiplexor is buffered by IC204 to present a low impedance signal to the Main AtoD convertor.

11.3.5.3 Main A to D Convertor

The remaining circuitry on sheet 3 of 2720-073 is the Main AtoD convertor. This is a monopolar "Voltage to Duty cycle" type of convertor producing 16-bit data at a reading rate of 512/sec. to the main microprocessor.

11.3.5.3.1 512Hz Generator

IC203, TR204, TR205 and associated components are configured to alternately switch the voltage at C207 between +6.2 and -6.2V at 512Hz. This produces a current through R220 which will be symmetrical about zero and is supplied to the integrator.

11.3.5.3.2 Integrator

IC207 and C209 form an integrator whose average output voltage (IC207 pin 6) will become more negative if the average sum of its input currents (through R218, 219, 220 and 222) becomes more positive. The component values are selected that the current through R220 from the 512Hz generator will always be more than that possible from any of the other resistors, thus the integrator output will be approximately a triangle waveform at 512Hz. The user should note that the average output of the integrator is not affected by the 512Hz waveform, since R220 is in series with a capacitor (C207) which will block any DC current flow, thus the average output will be dependent on the difference between the current flowing from the actual AtoD input (through R219), the offset current from the average reference (through R218) and the switched negative reference current (through R222).
The output of the integrator is connected to the input of the comparator.

11.3.5.3.3 Comparator and Clock Synchronization
The output of the integrator is compared with zero volts by the comparator IC208, which will produce a logic signal "1" when the integrator is below 0V. This output is synchronized with the system clock (16.777216MHZ) by latches IC211 to produce a waveform whose period can easily be measured by this clock. The outputs of the final latch is used to control the state of the negative reference switches and also as the input to the period measurement circuitry.

11.3.5.3.4 Negative Reference Generator
The negative polarity reference required by the AtoD convertor is generated from the average reference voltage by the inverting amplifier formed by IC205, R216 and R217. This produces a reference voltage of approximately -7.8V.

11.3.5.3.5 Negative Reference Switches and Drivers
The integrator input through R222 is switched between 0V and the negative reference voltage by TR206 and TR207 under the control of the comparator. The inputs to the FETs TR206 and 207 are generated by the fast switch drives formed by IC206, TR208, TR209 and associated circuitry. These switches are connected such that if the average voltage on the integrator output becomes more negative then more negative reference will be applied to R222, thus maintaining the integrator in balance.

The action of the above circuitry is to maintain the following equality :

Average current through R219 + Average current through R218 equals the average current through R222.

Thus the duty cycle of the comparator output gives a direct indication of the input voltage (on R219) with a small offset forced by the voltage on R218. Since the frequency of this waveform is fixed (512Hz), the duty cycle may be measured by measuring the period of the waveform.

11.3.5.3.6 Period Measurement
The period of the synchronized comparator output is measured by counting the number of 16.777216MHz clock pulses within a pulse of the waveform. This is achieved by the counters IC212 and 213 and the monostables in IC209. At the positive edge of the comparator output the monostables are triggered in sequence and will latch and then clear the contents of the counters. Thus the microprocessor may read the period at any time. As the counter contents are cleared (ready for the next measurement) the latch IC215 is set, causing the microprocessor to be informed that a new reading is available. The microprocessor will now clear IC215 and read the contents of the latches in IC212 and IC213.

11.3.6 Main Digital to Analog Convertor

Sheet 4 of schematic 2720-073 shows the main DtoA convertor in the 2720GS and is physically located on the Main Microprocessor PCB Assembly.

This convertor is made up from two (basically identical) DtoA convertors whose outputs are summed to produce the desired attenuation of the average reference voltage.

Each DtoA convertor is of the "Duty Cycle" type, producing the required voltage by switching between the reference voltage and zero with a controlled duty cycle.

The duty cycles are generated by comparing a number supplied by the microprocessor with the output of a continuously running counter. The output of this comparison will be a "0" only while the counter is lower than the number from the uP. The comparator for the most-significant DtoA (MSDAC) is formed by IC303 and 304, the LSDAC comparator being formed by IC301 and 302. The counter is formed by IC305, 306, 307 and 308 with the clock being generated by IC309. This clock (16.777216MHz) is used throughout the floating circuitry in the 2720GS as the "master" clock.

Any transients on the comparator outputs are eliminated by the re-synchronization to clock by IC310 and 311. These outputs are then applied to very high speed FET drivers formed by TR301-304 309-312 and associated devices, whose outputs drive the FET switches TR305-308 which provide the required outputs to be filtered by IC314 etc. to give the required output voltage.

IC315 and associated circuitry combine the two DtoA outputs, provide a small offset and produces a low impedance output from the main DtoA convertor.

11.3.7 Polarity Selection

The correct polarity of the output is achieved by reversing the output from the Main DtoA convertor. The user should note that the DtoA is capable of generating small negative voltages and thus this reversal is not performed at zero volts but slightly above (or below) zero. The reversal is achieved by relay RLD on schematic 2720-079 sheet 1 and is physically located on the Output System PCB Assembly.

11.3.8 Error Amplifier

The circuitry in this section is shown on sheet 1 of the schematic 2720-079 and is physically located on the Output System PCB Assembly.

The output from the polarity selection relay RLD is filtered by R37 and C1 then provided as an input to the comparison amplifier formed by IC1-4 and associated circuitry. IC1, 2 and 3 provide "bootstrapped" supplies for the actual amplifier IC4.

The other input to this section is selected (by RLC) to be either:

i) The Main Attenuator output (normal operation)
OR
ii) IC4 output, configuring it as a unity gain buffer (during Internal Calibration)

11.3.9 13, 130 and 1200V Amplifiers

The circuitry in this section is shown on schematics 2720-083 and 2720-081 and is physically located on the High-Voltage Power Supply PCB Assembly and Output Amplifier Assembly.
The output of the error amplifier is applied to one of the output amplifiers in the 2720GS either directly or attenuated by 5:1 through R7, R8 and RLB on schematic 2720-083 sheet 1. The required amplifier is selected by relays RLC, RLD, RLE and RLF on this same schematic and provided to the Output System PCB assembly.

11.3.9.1 13V Amplifier

This amplifier is shown on schematic 2720-083 sheet 1.
This is a non-inverting, gain of 2 amplifier formed by IC3, C9, R21, R9 and R10. This amplifier is capable of providing 15mA of output current.

11.3.9.2 130V Amplifier

The 130V amplifier is a non-inverting, gain of 20 amplifier with greater than 100mA output current capability.
This amplifier has two portions :

i) Preamplifier - This is formed by IC2 and associated components on schematic 2720-083 (High Voltage Power Supply PCB Assembly). This amplifier compares the output of the 130V output stage with the input to the amplifier and drives the output stages' input to provide overall control.

ii) Output stage - This is shown on schematic 2720-081 and is located on the Output Amplifier Assembly. The output of the pre-amplifier drives the input of opto-isolator IC101 through R116.
The amount of current flowing in the input of IC101 will control the current flow through its output transistor, thus controlling the current flow through the "bottom" half of the output stage (TR104, 105 and 106). This current is limited by R110, R111 and D109 to provide the maximum current "sink" protection.
The "top" section of the output stage is formed by TR101, 102, 103 and associated components. This stage provides a "quiescent" current flow in the complete output stage (defined by D107, R114 and R115) and also provides a source of output current (limited by D108, D107, R112 and R113). For user convenience components located on the Output Amplifier Assembly in the 130V amplifier are numbered from 100 to 199 (e.g TR101).

11.3.9.3 1200V Amplifier

The 1200V amplifier is a non-inverting, gain of 200 amplifier with greater than 30mA output current capability.
This amplifier has two portions :

i) Preamplifier - This is formed by IC1 and associated components on schematic 2720-083 (High Voltage Power Supply PCB Assembly). This amplifier compares the output of the 1200V output stage with the input to the amplifier and drives the output stages' input to provide overall control.

ii) Output stage - This is shown on schematic 2720-081 and is located on the Output Amplifier Assembly. The output of the pre-amplifier drives the input of opto-isolator IC201 through R210.
The amount of current flowing in the input of IC201 will control the current flow through its output transistor, thus controlling the current flow through the "bottom" half of the output stage (TR211-220). This current is limited by R241 and D210 to provide the maximum current "sink" protection.
The "top" section of the output stage is formed by TR201-210 and associated components. This stage provides a "quiescent" current flow in the complete output stage (defined by D209 and R234) and also provides a source of output current (limited by D211, D209 and R235). For user convenience components located on the Output Amplifier Assembly in the 1200V amplifier are numbered from 200 to 299 (e.g TR201).

11.3.10 Main Attenuator

This section is shown on schematic 2720-079 sheet 1 and is physically located on the Output System Assembly.
The voltage present on the SENSE terminals of the 2720GS is connected to the input of an attenuator string formed by R14, 15 and 16. RLG is used to select for no attenuation, RLF selects divide by 2, RLM selects for divide by 10 with divide by 100 being given if no relay selection is made.
The output of this attenuation stage is supplied (through R13 filtered by C26) to the input of a selectable gain amplifier. This amplifier has gains of 1 or 10 as selected by RLE. The output of the Main Attenuator section is the output of this amplifier directly, or divided by 2, as selected by RLB.

11.3.11 Nullmeter

The nullmeter is shown on schematic 2720-077 sheets 1 and 2.
The nullmeter is comprised of five sections :

11.3.11.1 Input Amplifier/Attenuator

The input to the nullmeter is first attenuated (if required) by R2-6 by a factor of 10000 (approximately). If the input voltage is below 200mV then RLA will be closed, selecting no attenuation. This voltage is then applied to the input of a selectable gain amplifier formed by IC2 and associated components. This amplifier has a gain of 10, 100, 1000 or 10000 as selected by the Main microprocessor. The gain is determined by RLD and RLE and is set by the ratio of the resistors R22-26. C1 and C4 provide filtering to reduce the affect of noise.
The output of this amplifier is thus a fixed 2V full scale for each of the nullmeters' ranges.

11.3.11.2 Filter

The output of the amplifier is filtered and amplified by the 2-pole active filter consisting of IC2, R13, R14, R15, C5 and C6. A half full-scale offset is introduced by D2 and R12 to provide a 0 to 10V signal for inputs between negative and positive full scales respectively.

11.3.11.3 Voltage to Frequency Convertor

The output of the filter stage is converted into a frequency in the range 0 to 100KHz by IC3 and associated components. The user is referred to the manufacturers data sheet for details regarding the operation of the AD537 VtoF convertor IC.

11.3.11.4 Over-Voltage Protection

The auto-ranging of the nullmeter is performed by the microprocessor thus it may take upto 2 seconds for the 2720GS to respond to an overload on the nullmeter inputs if this were the only method. To eliminate this, a separate fast-acting automatic overload detection circuit is included which will automatically select the input attenuator if the input to the amplifier exceeds 2V.
This is achieved by IC6 buffering the actual input to IC1, and providing this voltage to IC109 to detect the overload. The output of IC109 then when select RLA if an overload situation occurs.

11.3.11.5 Relay Drives and Power Supply

The power for the nullmeter is provided by an isolated power convertor IC (IC106) with regulation provided on both inputs and outputs by IC105, 107 and 108.
The relays are selected by the microprocessor pulsing the required code on IC101 inputs, which will select the required IC102 output, thus pulsing the required relay coil. As many other relays in the 2720GS, all of the relays on the nullmeter are of the latching type, i.e. each relay has two coils of which one (or the other) may be pulsed (for 20ms) to select either the SET or RESET positions of the relay.

11.3.12 External Reference

Input protection for the External Reference module is provided by R1, IC7, IC3, D1 and associated components. This is achieved by "catching" the input at voltages slightly higher, and slightly lower, than the nominal range of voltages allowed for each module. The protected voltage level is buffered by IC2, the supplies for which are generated by IC1 and IC5. EXR1 and EXR10 have the matched set of resistors R8 fitted, which are used to scale the buffered input voltage to a nominal 7V. The output from the R8 set of resistors is buffered by IC4 in option EXR10. The microprocessor may select the external reference to be used by closing RLA. The output of the external reference module may also be selected to be input to the A to D convertor by turning on TR1.

11.4 Relay Selections

The user should note that many of the relays in the 2720GS 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 (OFF condition) but has two coils, one of which may be pulsed to force the selection of the required state. With the absent of power on either coil the relay will remain in the same state as it was in. The "states" of this type of relay are called RESET and SET.

The "truth tables" for the relays in the various sections of the 2720GS are given below.

For the "normal" type of relay the ON condition is denoted by a "1", the OFF condition being indicated by a "0".

For the latching type of relay the RESET condition is indicated by a "R", the SET condition being indicated by a "S".

For either type, if either condition may be found then this is indicated by a "X".

11.4.1 Output System PCB Assembly Relays

The table below gives the states of all the relays on this assembly during normal operation. The states during SYSTEM CHECK, INTERNAL CALIBRATION and EXTERNAL CALIBRATION are not included.

	650mV	1300mV	0.65V	1.3V	6.5V	13V	26V	65V	130V	600V	1200V
RLA	1	1	0	0	0	0	0	0	0	0	0
RLB	1	0	1	0	1	0	0	1	0	1	0
RLC	0	0	0	0	0	0	0	0	0	0	0
RLD	x	x	x	x	x	x	x	x	x	x	x
RLE	R	R	S	S	R	R	R	R	R	R	R
RLF	0	0	0	0	0	0	1	0	0	0	0
RLG	0	0	0	0	0	0	1	1	1	1	1
RLH	S	S	R	R	R	R	R	R	R	R	R
RLK	0	0	1	1	1	1	1	1	1	1	1
RLL	R	R	S	S	S	S	S	S	S	S	S
RLM	0	0	0	0	0	0	0	1	1	0	0

RLD is in the RESET condition for positive outputs, SET for negative outputs.

When in OPEN CIRCUIT STANDBY mode then RLL is forced to the RESET condition and RLK is forced OFF.

11.4.2 Dual Reference Module Relays

Each relay is in the ON state to select the respective reference to be used.

11.4.3 Nullmeter

Range	RLA	RLD	RLE
200uV	S	R	S
2mV	S	S	S
20mV	S	R	R
200mV	S	S	R
2V	R	R	S
20V	R	S	S
200V	R	R	R
2000V	R	S	R

11.4.4 High Voltage Power Supply PCB Assembly

If the 1200V amplifier is selected, then RLA is ON if the output polarity requested is negative.
If a higher voltage amplifier than normally used for the output voltage is selected then RLB is ON.

Amplifier	RLC/E	RLD/F
13V	x	0
130V	0	1
1200V	1	1

11.5 Operation of Microprocessor Software

The user should note that these paragraphs contain supplemental information to enable the advanced user to fully understand how the 2720GS operates. An under standing of these paragraphs is not required either for operation or maintenance of the 2720GS.
A full description is beyond the scope of this manual and is unnecessary for understanding the operation of the 2720GS. However some knowledge of the method of operation of the software in both microprocessors in the 2720GS is of benefit, thus this section contains a brief description of the operating characteristics of the software in the 2720GS. Throughout this section some knowledge of microprocessor programming is assumed.
As mentioned in other sections of this manual there are two microprocessors in the 2720GS which communicate through a serial link. These microprocessors are the I/O uP and the Main uP.

The user should be aware of the following standard software organization features which are used in both uPs in the 2720GS:

i) Power-up routine
   To initialize all data areas, perform tests etc. required at power-up
ii) Interrupt routines (also called "Real Time")
   To perform actions requiring immediate response to hardware events.
iii) An executive control loop
   The loop which is normally being executed by the processor
iv) Individual "action" routines
   Called from the executive loop to action events or perform duties.

11.5.1 I/O uP Software Organization

The main purpose of this uP is to control all user interface with the 2720GS and to command the Main uP to carry out the user required operations.
The software is configured with the organization shown in 11.5 with the exception that there are actually four executive loops used.

11.5.1.1 Power-on Reset Routine

After a power-on reset the I/O uP performs the following tasks in the order given :

i) Check RAM operation for stack area.
ii) Initialize LEDs and displays
iii) Initialize RAM volatile data and real time clock
iv) Initialize serial link to Main uP
v) Check ROM and RAM operation and data contents
vi) Display greeting to user
vii) Compute variables required (warm up time etc.)
viii) Request and check Main uP software revision
ix) Request Main uP check statii and reply
x) Display failure report
xi) Initialize IEEE interface and parameters
xii) Command Main uP set up output etc.to required status

The I/O uP then starts to perform its "main executive" duties.

11.5.1.2 Main Executive Duties
This continuous loop is normally executed by the I/O uP all of the time. The processor only leaves this loop temporarily to perform one of the other duties. The duties within this loop are as follows :

i) Select required keyboard action level
ii) Once every day: Command Main uP check statii and reply
iii) If in last 4 minutes of warm-up:
Once every minute: Command main uP to start OBRMS cycle.
iv) Once every 10 minutes: Command main uP to start OBRMS cycle.
Command main uP set up output statii.
v) Once every second: Ensure display and LEDs updated
Update variables
vi) If key pressed: Perform action for key
vii) If IEEE command received: Perform action for command
viii) If CALIBRATE keyswitch at calibrate: Goto EXT CAL executive.
ix) If command/data from main uP: Action command
x) Repeat loop

The interested user should carefully read the contents of this loop since it is these sequences which totally control the user interface with the 2720GS.

11.5.1.3 Interrupt Routines
There are two sources of interrupt to the I/O uP in the 2720GS. These are :

i) Real Time Clock Interrupt
This interrupt is generated by the real time clock and occurs every 500uS (approx.). The uP uses this interrupt to multiplex the displays and also for timing functions. The front panel RESET key is actioned within this routine also.
ii) 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 2720GS. 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 (i.e. command) has been received from the controller so that it may be actioned.

11.5.1.4 Individual "action" Routines
This is a numerous set of routines which control the activity required due to an event. Examples of these events are a manual key being pressed, an IEEE command line being received, the requirement to send a command to the Main uP etc.. It is not necessary to explain the operation of these routines in this manual except to explain that they all perform the required task completely and then return to the previous action.
The user should note that all commands to the Main uP requiring

changes in status or requesting specific data are implemented within these routines, the commands sent from the main executive loop are purely to maintain the Main uP performing the required actions.

11.5.1.5 EXT CAL, SYS CHK and INT CAL Executives
Whenever the 2720GS is commanded, in a valid manner, into any of these states the processor exits the main executive loop and starts to perform the requested executive instead. These executives control the progress and user interface during these procedures. It is not necessary to describe these procedure executives here because they have been described in other sections of this manual. When the complete procedure has been accomplished then the processor is passed back to the main executive.

11.5.2 Main uP Software Organization
The main uP is organized in a similar manner to the I/O uP as follows:

11.5.2.1 Power-On Reset Routines
After a power-on reset, the main uP performs the following tasks in the order given (the user should note that the hardware is ALWAYS placed in a safe condition by the RESET circuitry):

i) Checks ROM and RAM
   If failure: Stop
ii) Set up hardware to required, safe conditions
iii) Wait for command from I/O uP: Action as requested

The user should note that, unlike the I/O uP, the main uP does not immediately start its main executive loop, but waits for the I/O uP to command it to do so. This is a general point for the main uP software organization - the main uP does nothing except when "told" to do so by the main uP.

11.5.2.2 Action of Commands from the I/O uP
Due to the main uP not performing anything unless commanded to do so, it is necessary for the user to understand the command types from the I/O uP. These commands fall into four major types:

i) Data requests - these commands (e.g. request for a particular calibration data point) are simply performed, the data being fetched or computed and then control passed back to whatever the main uP was doing previously.

ii) Hardware specific commands - these commands behave similarly to data requests but do not initiate a reply to the I/O uP (e.g. Turn on the nullmeter, or Initiate an OBRMS cycle). In general they do not alter the operating characteristics of the 2720GS.

iii) Operating set-up command - this single command informs the main uP of the output voltage, current limit, reference selection, output connection status, output amplifier requirement and also starts the main uP performing its main executive actions when received. The main uP responds by performing the required actions to achieve the requested status (or as near as it is able if the requested status is not available) and replies with the actual status achieved.

iv) Procedural commands - these commands cause the main uP to alter its operating characteristics and perform specific overall duties (e.g. System check, Internal calibration etc.). The reception of one of these cause the main uP to abort any present activity (including the main executive) and start performing the executive for the control of the requested procedure. One of these commands (executed daily, or following power-on) consists of the "Operating Set-up Command" and also a request to fetch, evaluate and calculate complete calibration data for all elements in the 2720GS prior to starting the main executive loop.

11.5.2.3 Main Executive Loop

The main executive loop for the main uP contains the following tasks (in order) :

i) If command from I/O uP: Action command
ii) Control DVM, Ammeter and nullmeter activity
iii) Check hardware status lines
If new failures: Inform I/O uP and take necessary action
iv) If performing OBRMS and completed cycle: Check data and action
v) Repeat loop

11.5.2.4 Interrupt Routines

The main uP has two sources of interrupt:

i) A timing and control interrupt - this hardware generated interrupt occurs at 256Hz and is used to performing general timing, control of the main AtoD convertor, collection of DVM Ammeter and nullmeter reading data.

ii) AtoD data ready - this interrupt every time that a new AtoD convertor reading is ready (usually at 512Hz) and is used to collect an AtoD measurement under the supervision of the timing interrupt above.

The user should note that, due to the above structure, all hardware "supervisory" measurements made in the 2720GS are operated on a "real-time" basis, thus they are continuously being performed and are capable of performing any required "safety" actions independent of the prevailing main uP activity.

11.5.2.5 Individual "Action" Routines

This is a numerous set of routines which control the activity required due to an event. Examples of these events are a command from the I/O uP, the requirement to send changed status to the I/O uP etc.. It is not necessary to explain the operation of these routines in this manual except to explain that they all perform the required task completely and then return to the previous action.

11.5.2.6 SYS CHK, INT CAL and EXT CAL Executives

When the 2720GS is performing any of the above procedures the supervisory task of the main uP is significantly changed, thus specialized executives are used to perform these duties. The exact contents of these executives are beyond the scope of this manual and are unnecessary for an understanding of the 2720GS software operation.

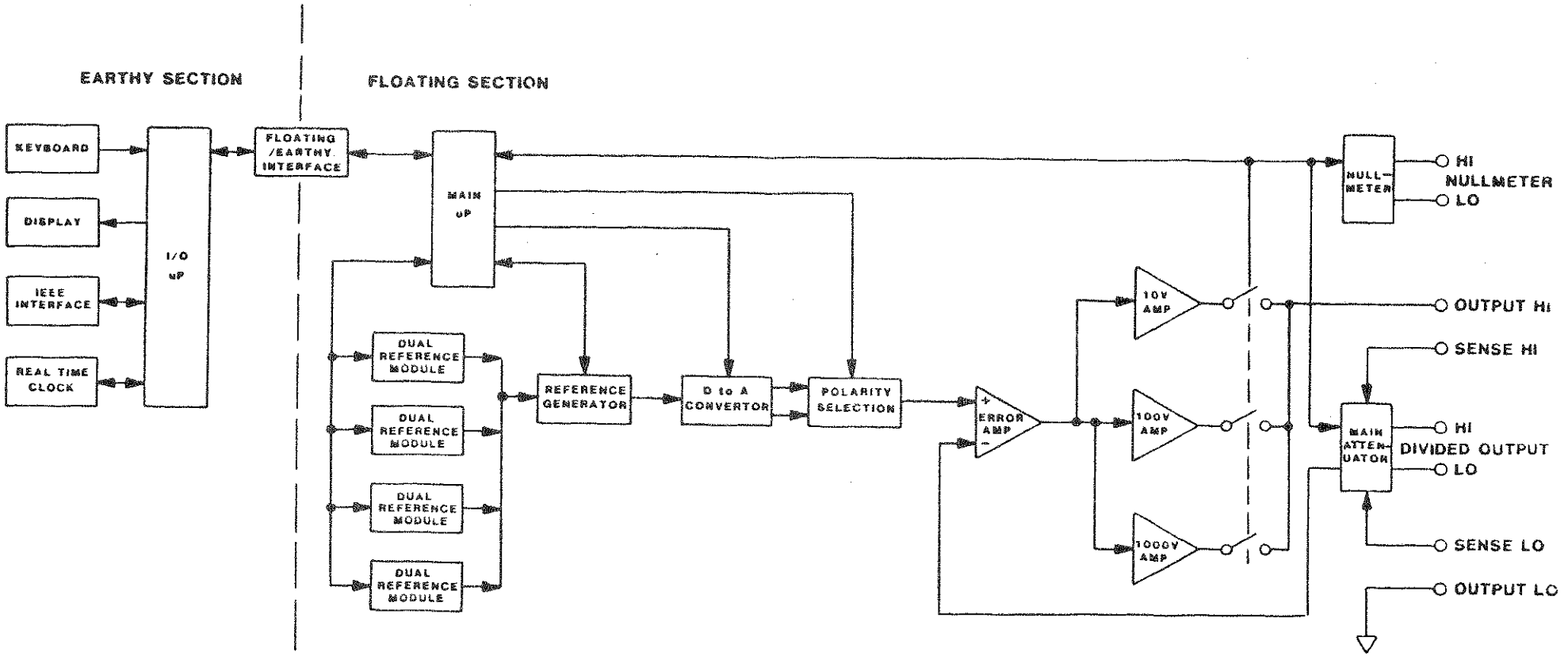


FIGURE 11-1 : 2720 BLOCK DIAGRAM

SECTION XII

PERFORMANCE VERIFICATION

12.1 General

Verification of the performance of the 2720GS may be performed at any time, and is especially recommended following receipt of the unit or following transportation. Verification may be achieved with two levels as follows :

12.2 Verification of Operation

To verify that the 2720GS is in operational condition, the following procedure should be followed. If any test fails then no further test should be performed and the 2720GS should be set aside for maintenance.

i) Ensure that the POWER switch (lower left hand corner of the front panel) of the 2720GS is in the STBY position, i.e. no yellow dot showing.

ii) Apply AC power to the 2720GS (connector is in lower right hand corner of the rear panel). Listen carefully to check that the fan inside the 2720GS operates.

iii) Press the 2720GS POWER switch to the ON position (yellow dot showing). The displays on the front panel should illuminate with a greeting message ("HI THERE" as standard).

iv) Allow 2720GS to warm up for 1 minute (a message will have been displayed as to the actual warm up to specification, this may be ignored at this time).

v) Ensure that all eight sections of the CONFIGURATION SELECTION switch, on the lower portion of the rear panel, are in the UP position.

vi) Press the key marked SYS CHK on the front panel (in the center of the panel, towards the right). The 2720GS should emit a "beep" sound and the lower display should request the user remove any connections.

vii) Press the ENTER(YES) key on the front panel (in the center of the panel). The 2720GS should emit a "beep" sound and the lower display request if to check the DIGITAL circuitry. Again press the ENTER(YES) key. The 2720GS will emit a "beep" sound. After a few seconds the 2720GS will again emit a short "beep" sound and display "PASS" in the lower display. If the 2720GS fails then it will emit a long "beep" sound and display "FAIL" or a message indicating the location of the fault.

viii) The lower display will now be requesting if the user wishes to check the AtoD's. Press the ENTER(YES) key on the front panel. The 2720GS should emit a short "beep" sound. The lower display will indicate the portion being checked and will emit a short "beep" sound and display "PASS" after each successful test. Each test will take a few seconds.

ix) The lower display will request if the user wishes to check the OUTPUT. Press the ENTER(YES) key on the front panel. The 2720GS should emit a short "beep" sound. The lower display will indicate the portion being checked and will emit a short "beep" sound and display "PASS" after each successful test. Each test will take several seconds.

x) The lower display will request if the user wishes to check the REFERENCES. Press the ENTER(YES) key on the front panel. The 2720GS should emit a short "beep" sound. The 2720GS will emit a short "beep" sound and display "PASS" after the successful test. This test will take approximately 30 seconds.

xi) The lower display will now give a complete status report on the 2720GS, the user should carefully read the contents to determine if any failures are present.

xii) The 2720GS should now be allowed to fully warm up (the time required was indicated when the unit was turned on).
From this point forwards the description of the "beep" sound will not be mentioned to provide clarity, it should continue to occur however.

xiii) Press the INT CAL key (next to the SYS CHK key). The lower display should request that connections be removed. Press the ENTER(YES) key. The lower display will display "CAL Krefav" shortly followed by "PASS". If the display shows "NOT WARM" then the warm up time was not allowed, and the 2720GS should be allowed to further warm up for the time indicated.

xiv) The lower display will now request if the user wishes to calibrate the OUTPUT GAIN. Press the ENTER(YES) key. The lower display will indicate the calibration point being performed and will display "PASS" after each one. Each calibration may take up to 1 minute.

xv) The lower display will now request if the user wishes to calibrate the NULLMETER. Press the ENTER(YES) key. The lower display will now request that the user provides CONNECTIONS. The OUTPUT SENSE RED and the NULLMETER RED terminals should be shorted together, as should the OUTPUT SENSE BLACK and NULLMETER BLACK terminals. Ensure that the BLACK and RED terminals are not shorted to each other. Press the ENTER(YES) key. The lower display will indicate the calibration point being performed and will display "PASS" after each one. Each calibration will take a few seconds.

xvi) The lower display will now request if the user wishes to calibrate the OUTPUT ZEROES. Press the NO key (below the ENTER(YES) key). If no option EXR is fitted the lower display will indicate that all calibrations have been performed. If an option EXR is fitted, then the lower display will request if the user wishes to calibrate the OPTION EXR. Press the ENTER(YES) key. The lower display will now request that the user provides CONNECTIONS. The OUTPUT SENSE RED, OUTPUT RED and the EXTERNAL REFERENCE RED terminals should be shorted together, as should the OUTPUT SENSE BLACK, OUTPUT BLACK and EXTERNAL REFERENCE BLACK terminals. Ensure that the BLACK and RED terminals are not shorted to each other. Press the ENTER(YES) key. The lower display will display "PASS" after completion. Calibration will take a up to 1 minute.

After successful completion of all the above steps the 2720GS is fully operational with no faulty parts apparent.

12.3 Verification of Specification

Before attempting to prove that the 2720GS is performing to specification the user must be aware of the following points:

i) The specifications in section II are valid for reasonable use of the 2720GS during the specified period of time. If the 2720GS has been transported then it has probably been subjected to temperature shock and extremes. As with any precision equipment some change in calibration will occur due to this. This effect has been carefully monitored by Valhalla Scientific and has been found to be less than 5ppm even in extreme cases, however the user can expect some effect due to transportation.

ii) The specifications in section II are relative to the calibration standards at Valhalla Scientific (or, in some countries, the local Service Center for Valhalla products). The uncertainty of the Valhalla Scientific standards to NBS is 1.5ppm, thus this must be added to these specifications for verification purposes (if verification is attempted prior to calibration to the users standards). If the 2720GS was locally calibrated then the uncertainty of those standards must be added instead.

iii) The above adder will obtain the uncertainty specification to National Standards. Thus, when a comparison is made, as it is here, the uncertainty of the users standards and equipment must also be added to the specifications. In cases where the 2720GS was not locally calibrated and the National Standards differ from the NBS (i.e. U.S.A.) standards then this difference must also be accounted for.

iv) Prior to specification verification it is recommended that the user familiarizes himself with the manual operation of the 2720GS, allows at least 24 hours (preferably 48 hours) for the unit to settle while powered and performs an Internal calibration of the OUTPUT GAIN followed by zeroing the nullmeter immediately

prior to testing.

If the 2720GS is found to be fully operational but not performing to specification then contact your nearest Valhalla Scientific Service Center before returning the unit for repair or attempting repair yourself.

SECTION XIII

USEFUL HINTS

13.1 Getting The Most Out of Your 2720GS

As with all precision instrumentation there are some general "care-taking" procedures that will help the user obtain even better performance than that specified. Most of the points listed below are good habits for any equipment, and if followed should also enhance all of the user equipments' performance and reliability at minimal cost.

i) Leave equipment powered at all times. If the equipment has a standby mode (as 2720GS does) then leaving it in this mode is alright but leave it powered whenever possible. This greatly reduces the drift and unreliability caused by temperature stresses during warm-up and cool-down.

ii) 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.

iii) Avoid operating equipment directly under an air-conditioning outlet duct. This will cause similar affects as in ii) 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).

iv) 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.

v) 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 significant, thus always sit or stand on a conductive surface and avoid movement whenever sensitive measurements are being made.

vi) Avoid high energy electro-magnetic 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.

vii) Always use the highest quality cables. Many "good looking" cables do not actually use pure copper for conductors and can cause many microvolts of thermal emfs. Also many banana jacks are actually made of steel or similar material and can cause several tens of microvolts of thermal emfs. If you are unsure then try reversing your connections and compare the measurements.

viii) 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.

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

x) 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. Thus always use the same gauge and type of wire to both terminations of sensitive measuring and generating devices (such as the 2720GS) to reduce the temperature differential between conductors. Care in balancing the routing of cables (i.e. route the Hi and LO terminal connections close together) will also reduce thermals and pick up of interference.

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

xii) Treat your equipment correctly and it will treat you correctly. Keep equipment clean, do not attempt any measurement that could yield damaging out of specification voltages or currents without protecting the instrumentation, and the equipment should perform well within specification for many years. Frequent breakdowns can be due to faulty equipment or design, but are more often caused by a lack of care and/or understanding of the product.

13.2 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 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 dissapation factor) data for cables and capacitors. The answer is that there is and there is not! There are two major effects in dielectric storage:

i) The initial stored quantity.
AND
ii) 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

in dependent on this and the "very high resistance". In practice most materials behave as if they had several of these capacitor-resistor combinations with widely varying values and time constants. In practice the use of polyethylene insulated cables (never use PVC or Teflon) will help with this effect.
If the user is unsure, or just wishes to see the effect, then try the following test on a two-conductor cable. The user is warned that this can be a dangerous test to the user, extreme caution must be exercised.

i) Ensure that neither end of the cable has any connections and are not shorted.

ii) Connect one end of the cable across a 100V (approx.) DC source and leave for several minutes.

iii) Connect a 1 megohm resistor across the input terminals to a DVM with 1uV sensitivity and a reading rate of greater than 1 per second. Allow sufficient time for the reading to settle.

iv) Very carefully and quickly disconnect the cable from the 100V DC supply (do not set to zero or standby first) and connect instead to the DVM and 1Mohm. The user will see many microvolts (millivolts for bad cables) of reading which may take several minutes to decay.

If the user wishes the DVM and 1Mohm (if high enough wattage) may be connected to the cable all of the time, in which case the dielectric storage of the DVM (as well as the cable) will be measured.

The effect of this is most visible in resistance measurements, particularly at higher values (above 10Kohm), 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 2720GS the effect can be easily seen if the cable on the OUTPUT SENSE terminals is of "bad" material, 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 "leakage" discharging into the 500 ohm output impedance of the divider. It is recommended that if this sequence of events is to take place then the user should change the cable after subjecting it to 1000V and leave it to discharge for several minutes before using it again.