Wahl

MODEL C-65

INSTRUCTION MANUAL

C-65 INSTRUCTION MANUAL

C-65 INSTRUCTION MANUAL

THERMOCOUPLE
CALIBRATION
STANDARD

NIST TRACEABLE

WC65 12-80

TABLE OF CONTENTS

Table of Contents Cont'd

1.0 INTRODUCTION AND SPECIFICATIONS

1.1 Scope

This Instruction Manual contains operating and maintenance instructions, as well as description of the principles of operation of the Wahl Precision Portable Thermocouple Calibration Standard, Model C-65.

The manual provides procedures for re-calibration should this be useful to the user. Re-calibration facilities are also available at the factory.

1.2 General Description

The C-65 is a microprocessor-based, laboratory grade, digital thermometer, calibrator, and voltmeter. Packaged in a rugged metal case, it is truly portable and especially designed for multi-function use in the harsh environments of the process and service industries.

The C-65 operates in any of four front-panel selected functions:

(1) As a thermometer (FUNCTION = MEASURE), providing direct ^{o}F or ^{o}C readout of a connected thermocouple. The T/C cold-junction reading is automatically compensated when selecting any T/C. There is no compensation when measuring mV.

(2) As a calibrator (FUNCTION = OUTPUT), providing precise voltage outputs equivalent to the tabular values expected from a selected thermocouple at a settable temperature, or a setable voltage from −12 to +80 millivolts. Cold-junction voltage is compensated by the instrument when a T/C is selected.

(3) As a voltmeter (FUNCTION = MEASURE, RANGE = mV), providing 4½-digit readout of a ± 100mV range input, with microvolt resolution and automatic polarity indicated in the display. The voltage on the display is the voltage available at the terminals.

(4) As a self-tester (FUNCTION = TEST), providing an overall system performance check, assuring a valid calibration against previously established mV for each measurement position. Appropriate microprocessor-generated error messages are displayed for malfunctions that may occur during other functional use.

The C-65 is available as a four-range or eight-range model, and each may be supplied for either 110 or 220 Vrms recharging power sources. Each model is configured for the mV RANGE selection, thus providing the millivoltmeter and direct settable voltage functions. The 4-range model provides for three thermocouple ranges (J, K, T), while the 8-range model provides for seven thermocouple ranges, (J, K, T, E, R, S, C), in addition to the mV range.

Measurements and calibration outputs for front-panel selected thermocouple types are automatically corrected for reference-junction offsets. Direct millivoltmeter measurements and settable direct-reading calibration voltage outputs are provided without reference junction compensation.

Front panel displays are presented on large (8mm high) LEDs. The decimal point is positioned automatically, and the minus (—) sign is displayed for any negative value. The digital display is actually 7 positions; five decade positions are available for the 4½-digit value; the decimal point is incorporated to the right within one of these positions; the polarity sign (when appropriate) is always positioned to the far left; the symbol F, C or E is displayed at the far right, as annunciators for Fahrenheit, Celsius, or EMF (millivolts), respectively.

Error messages of HIGH, LO, OPEN or ERROR are respectively displayed when the temperature is above full scale, the temperature is below full scale, an open thermocouple lead is detected (or less than minus 101.1mV) or when a voltage greater than 101.1mV is applied to the input terminals.

1.3 Mechanical Description

The C-65 is assembled in a rugged metal carrying case as shown in Figure 1-1, whose bottom half forms the instrument case, and whose lid may be used as a tilt stand support arrangement for easy viewing. Inside the lid is a handy compartment which stores the Instruction Manual and other items such as service cables.

The instrument is battery-powered, and is supplied with a battery pack of 5 rechargeable NiCad batteries and an integral battery charging circuit. The recharger line cord is attached to the instrument and is stored in the front-panel storage compartment.

A fully charged battery pack will deliver at least 8 continuous hours of operation, while 14 to 16 hours are required for full battery recharge. (The instrument may be operated while the batteries are being recharged.) The batteries are guaranteed for a minimum of 1000 charge/discharge cycles. Replacement battery packs may be installed at the factory or ordered from the manufacturer.

The C-65 Front Cover is made of stain and impact-resistant aluminum, consistent with the instrument's intended use as a Calibrator/Thermometer in harsh field environments. The hinged lid is deep enough so that C-65 accessories and documentation may be carried within the case without requiring additional storage space. An operation instruction label (see Fig. 2-4) is affixed to the inner lid surface for ready field use and reference.

Figure 1-1. Carrying Case and Dimensions

1.4 Accuracy and Conformity to Specification

Table 1-1 shows the International Specifications which the C-65 will meet. Table 1-2 shows the specific conformity and accuracy of the 8-ranges.

Table 1-1. International Specifications

Table 1-1 INTERNATIONAL SPECIFICATIONS
C-65 THERMOCOUPLE STANDARDS TABLE (X=C-65 MEETS STANDARDS)

Type and Standard	J	K	T	E	R	S	C
ANSI MC 96.1-1975 (U.S.)	X	X	X	X	X	X	
ASTM E230-72 (U.S.)	X	X	X	X	X	X	
BS-4937 (British)	X	X	X	X	X	X	
NIST Monograph 125 (U.S.)	X	X	X	X	X	X	
JIS C1602-1974 (Japanese)	X	X	X	X			
DIN (*) (Germany/Continental 437 10-1977 Europe)	(*)	X	(*)			X	
IPTS-68 (International)	X	X	X	X	X	X	X
IEC-584-1	X	X	X	X	X	X	
GOST (Russian)		X					

*It is anticipated new DIN Standards will be issued shortly for Type J and T in accordance with IEC-584-1 and the current C-65 Tables.

Table 1-2. C-65 Range, Conformity, Accuracy & Resolution

C-65 RANGE, CONFORMITY, ACCURACY AND RESOLUTION TABLE

T/C Type[1] (metals)	Scale	Temperature Range[2]	Resolution	Conformity[3]	RSS Calibration Accuracy[4]	Overall Accuracy, 1 year[5]
J (Fe/CuNi)	°F	−346 to +2192	0.1	±0.2	±0.29	±1
	°C	−210 to +1200	0.1	±0.1	±0.17	±0.6
K (NiCr/NiAl)	°F	−328 to +2501	0.1	±0.2	±0.33	±1
	°C	−200 to +1372	0.1	±0.1	±0.19	±0.6
T (Cu/CuNi)	°F	−337 to + 752	0.1	±0.2	±0.25	±1
		−405 to − 337	0.1	±9.2	±9.11	±10
	°C	−205 to + 400	0.1	±0.1	±0.15	±0.6
		−243 to − 205	0.1	±5.1	±5.10	±5.6
E (NiCr/CuNi)	°F	−389 to +1832	0.1	±0.2	±0.27	±1
		−422 to − 389	0.1	±5.0	±4.81	±5
	°C	−234 to +1000	0.1	±0.1	±0.16	±0.6
		−252 to − 234	0.1	±2.8	±2.71	±2.8
R (Pt13Rh/Pt)	°F	−58 to +3214	1	±0.2	±0.76	±2
	°C	−50 to +1768	1	±0.1	±0.65	±1.1
S (Pt10Rh/Pt)	°F	−58 to +3214	1	±0.2	±0.61	±2
	°C	−50 to +1768	1	±0.1	±0.54	±1.1
C[6] (W5Re/W26Re)	°F	+32 to +2192	1	±0.2	±0.68	±1
		+2192 to +3812	1	±0.2	±0.84	±2
		+3812 to +4200	1	±0.2	±0.97	±3
	°C	0 to +1200	1	±0.1	±0.56	±0.6
		+1200 to +2100	1	±0.1	±0.62	±1.1
		+2100 to +2315	1	±0.1	±0.69	±1.7
B[7] (Pt30Rh/Pt6Rh)	°F	+367 to +3308	1	±0.2	±0.6	±2
	°C	+186 to −1820	1	±0.1	±0.5	±1
J-DIN[8] (Fe/CuNi)	°C	−200 to + 900	0.1	±0.2	±0.17	±0.6
T-DIN[8] (Cu/CuNi)	°C	−200 to + 500	0.1	±0.1	±0.15	±0.6
N[9] (NicroSil/NiSil)	°F	−371 to +2372	0.1	±0.2	±0.43	±1.3
	°C	−224 to +1300	0.1	±0.1	±0.24	±0.7
mV measurement and output functions	N.A.	VOLTAGE RANGE −20.000mV and +20.000mV	0.001mV	N.A.	±(0.005% of reading +2 digits)	±(0.03% of reading +5 digits)
		−101.10mV to −20.00mV and +20.00 mV to +101.10mV	0.01mV	N.A.	±(0.01% of reading +1 digit)	±(0.03% of reading +2 digits)

Footnotes to Table 1-2

[1]For unlisted thermocouples, use the C-65 millivolt range, and appropriate millivolt versus temperature tables.

[2]For thermocouple output functions, the output range is −12mV to +80mV with resolution and accuracy per corresponding temperatures shown.

[3]Data conformity to ANSI spec. MC96.1-1975.

[4]Traceable to **NIST**. RSS = root sum squares of all the error contributions at 25° ±2°C.

[5]Instrument at 25° ±2°C.

[6]Per data from Hoskins Mfg. Co. Detroit, Mi. USA.

[7]Available only as a special modification where type C is replaced by type B.

[8]Available in C-65-8D-220 where types R and C are replaced by J-DIN and T-DIN.

[9]Data per **NIST** Monograph-161.

2.0 PREOPERATIONAL CHECKOUT

2.1 Scope

This chapter contains instructions for unpacking and repacking the instrument and registering your warranty with the Company. General information about the applications of the C-65, as well as instructions for the installation, set up, and preoperational check of the instrument are provided. This section should be read carefully before attempting to use the C-65 on site.

2.2 Unpacking & Repacking

(a) Figure 2-1 identifies the components of the packaging configuration for C-65. As shown in that illustration, the instrument is placed in a waterproof plastic wrapper, securely fitted between molded-foam shock isolators and placed with the documentation in its shipping carton. When unpacked, you should find:

1. C-65 Thermocouple Calibration Instrument*
2. Certificate of Calibration
3. Warranty Card (in back of manual)
4. Factory Test Data Sheet (Part of the Certificate of Calibration)
5. Instruction Manual

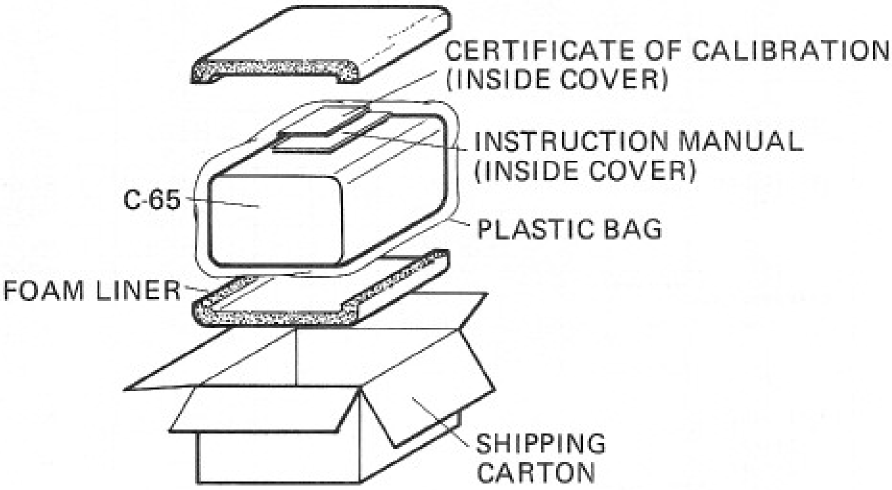


Figure 2-1. Shipping Configuration

(b) Carefully examine these articles, noting especially the matching serial numbers of the instrument and the test data. Inspect the packing case and the instrument for any signs of damage during shipment and report immediately to the carrier. Fill out and return the warranty card which you will find inserted at the back of this manual in order to register your instrument and to establish your warranty service interval.

(c) Accessories, such as a service cable, adaptor plugs, or thermocouple probes may have been ordered with the instrument. These will be shipped in their own containers.

(d) Retain the packing material for reshipment. When shipping C-65, use foam shock isolators and pack in original shipping carton, if available. If original shipping material is no longer available, use some shock isolators, such as bubble plastic, and wrap securely within a suitable carton.

2.3 Operating Controls & Indicators

Figure 2-2 illustrates the front-panel features showing the operating controls and indicators. Figure 2-3 is a schematic composite of a number of possible display formats, illustrating the location of decimal point, polarity sign and annunciator codes. The illustration also indicates the location and appearance of possible error messages.

*Battery pack and fuse are installed in the instrument. The recharger line cord is attached, and is located in the front panel accessed storage compartment.

2.4 Model C-65 Setup and Checkout

(a) The instrument is shipped in a complete configuration. The battery pack is installed, and is shipped in a fully charged condition. To assure that the batteries will be operational after any prolonged shelf life, or after any extensive shipping interval, charge the batteries for a period of 12 hours. After an initial warmup period of 1 minute for 1° resolution measurements (15 minutes for 0.1° of .001 mV resolution measurements), the instrument is ready for operation.

(b) Turn instrument (lower knob) from "OFF" to "SELF-TEST". Switch °F/°C switch to °C. Rotate "RANGE" knob to mV. Note the reading on the display, it should display the "TEST READING" shown on the label in the cover for "MV" within the tolerance shown (See Figure 2-4). Rotate Range knob to each of the thermocouple types and compare displayed readings with those on the table. This establishes the "operational readiness" of the C-65 instrument.

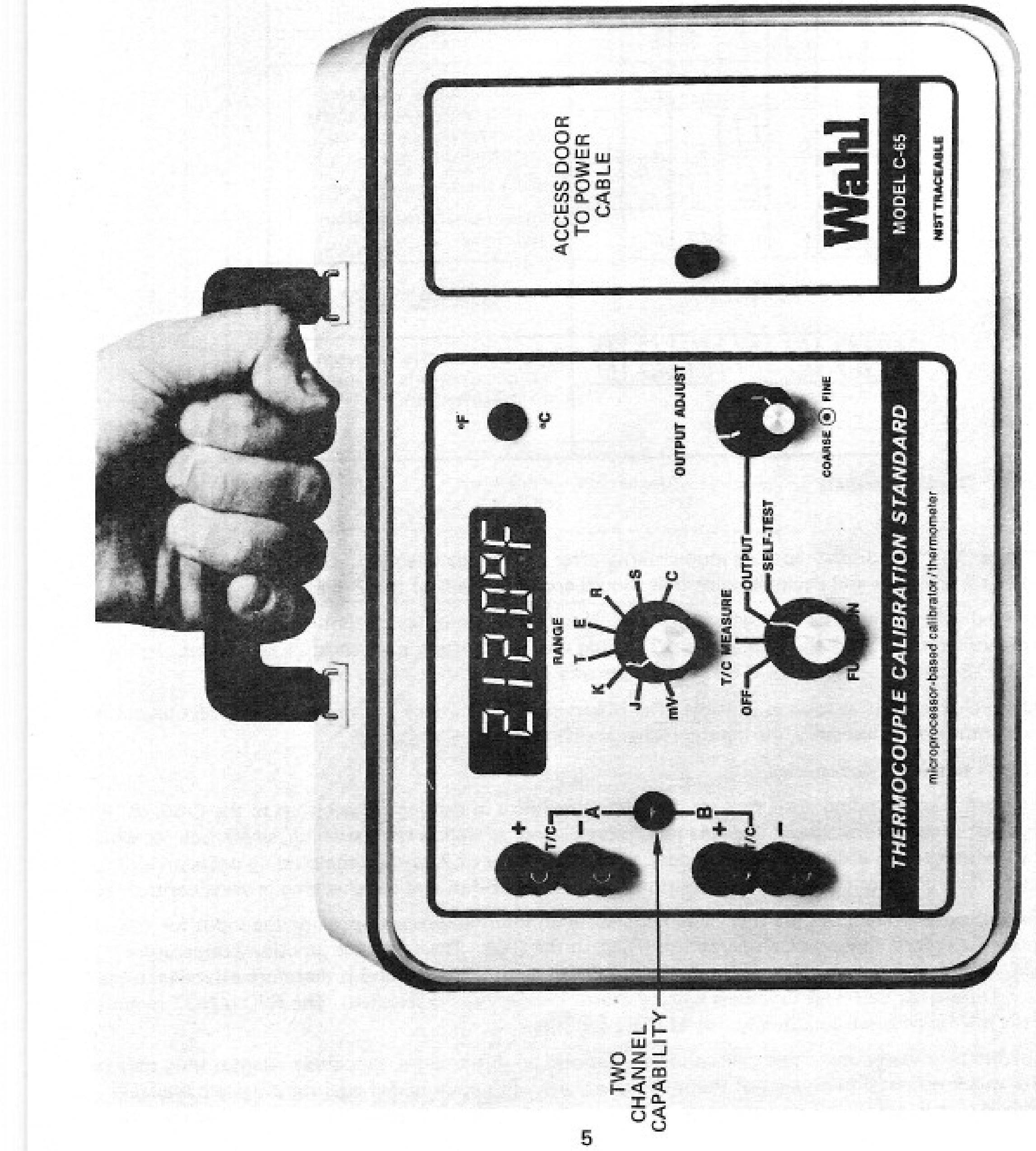


Figure 2-2. Front Panel Features

DISPLAY SHOWS							MEANING
2	5	0	1.	0	°	F	Measures temperature directly from T/C types J, K, T, & E, with resolution of 0.1°F and 0.1°C.
–	4	2	2.	0	°	F	
	2	3	1	5	°	C	Measures temperature directly from T/C types R, S, & C with resolution of 1°F and 1°C.
–			8	0	°	C	
	2	0.	0	0	0	E	Measures ± 20mV signals with resolution of 0.001 mV (1µ V)!
–	2	0.	0	0	0	E	
	1	0	1.	1	0	E	Measures ± 20mV to ±101.1mV signals with resolution of 0.01mV
–	1	0	1.	1	0	E	
		H	I	G	H		Automatically indicates faults: temperature above or below the calibrated instrument range, or . . .
		L	O				
	O	P	E	N			open thermocouple, or . . .
	E	r	r	o	r		input signal greater than 101.1mV
BLINKING							LOW-BATTERY
8.	8.	8.	8.	8.	8.	8.	Appears briefly between range selections & when first Turned on.

Figure 2-3. Display Formats

Note that a "full" 8's display appears momentarily after each range selection. Check the lighting of each of the 7 segments and decimal point that should appear in each of the 7 digits.

A blinking display indicates a low battery voltage. You have 15 minutes of continued in-spec C-65 performance from the time the display starts blinking until the battery pack must be recharged. At the end of the 15-minute interval, the C-65 is automatically programmed to stop its operation.

Start the recharge cycle as soon as possible after observing a low battery indication. The C-65 operation may be continued, if necessary, during the recharge operation.

2.5 Input terminals/Accessories

The standard 5-way binding posts provide complete flexibility in making connections to the C-65. A terminal pair is spaced for simple "banana-jack" connection, as well as the spade-lug, single jack, or wire lead connection to the individual binding post. The availability of 2 pairs of the binding posts provide maximum flexibility for checking multi-thermocouple installations, and for checking process control loops.

The binding post connections are thermally coupled to an internal sensor to provide the input for the automatic Reference Junction Compensation (RJC) in the C-65. The reference junction temperature compensation is scaled for any one of the selected thermocouple ranges, and is therefore effective in the Measure, Output, or Self-Test functions when a thermocouple type is selected. The RJC is NOT included when the mV range is selected in any one of these functions.

To expedite the measurement and calibration operations, an optional thermocouple adaptor plug may be used for quick connect/disconnect of thermocouple units. The color-coded adaptor plugs are available in standard or miniature sizes and are pre-wired with short lengths of appropriate flexible thermocouple

C-65 OPERATION

MEASUREMENT MODE

1. Connect the thermocouple leads or millivolt input leads to either the A or B set of input binding post terminals. Set the channel A/B input selector switch accordingly. Connect the red thermocouple lead to the minus (-) terminal for thermocouple temperature measurements. Use copper leads for millivolt measurements.
2. Set FUNCTION selector to T/C MEASURE.
3. Set RANGE selector to mV or to the thermocouple type attached to the instrument.
4. Select °F or °C for the temperature readout desired.
5. Readout displays measurement value. Readout displays °F or °C for temperature* and E for millivolts. Allow one minute warm-up for one degree resolution and a fifteen minute warm-up for tenth degree resolution.

NOTE

READ INSTRUCTION MANUAL FOR FURTHER OPERATIONAL DETAILS.
*Per ANSI Standards, IPTS-68, and NIST Monograph 125.

OUTPUT MODE

1. Disconnect the signal or sensor leads from the input of the instrument to be calibrated.
2. Connect the C-65 to the input of the instrument to be calibrated using thermocouple wire of the same type as the calibration; use copper leads for millivolt calibration. See step 1 of MEASUREMENT MODE.
3. Set the FUNCTION selector to OUTPUT.
4. Set the RANGE selector for the thermocouple type required for the thermocouple calibration, or to mV for millivolt calibrations.
5. Select °F or °C for thermocouple calibrations.
6. Adjust the COARSE AND FINE controls of the OUTPUT ADJUST potentiometer for the thermocouple calibration temperature* or millivolt calibration voltage desired as defined by the display.
7. Readout and warm-up per step 5 of MEASUREMENT MODE.

SELF-TEST MODE

1. Set FUNCTION selector to SELF-TEST.
2. Set °F or °C selector to °C.
3. Readout will be per the TEST READING of the below table (input leads need not be disconnected).

DIAGNOSTICS

1. Display reads OPEN for: an open input; sensor burnout; or millivolt readings below minus 101.1 mV.
2. Display reads HI or LO for temperatures outside the measurement range (see Chart).
3. Display reads ERROR for millivolt inputs greater than + 101.1 mV.
4. A flashing display indicates a low battery condition.

OPERATING RANGE

RANGE*	ANSI ALLOY	ANSI COLOR	°F	°C	RESOLUTION
mV	Copper/Copper	———	±101.1 mV		.001/01**
J	Iron/Constantan	White/Red	−346 to 2192	−210 to 1200	0.1
K	Chromel/Alumel	Yellow/Red	−328 to 2501	−200 to 1372	0.1
T	Copper/Constantan	Blue/Red	−405 to 752	−243 to 400	0.1
E	Chromel/Constantan	Purple/Red	−422 to 1832	−252 to 1000	0.1
R	Pt/Pt 13% Rhodium	Black/Red	−58 to 3214	−50 to 1768	1.0
S	Pt/Pt 10% Rhodium	Black/Red	−58 to 3214	−50 to 1768	1.0
C	W5Re/W26Re	———	+32 to 4200	0 to 2315	1.0
N	Nicrosil/Nisil	———	−327 to 2372	−224 to 1300	0.1

*(−4 or −8 as required) **0.001 mV from −20 mV to +20 mV

TEST READINGS AT 25 ± 10°C

mV	________	±0.012 mV
J	________	±0.3°C
K	________	±0.4°C
T	________	±0.4°C
E	________	±0.3°C
R	________	±2°C
S	________	±2°C
C	________	±2°C
N	________	±0.5°C

These are typical "test" values

Wahl

THERMOCOUPLE CALIBRATION STANDARD

MODEL

C-65-8-

S/N

Figure 2-4. Operation Instruction Label

leads terminated at the other end in color-coded spade lugs. An optional Instrument Service cable is also available, providing a 6-ft. length of flexible, paired thermocouple leads.

For economy, the Platinum Rhodium leads in the R and S thermocouple Instrument Service cables are replaced with Copper vs. Copper Alloy 11 wire that substitutes for the thermocouple leads at ambient temperatures.

3.0 OPERATION AND APPLICATION

3.1 Applications

In this section, there will be found detailed instructions for each of the following areas:

(a) Measuring temperature with a thermocouple (T/C) in the C-65 range.

(b) Measuring temperature with T/C's not in the C-65 memory.

(c) Calibrating T/C-type Recorders, Indicators, Transmitters, or Controllers.

(d) Check Thermocouples.

(e) Checking mV-type Recorders, Indicators, or Controllers.

(f) Using the C-65 as a general-purpose millivolt digital voltmeter.

A variety of configurations are illustrated in the setups shown for these applications, including the use of accessory leads, adaptors and different techniques to introduce reference junction compensation. Different combinations of these arrangements may be applicable depending on the circumstances and on-site application of the user.

Some helpful hints:

Be sure the battery pack is adequately charged before starting a C-65 operation.

Turn the C-65 off when not in use to extend battery operation intervals between charging cycles.

Perform a TEST function as described in Section 2.4 before operating the C-65 in an on-site operation.

Allow adequate warmup time.

When a choice of thermocouples is available, consider using the one that will give a greater resolution and accuracy.

3.2 As a Field Calibrator/Simulator, Calibrating T/C Type Indicators, Recorders, & Controllers

. . . When the T/C type is among the C-65 Ranges (7 basic types or 3 basic types) (See Figure 3-1).

(1) Disconnect the T/C leads from the Instrument to be calibrated.

(2) Use appropriate T/C type and quality grade leads to connect the instrument to C-65 terminal pair. (See page 33, Table 8-1 for error limits of thermocouples).

(3) Select the C-65 "OUTPUT" function.

(4) Select the appropriate T/C on "RANGE".

(5) Use C-65 coarse and fine OUTPUT ADJUST controls for a 0^{o} display value.

Select C-65 temperature unit $^{o}F/^{o}C$ as used in the instrument being calibrated.

If the instrument being calibrated does not include zero value in its full scale range, set up the minimum value that can be displayed (or indicated).

(6) Adjust the instrument ZERO for 0^{o} (or minimum value) instrument display (or indication).

(7) Use C-65 OUTPUT ADJUST controls for an instrument full scale range output value.

(8) Adjust the instrument RANGE (GAIN or SPAN) control for equal instrument display (or indication).

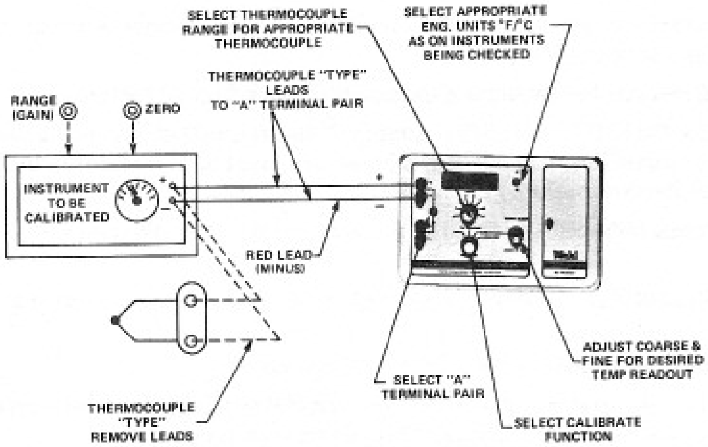


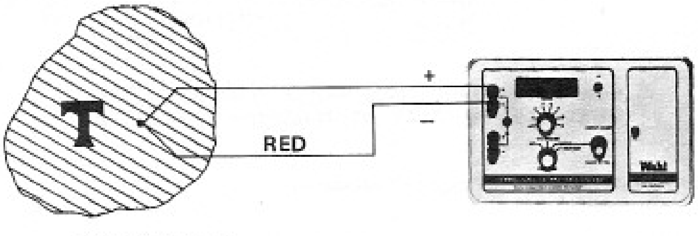
Figure 3-1. Standard C-65 Setup for Temperature Measurement

3.3 Measuring Temperatures with Thermocouples in the C-65 Range

This procedure is applicable to circumstances where the thermocouple is of the type shown on the front panel RANGE selection (7 basic types or 3 basic types).

See Figure 3-2.

(1) Use special or standard thermocouple leads to connect to the thermocouple input terminals of C-65. You may use either pair of T/C terminals. Observe caution in connecting proper polarities. The red thermocouple lead is to be connected to the negative binding post terminal; connect the other lead to the positive terminal. Refer to the listing below for the color codes of the leads used with standard thermocouples.



J, K, T, E, R, S, C

Figure 3-2. Temperature Measurement with C-65 T/C

THERMOCOUPLE LEAD COLOR CODES (ISA)

TYPE	PLUS (+)	MINUS (–)
T	Blue	Red
J	White	Red
E	Purple	Red
K	Yellow	Red
R, S	Black	Red
B	Green	Red

(2) Turn the A/B channel select switch to the connected terminal pair. (Figure 3-2 indicates connection to the "A" terminal as an example only).

(3) Rotate the RANGE selector switch to the appropriate thermocouple type.

(4) Rotate the FUNCTION selector switch to the MEASURE function.

(5) Select the desired temperature units, $^oC/^oF$.

(6) Read the temperature in the display. The value has been compensated automatically for the reference junction temperature.

3.4 As a Millivolt Generator for Calibrating Voltage Measuring Display Indicators

When used in the OUTPUT FUNCTION and mV RANGE, the C-65 provides a precision millivolt range calibration signal that may be used as a standard input to calibrate such devices as X-Y Plotters, Strip Chart Recorders, Data Loggers, etc.

Replace the normal millivolt-level input to the instrument to be calibrated with the output of the C-65.

Adjust the C-65 output with the Coarse and Fine controls for the desired value as indicated in the display.

Adjust the instrument GAIN for the proper indicated value.

NOTE: It may be necessary to re-adjust the "OUTPUT ADJUST" potentiometer to maintain the exact mV output required over a period of time.

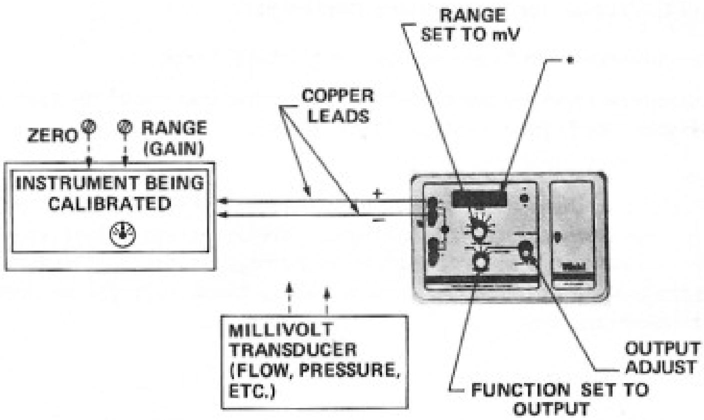


Figure 3-3. Calibrating mV Measuring/Display Indicators

3.5 As a Precision Millivoltmeter, Measuring Thermocouples Not Covered in the C-65 Range or Other Transducers

The C-65 is a convenient field portable device for measuring the outputs of transducers such as pressure gauges, flow meters, level indicators, force indicators, etc., where such outputs are in the millivolt level.

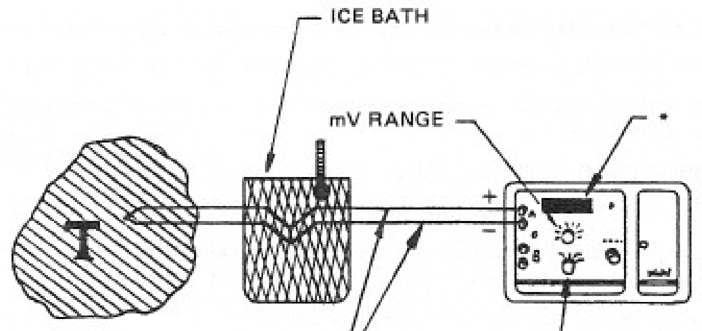
Connect the output of such devices to the C-65, and operate the C-65 in the MEASURE FUNCTION and mV RANGE. (The reference junction temperature compensation is removed from the measuring circuit in the mV RANGE).

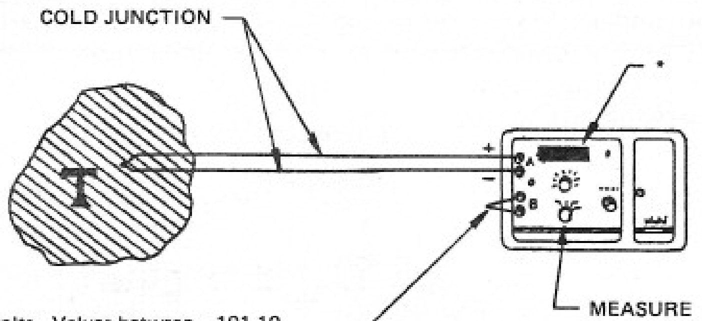
Consult available tables of EMF vs. Engineering Units to convert the millivolt readings to appropriate engineering units.

Where temperature-vs. -EMF tabular data is available, the C-65 may be used to convert precision measurements of thermocouple outputs into values of temperature when the thermocouple is not one of those in the C-65 memory. (See Figure 3-4).

(1) Connect the transducer reference terminals to C-65 with copper leads. Observe the proper polarity conventions: being sure to connect the negative T/C terminal to the negative grinding post terminal. An ice-bath may be used to provide cold junction reference to allow direct C-65 readout conforming to tables referred to 0^oC.

(2) Or, connect the T/C directly to Channel A. Then short the terminal on Channel B, and measure room temperature (any T/C range - - not mV).





1. Read Cold Junction Temperature with shorted input on Channel B. Use "RANGE" type K or J.
2. Measure millivolts on Channel A. Use "RANGE" mV.

Figure 3-4. Temperature Measurement Via mV Function

(3) Select the C-65 MEASURE function.

(4) Select the C-65 mV range.

(5) Read the millivolt value on the C-65 display. Record.

(6) Use an approved tabular listing of transducer temperature vs. voltage and convert the values recorded in steps (2) and (6) above as shown in the sample below.

Assume the use of thermocouple Type B. Tables for this type are available in NIST Monograph 125.

Assume reference junction temperature is 65°F as measurement in step (2). Look up the tables, and obtain the equivalent millivolt value for 65°F:

65°F −0.003 mV

Assume a millivolt display value of 0.549 is step (5).

Since the reference junction temperature is above the table reference point of 32°F, add the two values algebraically:

$$\begin{array}{r} -0.003 \text{ mV} \\ +0.549 \text{ mV} \\ \hline +0.546 \text{ mV} \end{array}$$

. . . the true 32°F (0°C) reference-junction compensated voltage.

Look up the tables to obtain the temperature for 0.546 mV:

It is between 635 and 636°F. The Temperature is 635.5°F.

3.6 As a Precision Comparator, Comparing Two Thermocouples or Other Signal Sources

A. When both T/C elements are of the same type and one of the C-65 Range Types:

(1) Connect each to a pair of binding-post terminals, using the same type of quality grade of thermocouple leads.

(2) Select the C-65 MEASURE function.

(3) Select the C-65 RANGE type for the T/C involved.

(4) Be sure the thermocouple probes are as close together as possible in the heat source. Tight contact of the two probes is a preferable condition, if obtainable.

(5) Alternately select input terminal pair A and B.

(6) Read and record the alternate displays. Remember that the C-65 goes into a display test mode with each new selection, before the measured value appears.

B. When the T/C units are not among those in the C-65 Range:

See Figure 3-5.

(1) Connect the thermocouple leads to copper extension wires. These connections form the reference junction. Immerse the reference junction in an ice bath which is maintained at 0°C (32°F) by using crushed ice and water and stirring thoroughly.

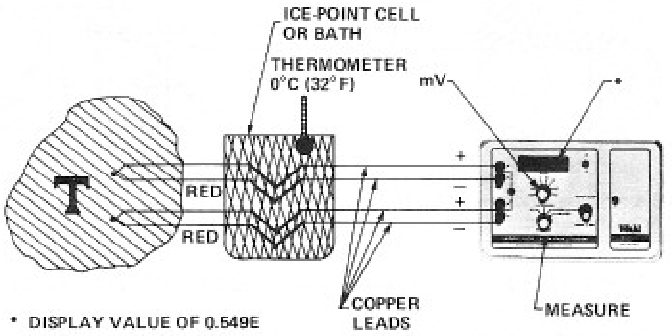


Figure 3-5. Comparing Thermocouple Performance

(2) Connect the reference junction ice point to the C-65. Observe the proper polarities; red lead to negative terminal.

(3) Select C-65 MEASURE function.

(4) Select C-65 mV range.

(5) Select Alternate C-65 input terminals A, B.

(6) Read and record the alternate display values.

C. When different T/C Types are to be compared:

.... (1) and both are among the C-65 ranges, follow procedure A. above, but select the appropriate T/C Range type corresponding to the T/C connected to the input when A/B selection is made.

.... (2) and at least one is not among the C-65 ranges, follow the procedure of B. above, but use the different electronic ice point adaptors for each T/C element. Compare display values.

3.7 As a Calibrator of Thermocouples, Using Precision Temperature Baths

The C-65 is a laboratory grade instrument. Its accuracy as a precison measuremeter and its display resolution make it suitable for laboratory calibration of thermocouples (whether or not they are within the C-65 memory). To accomplish the procedure described in this paragraph, one or more of the Precision Temperature Baths shown in Figure 3-6 must be available.

(1) Immerse the thermocouple in the Precision Temperature bath, whose temperature is known to an accuracy of ± 0.01°C to ± 0.1°C.

(2) Select the appropriate thermocouple type RANGE. Select the MEASURE FUNCTION. If the thermocouple is not among the C-65 ranges, select the mV RANGE.

(3) Read the sensed temperature (or millivolt value).

(4) Record the difference between the value of the Precision Temperature Bath and the measured value on the display.

(5) Calculate the instrumentation error as the root-sum-square of the possible error introduced by the C-65 for the thermocouple type and temperature range (see Range Conformity, Table 1-2) plus the error introduced by the thermocouple wire (see paragraph 3.2) plus the inaccuracy of the Temperature Bath.

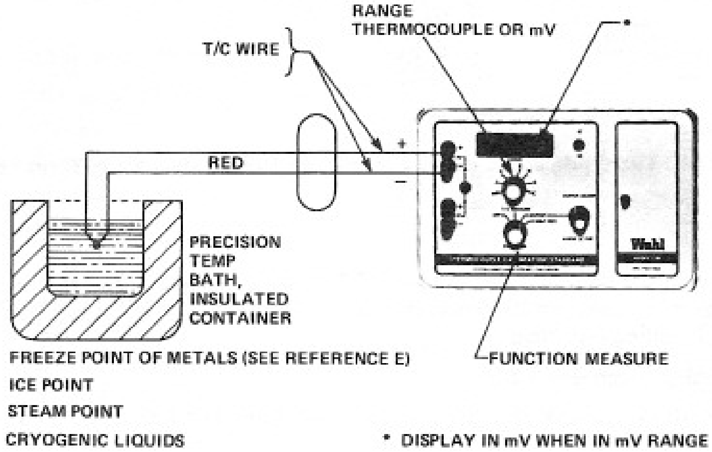


Figure 3-6. Calibrating Thermocouples in Precision Temperature Baths

3.8 As a Precision Digital Thermometer Using Calibrated T/C's

The precision and accuracy of the C-65 make it possible to perform temperature measurements with a Special Grade thermocouple with an accuracy hitherto unavailable for field instruments. (The accuracy of the precision thermocouple may be checked by using the procedure of the previous paragraph).

Use the C-65 in the MEASURE FUNCTION and select the RANGE of the thermocouple in use.

Determine the possible error of the measurement by calculating the root-sum-square of the errors determined from the table of limits of Error for the thermocouple used plus the error of the C-65 as determined from Table 1-2 (Range Conformity).

3.9 As a Laboratory Instrument, where High Precision, Long Term Temperature Measurements are Required.

Refer to Figure 3-7.

The C-65 is particularly well suited for laboratory use where very precise temperature measurements ($\pm 0.1^{\circ}$) are to be monitored unattended over long periods.

(1) Connect the temperature measuring device (chart recorder, indicator, controller, data logger, etc.) to the C-65.

(2) Use the C-65 in its recharging mode (the battery life is typically 6 to 8 hours when fully charged).

(3) Place the thermal measuring environment in a protected enclosure to insure the absence of draft-induced changes in ambient temperature.

(4) Pack the C-65 input terminals in foam rubber or plastic to maintain an insulated reference junction environment.

(5) Set up the C-65 for the appropriate RANGE and OUTPUT FUNCTION.

(6) Adjust the C-65 output for the desired reading. Operate the C-65 as for normal procedures.

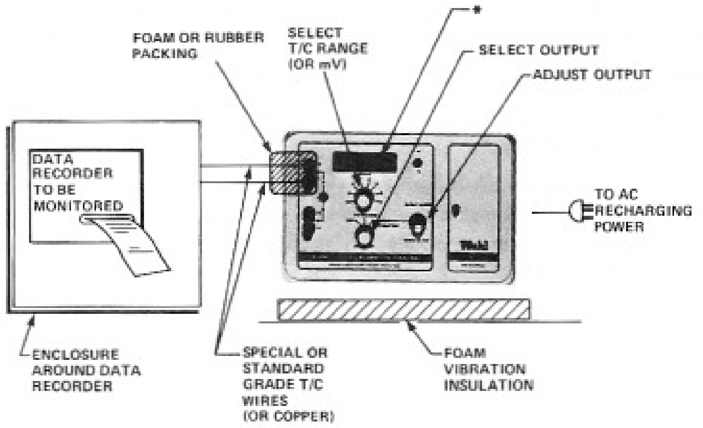


Figure 3-7. Check T/C Type Indicators, Recorders and Controllers Over Long Term Periods

(7) Because of the precision and stability of C-65 over long periods of time (such as overnight), you can now detect small temperature variations of 0.1^{o} in process recording, monitoring and controlling instruments.

3.10 As a Self-Testing Diagnostic Tool

The C-65 may be used as a trouble-shooting tool in installations where malfunctioning thermocouples are suspected.

Merely connect the suspect thermocouple (or other millivolt transducer) to the C-65 and set the front panel controls for the appropriate RANGE (T/C type or mV) and FUNCTION (MEASURE).

The C-65 will display an appropriate error message if the transducer has an open lead or if the output exceeds the high or low levels of the specified component. See the table of such error messages in Figure 2-3.

3.11 Special Applications

For the petrochemical and pipeline industries, where intrinsic safe operation is required, the C-65 may be used with an approved barrier system without serious degradation of performance in either the Measurement or Calibration Mode.

4.0 SERVICE AND REPAIR

4.1 Scope

This chapter describes rudimentary field maintenance for C-65. Such maintenance is limited to replacement of fuses, battery packs, and some mechanical components.

CAUTION

The C-65 is covered by a factory warranty, and it should be returned to the factory for any repairs required within the warranty period. Attempts to effect repairs during the warranty period may void the warranty. Only qualified service personnel should attempt to make such repairs.

4.2 Preventative Maintenance

The C-65 should be inspected regularly for the appearance of dirt, loose terminals, knobs and switches. A thorough inspection cleaning, and mechanical checking should be performed as soon as possible after any period of operation in particularly severe dusty or corrosive areas. Keep the instrument covered when not in use to minimize the effects of the field environment.

4.3 Corrective Maintenance and Repair

Apparent malfunctions should be confirmed by performing the TEST FUNCTION and comparing results with the performance data in the calibration label in the C-65 case lid. When this test indicates a proper functioning C-65 and there is still evidence of improper results, check external connections very carefully. Be sure that all external effects, such as draft-induced ambient temperature fluctuations, crossed-terminal polarity connections, and incorrect lead materials are identified and checked before assuming an equipment malfunction.

Repair of the C-65 is limited to pc-board replacement, and should be accomplished by the Factory Service Center. All such certified repairs will include a complete recalibration. However, Section 4.3.1 describes pc-board replacement if fault isolation has been made. The most common problem will be battery failure.*

4.3.1 General

This Section describes how to gain access to the battery pack and printed circuit boards for repair or replacement.

For all repair work, start by unplugging the AC power cord, removing the six screws on the front panel, slipping the unit out of the case, and disconnecting the ground wire from the case.

4.3.2 Battery Pack Replacement (Refer to Figure 4-1)

1. Unplug battery cable from J4 on power supply PC board.
2. Remove four screws that attach battery holder to power supply unit assembly.
3. The battery pack can now be changed. Unplug the connector and replace with P/N 1568 which is supplied with mating connectors for ease of replacement. Replace the Bracket and four screws.

4.3.3 Replacement of Power Supply PC Board (Refer to Figures 4-2 and 4-2A)

1. Unplug P3 (16 pin DIP plug with locking clip) and P4 (3-pin plug) from the board.
2. Remove mounting screw on power transistor Q1.
3. Remove the four PC board mounting screws.
4. Unsolder the transformer leads from points E3 and E4.
5. The PC board can now be changed. Be sure that the transistor insulator is in place (between power transistor Q1 and the case).

4.3.4 Replacement of Analog Board (Refer to Figure 4-2 and 4-2A)

1. Remove the COARSE and FINE output adjust knobs from the front panel, using a 3/32" Allen wrench to loosen the set screws.
2. Unplug P2 (5-pin connector).
3. Remove the four mounting screws.
4. Lift the board straight up.
5. When re-installing the board, be sure that the switch key is lined up as shown in Figure 4-2., and that the mode switch is set to OFF.

4.3.5 Replacement of Digital/Display Board (Refer to Figures 4-2 and 4-3)

1. Remove the COARSE and FINE output adjust knobs, using a 3/32" Allen wrench to loosen the set screws.
2. Remove the dress nut from the °C/°F toggle switch.
3. Unplug P2 (5-pin plug) from the analog board, and P3 (DIP plug with clip) from the power supply board.
4. Remove the four nuts that hold the PC board mounting chassis onto the front sub-panel.
5. Lift off the PC board mounting chassis.
6. Remove the four PC board mounting screws; two from the display board and two from the digital board.
7. The Digital/Display board can now be removed. When re-installing, make sure that the switch keys are aligned as shown in Figure 4-3. The front panel controls must be set to OFF mode and mv range.

   Wiring array is shown in Figure 4-4.

*Nickel Cadmium rechargeable battery packs will function well with a few simple precautions. The cells discharge at 10% per week when not in use. If allowed to discharge completely one or more cells may not recover when recharge is attempted. To avoid battery failure, keep on "charge" when unit is stored (not in use). Continuous recharge is possible indefinitely without damage.

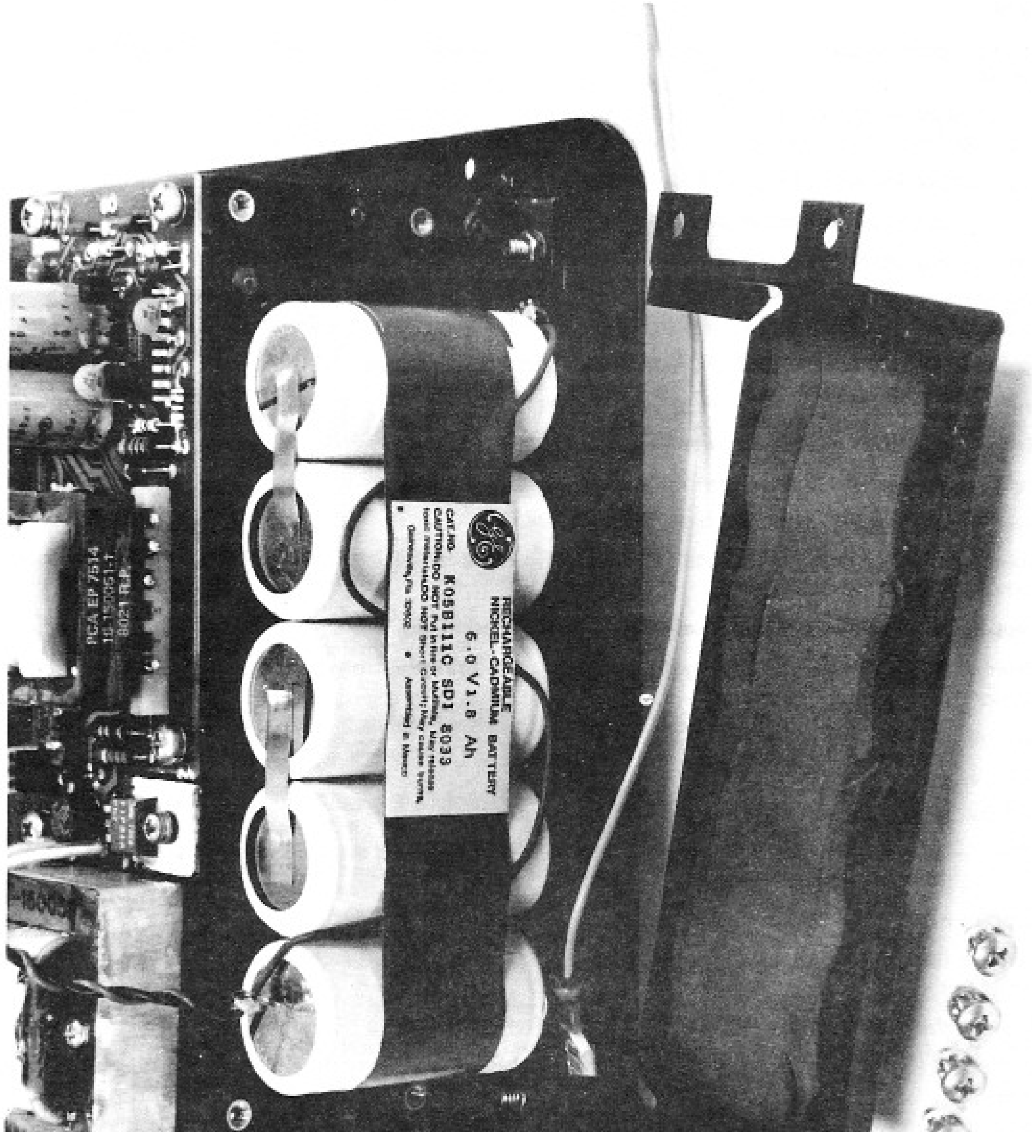


Figure 4-1. Battery Pack Replacement

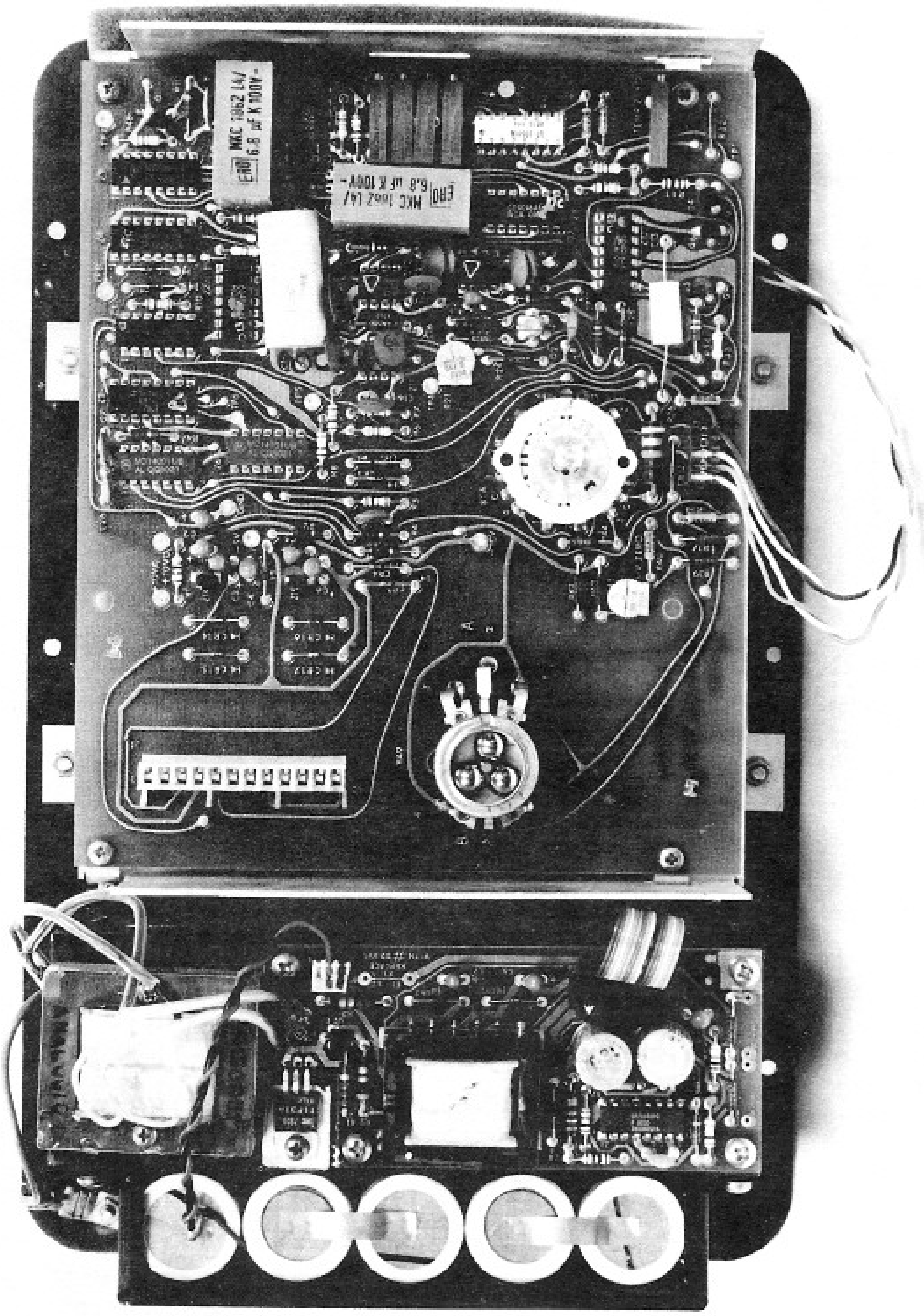


Figure 4-2. Replacement of Power Supply PC Board

NOTE: DIGITAL/DISPLAY BOARD IS MOUNTED BETWEEN SUB-PANEL & CHASSIS AND IS HIDDEN FROM VIEW.

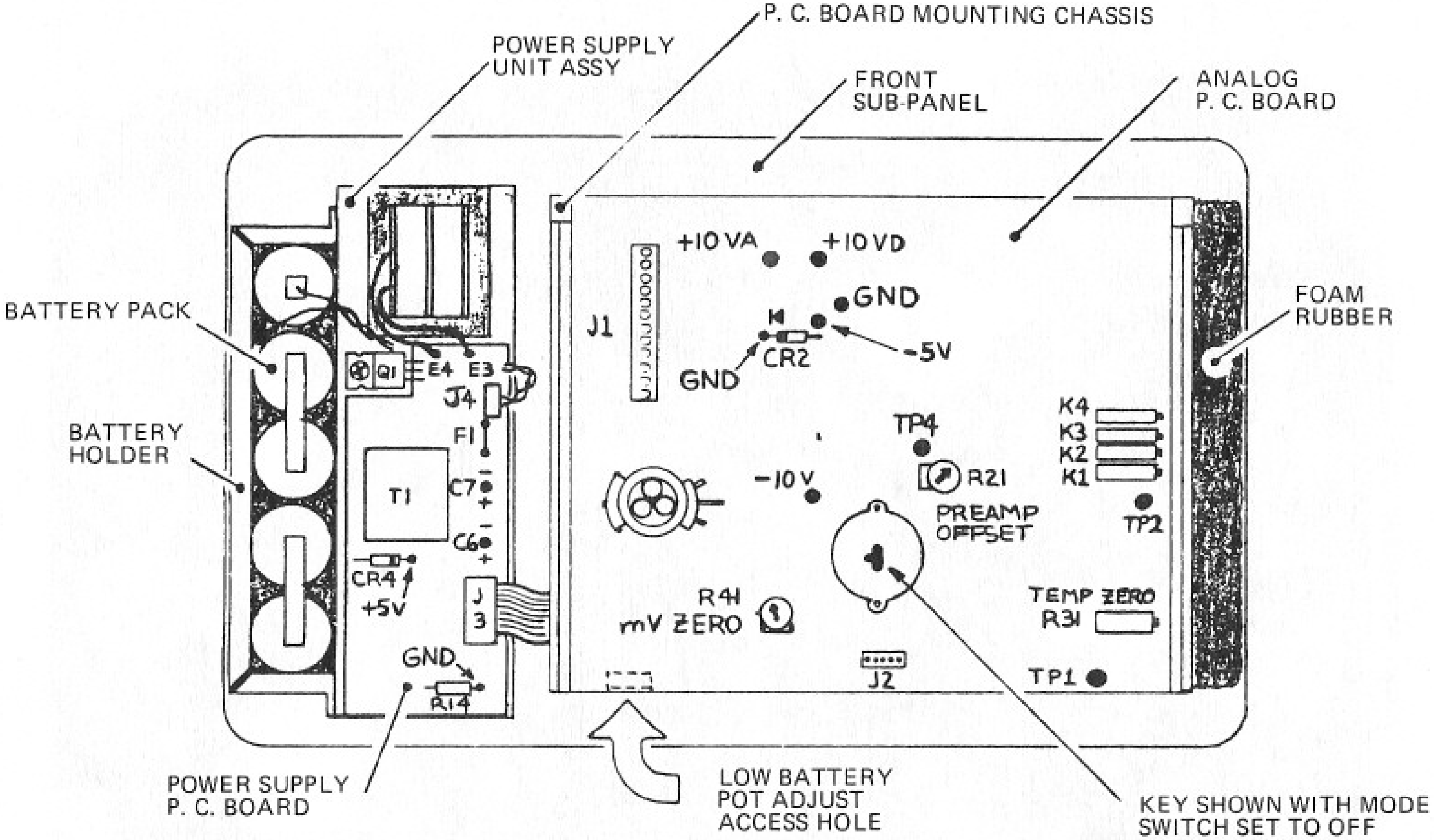


Figure 4-2A. System Rear View

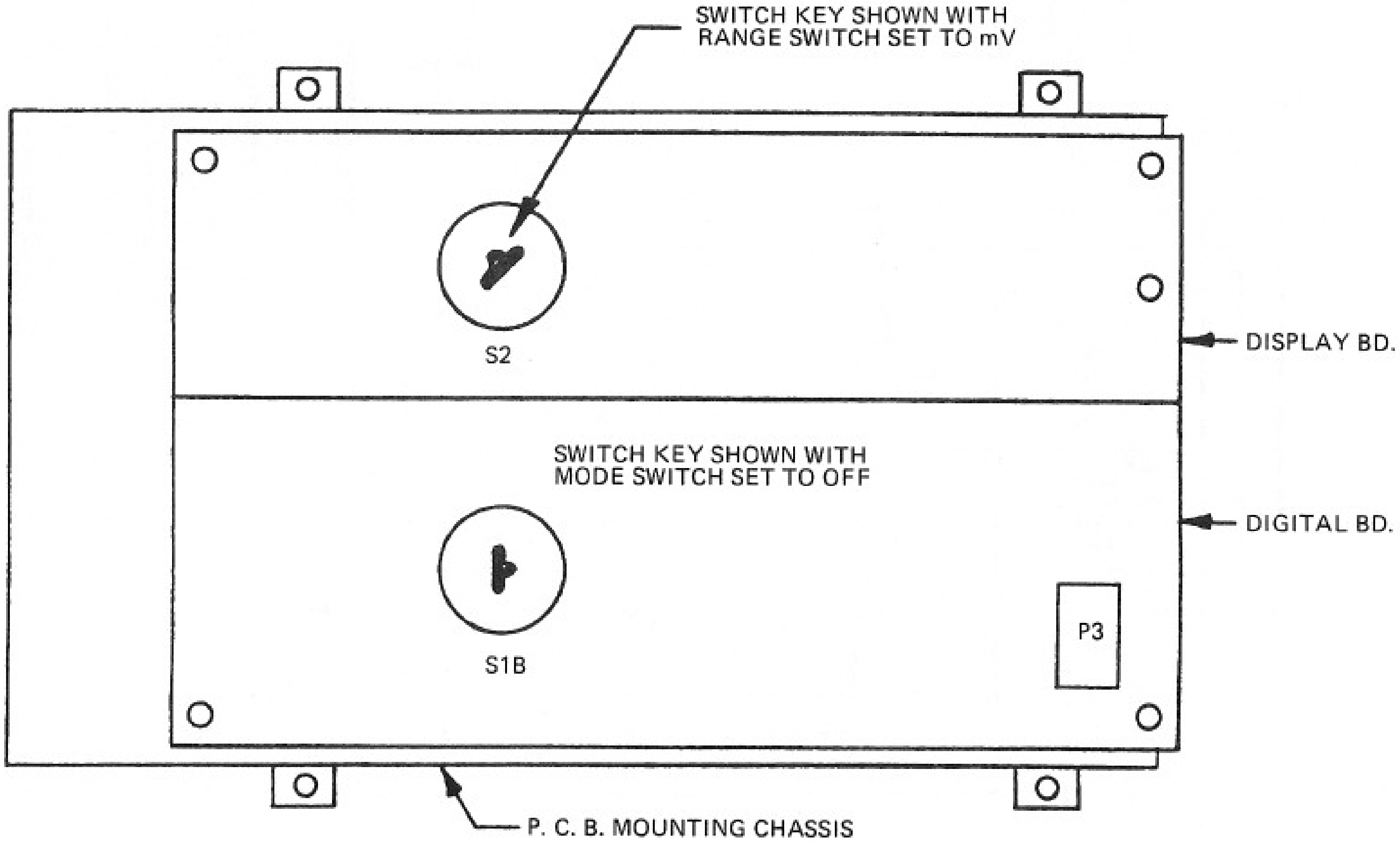


Figure 4-3. Switch Key Alignment on Digital Display Board

NOTE: WIRE COLORS MAY VARY IN SOME UNITS

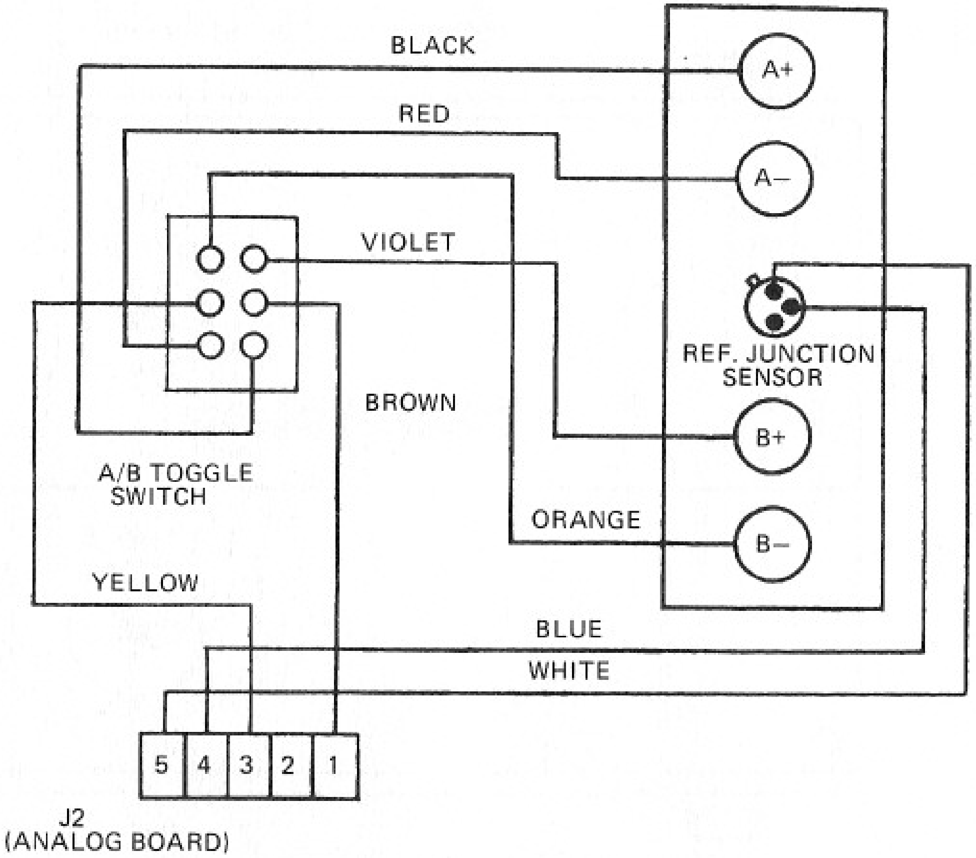


Figure 4-4. Front Sub-Panel Wiring

4.4 CALIBRATION

4.4.1 General

Instrument calibration can change because of long term drift when critical parts have been replaced or when the instrument is subjected to severe blows.

The instrument should be calibrated once a year, or whenever parts have been replaced on the analog card.

To prepare the instrument for calibration, remove the six screws on the front panel. Remove the assembly from the case and disconnect the ground wire from the case. All adjustments are located on the analog card, except for the BTRY LOW adjustment which is located on the digital card. Figure 4-5 shows the location of the adjustments and test points.

The following precautions should be observed before starting calibration:

Battery must not have been recharged within the last one hour interval.

Instrument must be operating properly.

Calibration should be performed in an area free from drafts where temperature is stable at 25°C ±2°C.

4.4.2 Equipment Required

1. Precision, adjustable voltage standard, ±100mv, 0.01% accuracy, 1 v resolution. Data Precision Model 177DMM or equivalent.
2. Ice point reference, 32.0 ±.1°F (Kaye Model 140-4 or equivalent).
3. J, K, T or E thermocouple, T preferred, calibrated to ±0.1°F at 75°F.
4. Power supply, adjustable 5 to 7 volts, 0.5 ampere.
5. Digital voltmeter (DVM), 5 to 7 volts, .01 volt resolution, 0.1% accuracy.
6. Oscilloscope.

4.4.3 Calibration Procedure (See Figure 4-5 for Calibration Schematic)

NOTE: Calibration may also be performed in the following steps using the battery pack in the instrument.

1. Disconnect battery cable from connector J4 on the power-supply card. Connect the power supply to the same connector (Positive to pin 2, Negative to pin 3). Set the power supply to 6.2 volts.
2. Connect the voltage standard to the "A" input terminals with copper wires. Set the A/B toggle switch to "A".
3. Set the voltage standard to 0.000 mV.
4. Select mV range and MEASURE mode. Allow the instrument to warm up for at least 30 minutes before proceeding.
5. Connect ground lead of oscilloscope to GND test point on analog board. Connect scope signal input to TP2. Set scope for free-running or automatic triggering. Adjust preamp offset (R21) for approximately straight, zero voltage trace (within ± 1cm) with scope sensitivity of 0.1V/cm. Note that once every five seconds there will be a large positive pulse (approx. +3V). This is the output of the reference junction temperature sensor and should be ignored.
6. Set the voltage standard as shown in the following table. Then adjust the indicated controls to obtain the displayed reading shown.

Set Voltage Standard At	Adjust	Display
0.000 mV	mV ZERO (R41)	0.000
+15.000 mV	K4	15.000
+40.000 mV	K3	40.000
+70.000 mV	K2	70.000
+90.000 mV	K1	90.000

7. Check error of displayed readings for voltages shown below. If error exceeds that shown, adjust the indicated control to balance the error between positive and negative inputs.

Set Voltage Standard At	Allowable Display Error	Adjust
−15.000 mV	± .002 mV	K4
−40.000 mV	± .01 mV	K3
−70.000 mV	± .01 mV	K2
−90.000 mV	± .01 mV	K1

8. Connect a J, K, T or E thermocouple to the input terminals. Place the thermocouple in the ice point reference.

9. Select the appropriate thermocouple range on the instrument being calibrated. Select °F. Allow 30 minutes stabilization.

10. Adjust the TEMP ZERO control for a display of 32.0°F. Modify this value as follows if the thermocouple has a calibration error. NOTE: This calibrates the measurement of the reference junction temperature. However, this temperature is actually measured at five second intervals. Therefore, the change in the displayed reading will be delayed for up to five seconds after the TEMP ZERO control has been adjusted.

    10a. Determine the thermocouple calibration error by subtracting the calibration bath temperature (i.e., output = 74.4°F at 75°F bath, error = −0.6°F).

    10b. Adjust the TEMP ZERO control for a display of (32.0 − thermocouple error). (i.e., 32.0 − (−0.6) = 32.6°F for above case).

11. Select the TEST mode. Select °C. Verify that the displayed reading for each range falls within the limits shown below. Record the new test values on the Instruction Label in the top cover of the instrument.

Range	Display
mV	4.450–5.550 mV
J	84.9–105.2°C
K	108.6–135.5°C
T	103.7–126.7°C
E	71.8–88.6°C
R	498–598°C
S	522–631°C
C	277–337°C

This completes the calibration for all ranges.

4.4.4 Low Battery Adjustment

1. Turn the BTRY LOW control on the digital card fully counter-clockwise.
2. Set the adjustable power supply at 5.90 volts.
3. Slowly turn the BTRY LOW control clockwise until the display starts to flash.
4. To check the setting of the BTRY LOW control, increase the power supply voltage until the display stops flashing. Now, slowly decrease the power supply voltage to the point where the display starts to flash. The power supply voltage should be 5.90 ± 0.03 volts.

5.0 FUNCTIONAL DESCRIPTION

5.1 General

Under the microprocessor control the C-65 "reads" the front-panel selected FUNCTION and RANGE switches and sets up the instrument to MEASURE, CALIBRATE, or TEST for the selected thermocouple (where appropriate). Figure 5-1 is a greatly simplified block diagram that illustrates the multifunction capabilities of this compact instrument. As shown in the illustration, the displayed value is derived from any one of several selectable inputs to the analog-to-digital (A/D) chain. The front-panel FUNCTION select switch determines whether the A/D input will be the signal connected to the front-panel termi-

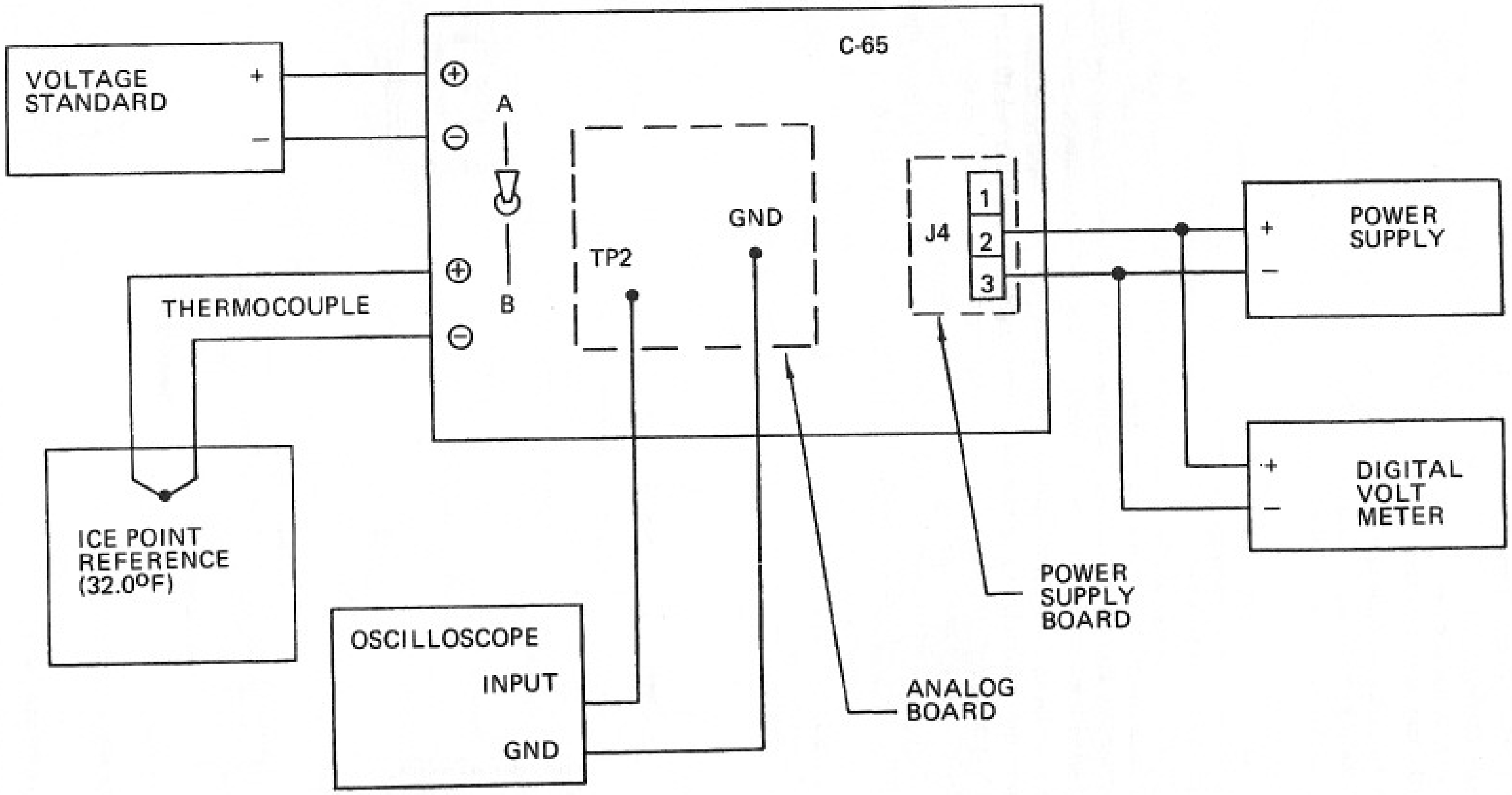


Figure 4-5. Calibration Schematic

nals from some temperature sensor, or a voltage derived from one of three internal sources. The front-panel RANGE switch setting causes the microprocessor to calibrate the digitalized signal in terms of the stored thermocouple tabular data and in °F and °C, as selected by a front-panel switch or in units of millivolts when no thermocouple range has been selected.

In the measurement function, the signal connected to the input terminals is connected to the A/D chain. If a thermocouple range has also been selected, the signal from a reference junction sensor is also connected to the A/D chain, as will be described later.

In the calibration function, a setable voltage, whose value is similarly scaled, converted, and displayed is connected internally to the front-panel terminals. If a thermocouple range has also been selected, the output voltage is conformally mapped by the microprocessor and compensated for the reference junction voltage.

In the self-test function, an internal precision reference voltage is similarly scaled and converted. (It is not connected to the terminals for external use, however). As for the other functions, if a thermocouple range has also been selected, the converted value is conformally mapped for the particular thermocouple and compensated for the reference junction voltage value as well. Its digital value is displayed, and the reading may be compared with the value established at the factory final test and calibration. Because the test signal is processed through the complete chain as for many measure or calibrate function, the self-test exercises all of the components that are included in the normal operation.

Error messages are displayed if the performance does not meet preprogrammed requirements. If an open sensor lead (or open thermocouple or a voltage input more negative than minus (−) 101.1mV) is detected, the message OPEN is displayed. If the input value exceeds the preprogrammed full scale range for the selected thermocouple, the message HIGH or LO appears for the appropriate direction in which the signal exceeds the limits. If the input exceeds the maximum full scale range of 101.10mV, the message ERROR is displayed. More detailed operational description is given in Section 3.0.

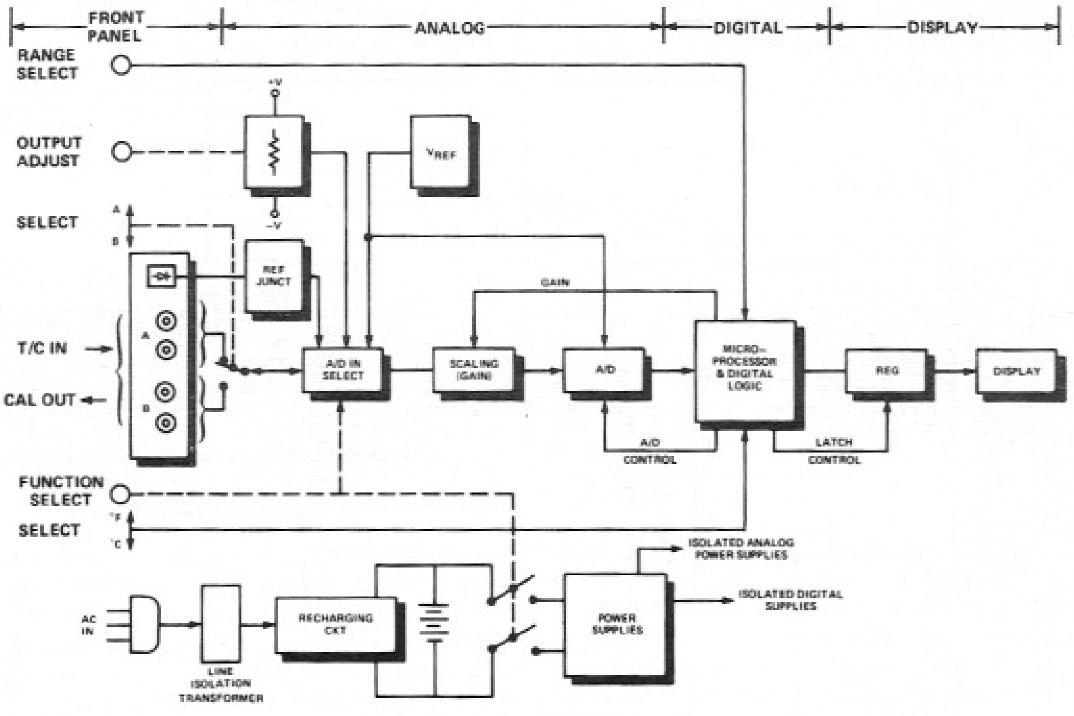


Figure 5-1. System Block Diagram

5.2 The Two-Conversion Cycle

The digital display is updated twice a second for nine successive updates of the selected input signal to the A/D conversion chain. In the tenth 500-millisecond interval, only the output of the reference junction sensor is connected to the A/D chain. Its value is digitalized and stored to be applied in the next nine display updates.

During the 500-millisecond period, the C-65 performs two analog-to-digital conversions. In the first such conversion, lasting 200 milliseconds, the instrument makes a conversion with a minimum amplifier gain of 20. The microprocessor examines the results of that conversion and then sets the gain at 20, 50, 70 or 200 so that the next conversion will occur with a scaling for the greatest possible resolution of the displayed result. In effect, the C-65 autoranges before every measurement or calibration, and updates its cold-junction reference compensation every 5 seconds.

5.3 Thermocouple Interface

All thermocouples by international accord and specification tables are referenced to the ice point of water or 0^oC (32^oF). At ice point it is considered that all thermocouples have 0.0 mV output. Tables for type K and type B thermocouple values are included in Appendix C.

The cold junction or the point at which the thermocouple wires are brought to the measuring instrument is usually not at ice point, but at room temperature, therefore, and EMF with respect to ice point is produced where the T/C is connected to the instrument, (for type K, at 25^oC (77^oF) the EMF is 1.0 mV. This EMF is compensated for by the C-65 instrument which continuously measures the temperature of the underside of the terminals. This also leads to a convenience of the instrument. By shorting the input on any T/C type, one can measure the room temperature, because the instrument is always doing this as part of the cold-junction compensation. This function can be useful in measuring an untabled T/C such as Type B in the mV measure mode. The room temperature will be known without use of an additional thermometer. More information is given in Section 5.4.

5.4 Principles of Thermocouple Operation

Each junction of two dissimilar metals is a thermocouple with a voltage versus temperature, or thermoelectric, relationship. Thus there are three (3) junctions in the circuit of Figure 5-2. The T/C + to T/C – measurement junction; the T/C + to copper reference junction; and, the T/C – to copper reference junction. Each junction generates a thermoelectric voltage versus temperature signal such that the resulting thermoelectric output from the thermoelectric circuit, E_{TC}, is the difference between the measurement junction signal and the reference junction signals when both reference junctions are maintained at the same temperature. That differential output will result in a zero millivolt output signal, E_{TC}, when the temperature of the measurement junction T_M, is equal to the temperature of the temperature reference junction, T_{RJC}. This is irrespective of whether the equal junction temperature occurs at 32^oF, 70^oF, or 212^oF. Thus, $E_{TC} = 0$ if $T_M = T_{RJC}$.

When the reference junction is maintained at 0^oC, the thermocouple output, E_{TC}, will nominally be equal to the value of standard thermocouple tables, E_T, for a reference junction at 0^oC.

In practice, the reference junction of an instrument is not maintained at 0^oC and is usually the input thermocouple connections to the instrument. Therefore, it is necessary to measure the reference junction temperature and to add a corresponding thermoelectric correction signal, E_{RJC}, to the thermocouple signal, E_{TC}, see Figure 5-3. The resulting sum is the thermoelectric table voltage, E_T, for a 0^oC reference junction, where

$$E_T = E_{TC} + E_{RJC}. \qquad \text{(Eq. 5.1)}$$

For example, if the measurement junction and the reference junction are at the same temperature, assume 70.0^oF, E_{TC} is 0.000 millivolts. The reference junction temperature of 70.0^oF is measured, and assuming a J thermocouple, converted into an E_{RJC} signal of 1.076 millivolts. Thus, $E_T = 0.000 + 1.076 = 1.076$ millivolts where 1.076 millivolts is from the correction circuit and zero millivolts is from the thermocouple.

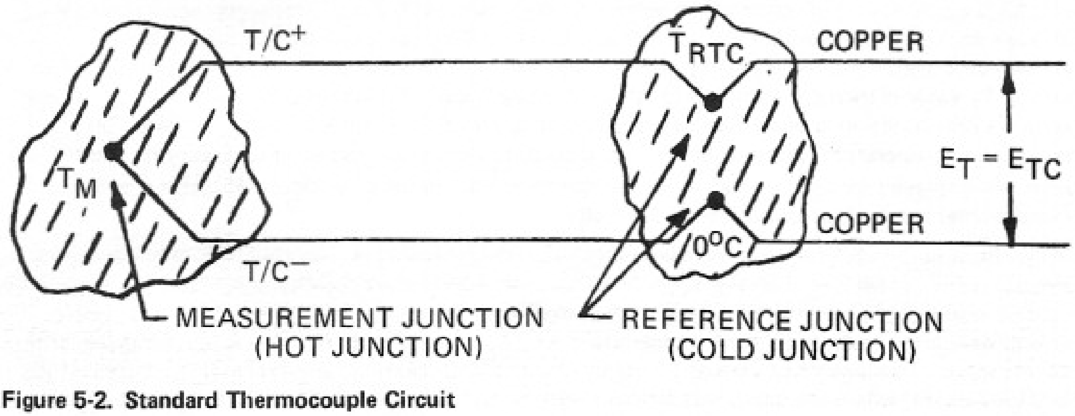


Figure 5-2. Standard Thermocouple Circuit

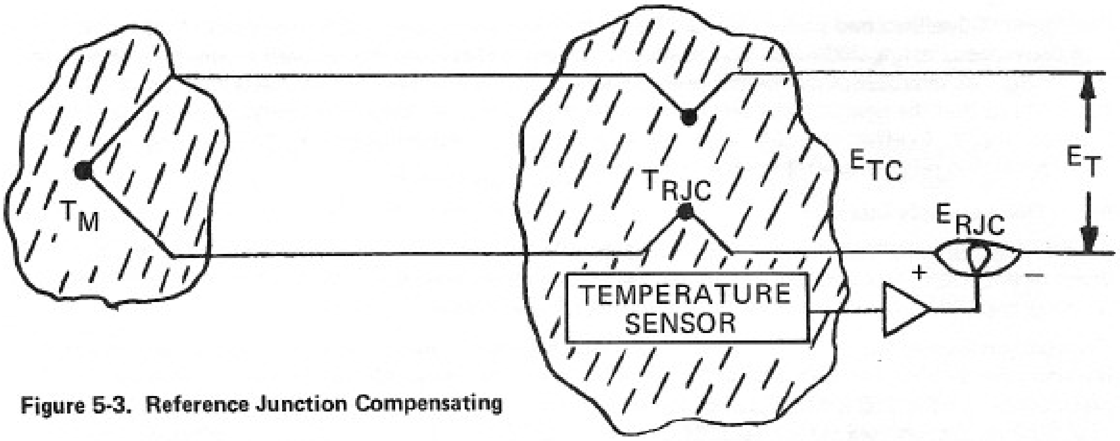


Figure 5-3. Reference Junction Compensating

The E_T thermoelectric's signal conversion into a linear measurement temperature output signal, T_M, is performed by an inverse transfer function or equation, see Figure 5-4 Sections of the input E_T input signal range are processed through gain bias networks in accordance with the equation,

$$T_m = mE_T + b \qquad \text{(Eq. 5.2)}$$

(where m is the gain of the amplifier and b is the bias). This process is called piecewise linearization where the m and b coefficients are dependent on the section for which E_T is processed. Typically, eight (8) segments per thermocouple are required for 1°F conformity and 64 to 128 segments per thermocouple are required for 0.1°C conformity.

A more sophisticated process is to use a higher order polynomial for the inverse transfer junction where,

$$T_M = a_0 + a_1E_T + a_2E_T^2 + a_3E_T^3 + \ldots + a_nE_T^n. \qquad \text{(Eq. 5.3)}$$

The larger the value of n, the larger the E_T segment span that can be covered by a single transfer function for a given accuracy. The values of the "a" coefficients are changed in each section for best fit of the inverse transfer function. This process is compatible with microprocessor or computer-based products and used on the C-65.

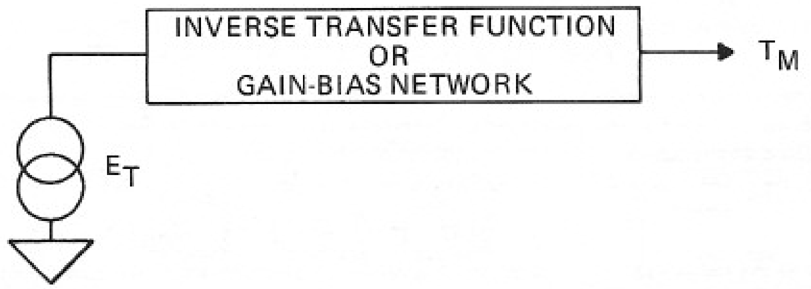


Figure 5-4. Thermocouple Linearization

5.5 C-65 Signal Processing

The C-65 is a precision millivolt digitizer with ± 40,000 counts (15.3 bits) resolution and a variable gain front end. In the measurement mode of operation, under microprocessor control, the input thermoelectric signal and the reference junction signal are processed as defined by Equation 5.1. The resulting E_T value is then converted to temperature as defined by Equation 5.3, where the appropriate inverse transfer function conforms to the corresponding standard thermoelectric table (NIST, DIN, etc.). The resulting temperature is output on an LED display to define the measured temperature value. Diagnostics are displayed for out of range or open thermocouple (input) conditions. Millivolt signals (non-thermocouple) are digitized and displayed directly.

In the calibration mode of operation, a high resolution millivolt source, controlled by dual concentric potentiometers, is switched into the input circuit and provided as a calibration output signal to calibrate a user's thermocouple (or millivolt) input type instrument. The signal is also processed as discussed above to define the calibration signal temperature per (ANSI, NIST or DIN) thermoelectric tables of the millivolt value. Thermocouple wire of the same type as the calibration interconnects the C-65 and the user's instrument, where the user's instrument performs an identical reference junction compensation function. The user's reference junction compensation circuit typically is calibrated by providing a 32.0°F or 0°C output from the C-65. Additional points are selected as required for user instrument calibration.

In the Test mode of operation, a precision millivolt signal is provided as an input signal to the C-65 (less reference junction correction). The digitized value of the signal is provided both as a millivolt value and as converted temperature value for the respective thermocouple types. These values are recorded on the instruction label of the unit and may be used to ascertain the long term stability and performance of the unit.

Digital linearization by inverse transfer equations results in an instrument that is easily calibrated. The C-65, is calibrated as a millivolt meter for each of the front end gains, and the reference junction compensation circuit is calibrated using a 0°C ice point. The inverse transfer functions provide the corresponding NIST equivalent temperature within the specified error budget.

Internally programmed front end gains of 20, 50, 70 and 200 provide corresponding input signal sensitivities of 5, 2, 1.4286, and 0.5 microvolts per digitizer count. The 0.5 microvolt resolution is used for signals up to 20.000 millivolts. In this signal range and thermoelectric sensitivity (in microvolts per degree) is minimum and high resolution is required for 0.1°F thermometry. At higher temperatures the other gain ranges provide 0.1 degree resolution up to 2500.0°F (K thermocouple).

Errors in the inverse transfer functions (per Equation 5.3) result in deviations to the ANSI (etc.) standard millivolt to temperature conversion values. These errors are specified to be less than ±0.1°C. They are actually less than ± 0.04°C and typically 0.02°C or less.

5.6 Circuit Operations

The C-65 operates at a two sample per second conversion rate using a ± 40,000 count analog-to-digital converter, (see Figure 5-6) where each conversion results in an updated display of the measured value, except as noted below. The A/D In Select function of Figure 5-6 is controlled both by the front panel function selector and by the microprocessor. The front panel selector determines whether the instrument: 1) Measures the input signal (millivolts or thermocouple); 2) Provides and measures a calibration millivolt or thermoelectric voltage signal source; or, 3) performs a self-test function by measuring a 5 millivolt source derived from the reference power supply. The microprocessor controls the A/D In Select function such that one out of each ten input samples (or one sample each 5 seconds) is a reference junction temperature measurement, T_{RJC}, (not used in the millivolt mode of operation). Each 0.5 second sample conversion is performed by a dual conversion process under microprocessor control, called conversion A and conversion B. (Figure 5-6).

Conversion A is used to measure the magnitude of the input signal plus a current source is turned on to detect an open sensor (input) or a sensor burnout condition. Following conversion A, the current source is turned off, thereby eliminating sensor lead-in resistance errors, and the gain of front-end amplifier (scaling-gain) is set for maximum conversion B resolution. The B conversion then digitizes the uncompensated sensor thermoelectric signal E_{TC}, or the millivolt signal or the reference junction temperature with maximum resolution and minimum error.

The microprocessor then processes the measured temperature of the reference junction through a forward transfer equation that converts the temperature signal into the corresponding millivolt signal, E_{RJC}, for the thermocouple type selected (J, K, T, etc.). Addition of the E_{RJC} value with the uncompensated E_{TC} value results in the compensated value. E_T value is then processed through the appropriate inverse transfer equation for the thermocouple type selected, thereby resulting in the displayed temperature value.

NOTE: DIGITAL/DISPLAY BOARD IS MOUNTED BETWEEN SUB-PANEL & CHASSIS AND IS HIDDEN FROM VIEW.

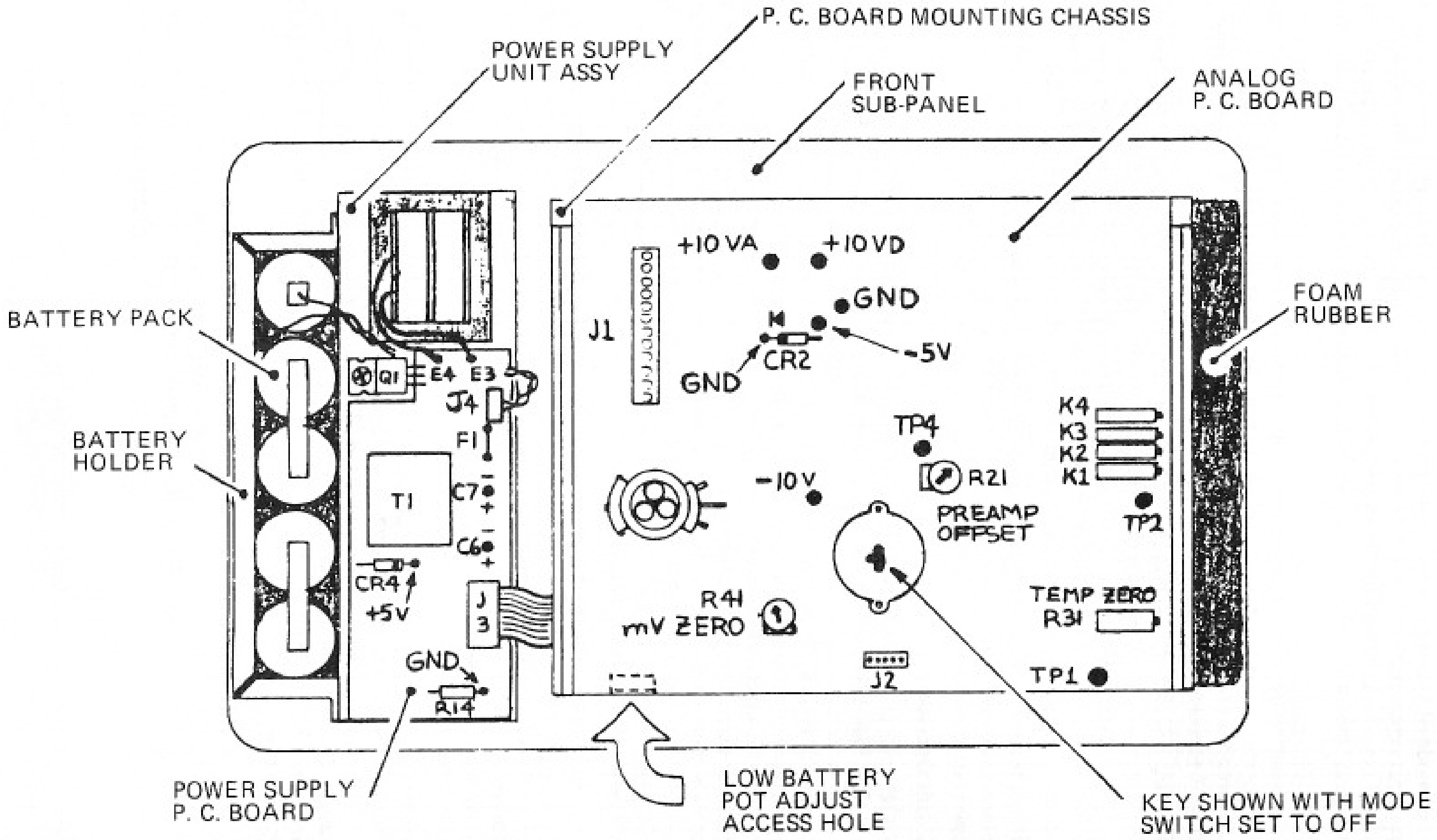


Figure 5-5. Rear View of Panel Removed From Case

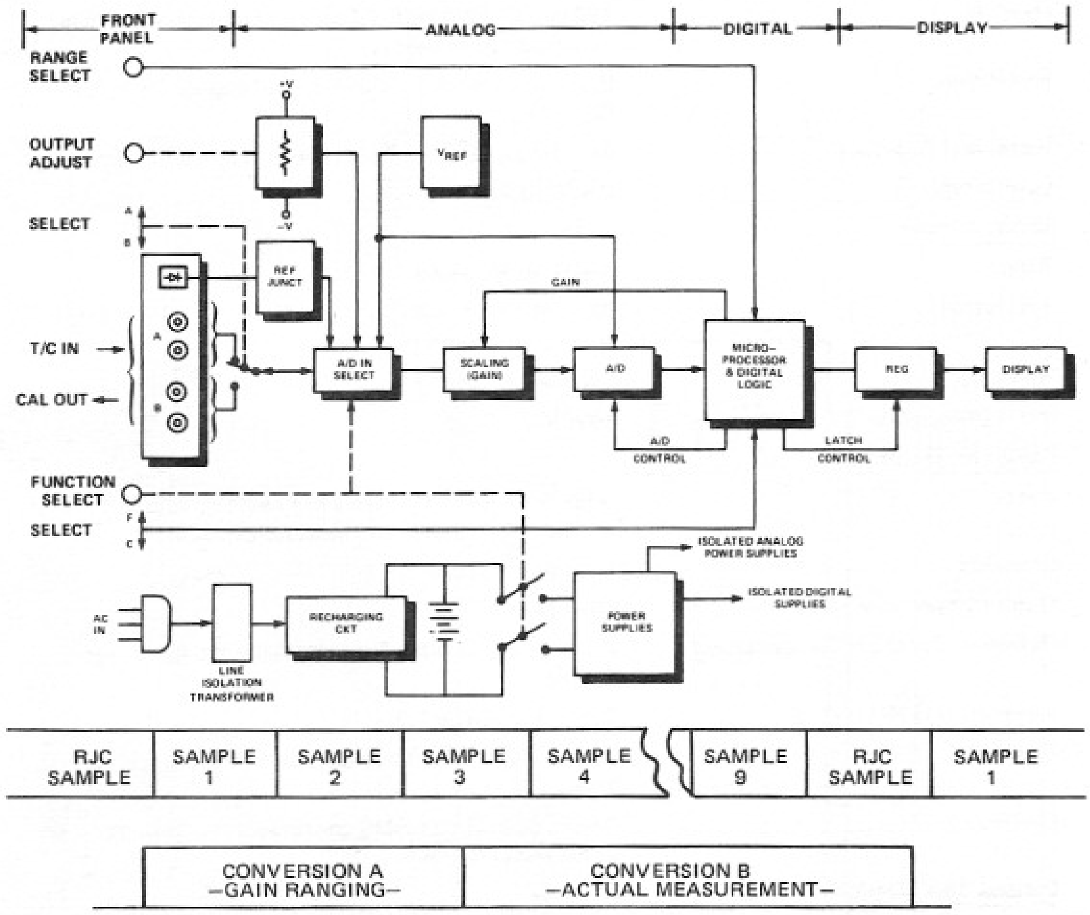


Figure 5-6. ADC Sampling & Sample Conversion Timing

6.0 SPECIFICATIONS

Unit Types

Four Range	ANSI (J, K, T) and mV
Eight Range	ANSI (J, KT, T, E, R, S) and IPTS-68 (C) and mV

Thermocouple Input

Thermocouple Types	J, K, T, E, R, and S per ANSI MC 96.1 - 1975. Type C per IPTS-68. See Thermocouple Standards Table.
Input Impedance	1000MΩ or greater, during measurement interval.
Maximum Source Resistance	5KΩ source or external lead resistance will cause less than 0.1°F (less than 0.05°C) error.
Reference Junction Accuracy	Automatically compensated, maximum error ± 0.017°/degree over 25°C ± 10°C (60-90°F) ambient range. Over wider ambient –10°C to + 40°C the max. error is ± .035 deg/deg.
Range Temperature Coefficient	± 15ppm/°C typical; ± 25ppm/°C max.
Zero Temperature Coefficient	± 0.00036mV/°C (± 0.0002mV/°F) max.
Open Thermocouple	Display reades "OPEN"
Sensitivity	1µ v/count or 10µ v/count nominal (Range dependent)

Noise	1.5 µV peak-peak ± (3 sigma)
Overload	120Vdc or 120Vac RMS continuous without damage in measurement mode.
Resolution	0.1 degrees for J, K, T and E. 1.0 degree for R, S and C.
Range and Accuracy	See Range, Conformity and Accuracy Table 1-2.
Conformity	0.1°C (0.2°F)
Millivolt Input	
Range	± 101.10 Millivolts
Resolution	0.001mV from –20mV, to +20mV, 0.01mV otherwise.
Accuracy	See Range, Table 1-2.
Input Impedance	1000Mµ
Calibrator Output	
Range	–12mV to +80mV (covers full range of all thermocouples contained in the measurement mode)
Setability	Infinitely variable
Output Impedance	40 ohms
Reference Junction Compensation	Automatic, provided for each thermocouple range selected.
Accuracy and Resolution	See Range, Table 1-2.
Readout	Temperature (°F/°C as selected by switch) or millivolts.
Overload	3 volts dc or 3 Vac RMS continuous, without damage in calibrator mode.
General Specifications	
Connectors	Four five-way binding posts. (Two sets, one set each of Channel A and B).
Warm-up	One minute for 1° thermocouple ranges and 0.1µ V resolution ranges. Fifteen minutes for 0.1° thermocouple ranges and 0.001µ V resolution ranges.
Settling Time	0.5 seconds for rated accuracy.
Normal Mode Rejection	50db @ 50Hz or 60Hz
Common Mode Rejection	Not applicable for battery operation. 140db when line powered (in recharge mode).
Common Mode Voltage	500 volts RMS battery or AC mode.
Package	
Housing	Metal case with handle; epoxy paint.
Weight & Size	9.5 lbs. (4.3kg); Dimensions: 6' D x 8" W x 12.25" L (15cmD x 20cmW x 31cmL).
Power	
Type	Internal nickel-cadmium battery pack, rechargeable.
Continuous Operation	Eight hours minimum
Recharge	14 to 16 hours for full battery charge. Instrument can be operated continuously while on recharge (+5°C to +40°C).
Battery Life	1000 charge/discharge cycles min.
Continuous Recharge	Indefinitely without damage.

AC Power	110Vac or 220Vac ± 20%, 47 to 400Hz. Includes grounded, three-wire line cord for specified power source. Externally accessible fuse.
Controls	
Range Select	Rotary switch four or eight ranges.
Function Select	Rotary switch, four position: OFF, T/C MEASURE, OUTPUT and SELF-TEST.
^{o}F/^{o}C Select	Toggle switch, two position: ^{o}F or ^{o}C.
Output Adjust	Dual concentric potentiometer, Coarse Fine adjustment of (1) output millivolts at output terminals; (2) output adjustment of corresponding temp. on display.
Channel A/B Select	Toggle switch, two position (Channel A can be receiving information, and Channel B, when selected can be sending information.)
Display	
Type	Seven digit, seven segment planar, red LED display, 0.30 inch (8mm) high
Readout Units	^{o}F or ^{o}C for temperature, E for millivolts
Diagnostic Displays	
Low Battery	Display blinks for 10 minutes, then unit powers down and display turns off.
Positive Temperature Overrange	"HIGH"
Negative Temperature Overrange	"LO"
Open Thermocouple Input	"OPEN"
Overrange Input	"ERROR"
Display Test	Display reads all "8's" when unit is turned on or range is changed.
Environmental and Reliability	
Operating Temperature	-10^{o}C to $+40^{o}$C ($+14^{o}$F to $+104^{o}$F).
Storage Temperature	-40^{o}C to $+60^{o}$C (-40^{o}F to $+140^{o}$F).
Relative Humidity	0–90%, non-condensing
Moisture Seal	O-Ring sealed waterproof case; splash-proof panel.
Vibration	Each unit vibrated at 2g's for 30 seconds.
Shock (Drop Test)	Meets the requirements of Mil-Std. 202E for safe transit.
EMI/RFI	Shielding on six sides in standard metal case.
Burn-In	>100 hours (without batteries) from 0^{o}C to $+50^{o}$C temperature cycles and power ON/OFF cycles.
Calibration	NIST traceable. Detailed certificate of calibration shipped with each unit.
Warranty	Twelve Months
Safety	500 volts RMS max. on input terminals.

7.0 NIST TRACEABILITY

The C-65 Instrument is provided with a Certificate of Calibration traceable to NIST to provide the assurance that measurements can be made to accepted standards. This certificate also provides quality assurance information on basic inspection values that we have deemed to be necessary to provide operating conformance of the C-65 Instrument.

1. The C-65 is factory calibrated using a voltage standard (Analogic Model No. AN3100 or Precision Digital Model 8200).

   a. The AN3100 voltage standards are calibrated twice a year using an Eppley Lab saturated standard cell Model SCO-106.

   b. The standard cell is calibrated twice a year by the manufacturer, the Eppley Laboratory, Inc., Newport, R.I. Their NIST test number is 220691.

Sample of Certificate is enclosed in Appendix A.

8.0 REFERENCE DATA

8.1 Definitions

CRYOGENIC - Very low temperatures; used in reference to liquified gases such as LOX (−297°F) and LN2 (−320°F). Requires use of high resistance Platinum RTD's (500-5,000 ohms), gold-chromel thermocouples or low temperature thermistors.

DIN STD. - A European Temperature Standard. DIN STD. 43710 establishes thermocouple curves.

DUPLEX SENSOR - A dual thermocouple usually isolated from each other and in the same housing or sheath.

FREEZE POINT STD. - provides known fixed reference temperatures, the freezing points of metals. They are usually not monitored by a reference thermometer since the pure metal samples are certified. Typical examples:

METAL	FREEZING POINTS	
	°C	°F
Tin	231.97	449.55
Zinc	419.58	787.24
Aluminum	660.37	1220.67

KAPTON - A Dupont Company Polyimide insulation material; Radiation Resistant, Maximum Temperature 285°C. Used for high temperature lead wire insulation for RTDs and T/C.

MINERAL INSULATED - A term used to express a swaged or drawn thermocouple construction where a mineral oxide insulation, usually magnesium oxide or aluminum oxide, is densely compacted in a sheath for rugged bendable high temperature, sensor construction.

O.D. (Tubing vs. Pipe) - Outside diameter, the proper way to size thermocouple sheath tubing vs. inside diameter used for pipe sizing.

PLATINEL - A special high output/high temperature platinum alloy thermocouple (Trademark of Englehard Industries). Has an EMF output of 0-51 mv. over span of 32°F to 2372°F. Composition is gold, platinum and palladium. Usual diameter is .020" per lead.

REFERENCE JUNCTION - The other junction (usually at ice point) to which the measuring thermocouple junction is compared. The output voltage of a T/C is approximately proportional to the temperature difference between the measuring (hot) junction and the reference (cold) junction.

RESPONSE TIME - (Time constant of a sensor). The time necessary for the sensor to reach 63.2% of step change in temperature with the sensor in water at a velocity of three (3) Ft/Sec. transverse to the sheath.

TEFLON/TEFZEL - Medium temperature wire insulation useful to 500°F and 390°F, respectively. Tefzel has some radiation resistance.

THERMOCOUPLE - Two dissimilar metals with a voltage output proportional to temperature. ANSI types:

	J	Iron - Constantan (Copper - Nickel)	2192°F*
	K	Chromel - Alumel (NiCr vs. N1-A1.)	2501°F
	T	Copper - Constantan (Copper-Nickel)	752°F
	E	Chromel - Constantan (NiCr. vs. Cu-Ni)	1832°F
	R	Platinum - vs. Plat. 13% Rhodium	3214°F
	S	Platinum vs. Platinum 10% Rhodium	3214°F
	B	Plat. 6% Rhodium vs. Plat. 30% Rhodium	3308°F
(Non-ANSI):	C	W 5% Rhenium vs. W 26% Rhenium	5000°F

*When used for ANSI extended range.

THERMOWELL - The pressure vessel into which a thermocouple is inserted for easy removal and/or replacement purpose..

8.2 Temperature Definitions Supplement

OFHC - Oxygen free high conductivity copper, one leg in type T thermocouples, the other leg being an alloy of approximately 60/40 copper nickel.

ALLOY 11 - An alloy of copper with addition of approximately 0.5% nickel. Used with pure copper as compensating lead wire for platinum/Platinum-Rhodium thermocouples types R & S.

NICROSIL/NISIL - Thermocouple improvements on type K to eliminate the instability caused by high-temperature drift and short-term changes in EMF in the 250-550 C range. Data available in NIST Monograph 161. Composition is:

	Nicrosil	Nisil
Chromium	14.2%	
Silicon	1.4%	4.4%
Nickel	Balance	Balance

Nicrosil/Nisil are useful from $0^{o}C$ to $1300^{o}C$ ($2372^{o}F$), where the EMF output is about 47.5mV.

8.3 Limits of Error

LIMITS OF ERROR - The deviation in degrees or % of Standard or Special grade (see table below for definition if standard, special) thermocouples in EMF outputs from an ideal calibration. This tolerance or calibration normally applies only from $0^{o}C$ up to the maximum temperature for each thermocouple. Sub-zero limits require special calibration.

JUNCTION-FORMING - This means of forming the electrical contact between the two wires of a thermocouple. Methods include: Type E - Soft or silver soldering for low temperature operation.

Type J, K, T - Gas Welding; the wires are twisted together through two or three turns, held vertically in a vise and joined by fusion with a gas flame (using only borax as a flux).

Table 8-1. Limits of Error of Thermocouples

			Limits of Error			
	Temperature Range		Standard		Special	
Type	°F	°C	°F	°C	°F	°C
B	1600 to 3100	871 to 1705	±1/2%			
E	32 to 600	0 to 316	±3°F	±1.7	±2 1/4°F	±1.3
	600 to 1600	316 to 871	±1/2%		±3/8%	
J	32 to 530	0 to 277	±4°F	±2.2	±2°F	±1.1
	530 to 1400	277 to 760	±3/4%		±3/8%	
K	32 to 530	0 to 277	±4°F	±2.2	±2°F	±1.1
	530 to 2300	277 to 1260	±3/4%		±3/8%	
R or S	32 to 1000	0 to 538	±2 1/2°F	±1.4		
	1000 to 2700	538 to 1482	±1/4%			
T	-300 to -150	-184 to -101			±1%	
	-150 to -75	-101 to -59	±2%		±1%	
	-75 to 200	-59 to 93	±1 1/2°F	±0.8	±3/4°F	±0.4
	200 to 700	93 to 371	±3/4%		±3/8%	

*Per ANSI Standard C96.1.

Arc Welding. For small or medium diameter wires. Requires no flux. The arc is struck between the twisted tip and a piece of carbon rod.

Resistance Welding. For all thermocouples of very small diameter wires. Uses a capacity discharge type welder. Useful for R, S, B, C, W, J, E, T, & K.

8.4 Standards Organizations

ANSI	American National Standards Institute
ASTM	American Society for Testing & Materials
BS	British Standards (Nat'l Physical Laboratory - U.K.)

CSA	Canadian Standards Association
DIN	Deutsches Institut fur Normung (Germany)
IEC	International Electrotechnical Commission
IPTS	International Practical Temperature Scale
JIS	Japanese Industry Standards
NIST	National Institute of Standards and Technology (United States)

8.5 Hi-Temp Thermocouples (over 2000°F)

HI-TEMP THERMOCOUPLES (OVER 2000°F)

T/C	MAXIMUM TEMPERATURE °F	°C	COMPOSITION
R	3214°F	1768°C	Pt13Rh/Pt
S	3214°F	1768°C	Pt10Rh/Pt
B	3308°F	1820°C	Pt6Rh/Pt30 Rh
W	4200°F	2315°C	W/W-26Re
C	5000°F	2760°C	W5Re/W-26Re
W-Re(Englehard)	4352-5072°F	2400-2800°C	W3Re/W-25Re
Planinel**	2372°F	1300°C	Gold-Plat.-Palladium
Nicrosil/Nisil (N)	2372°F	1300°C	Nicrosil/14.2%Cr 1.4%sl/Bal Ni Nisil/4.4%Si/Bal Ni
K	2501°F	1372°C	NiCr/NiAl
PIMo	2900°F	1600°C	Platinum-Molybdenum
PI20Rh/PL40Rh	3272-3362°F	1800-1850°C	Platinum-Rhodium
Iridium vs.*____ Iridium-Rhodium	3632°F	2000°C	Iridium-Rhodium

*40,50 or 60%

**Platinel is a registered trademark of Englehard Industries.

8.6 Reference Publications

NIST MONOGRAPHS 125: Thermocouple reference tables based on IPTS-68. Covers standard thermocouple types J, E, T, K, R, S, B. Emf vs. T tables in both Fahrenheit and Celsius degrees.

NIST MONOGRAPH 161: Thermocouple reference tables for Nicrosil/Nisil, high temperature thermocouples.

Monographs 126 and 161 are available from Superintendent of Documents, U.S. Government Printing Office, Washington, D. C. 20402 USA. Monograph 125 is SD Catalog No. CD13.44:125.

ANSI publication MC96.1-1975, covers thermocouples J, K, T, E, R, S, B.

Available from American Standards Institute, Inc., 1430 Broadway, New York, N.Y. 10018 USA.

ASTM publication E230-72, covers thermocouples J, K, T, E, R, S, B.

ASTM publication 470A, Manual on the Use of Thermocouples in Temperature Measurements.

ASTM publication STP-492, The Theory and Properties of Thermocouple Elements.

ASTM document E696, on Tungsten-Rhenium thermocouples.

ASTM publications are available from American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103, USA.

ISA Publications:

R.P.1.1	Coding of Thermocouple Wire
R.P.1.2	Thermocouple & Extension Wire
R.P.1.4	Thermocouple Fabrications
R.P.1.6	Temperature EMF Tables for Thermocouples

ISA publications are available from Instrument Society of America, 67 Alexander Drive, P.O. Box 12277, Research Triangle Park, North Carolina 27709, USA.

8.7 Temperature Standards

Freeze Points of Metals*	°F	°C
Tin	449.55	231.97
Lead	621.36	327.42
Zinc	787.24	419.58
Antimony	1167.33	630.74
Aluminum	1220.67	660.37
Silver	1763.47	961.93
Gold	1947.97	1064.43
Copper	1984.10	1083.20

Cryogenics	Melt Pt. °C		Boiling Pt. °C
Absolute Zero		(−273.15)	
Oxygen	−218.4		−183
Nitrogen	−209.9		−195.8
Hydrogen	−259.14		−252.8
Helium	−272		−268.94

Standard Temperature Points	°F	°C
Ice Point	32	0
Boiling Point H_2O	212	100
Triple Point H_2O		0.01

*From IPTS-68

APPENDIX A

Sample of Certificate of Calibration

Wahl

THERMOCOUPLE
CALIBRATION STANDARD

Wahl Instruments, Incorporated
5750 Hannum Avenue
Culver City, California 90230 U.S.A.
(310) 641-6931 Telex 66-4406

C-65

CERTIFICATE OF CALIBRATION

For Thermocouple Calibration Standard C-65/ / Serial No. ______________

Wahl Instruments certifies that this Instrument has been duly inspected and tested prior to shipment and that it meets or exceeds all of the requirements specified in its published mechanical, electrical and operational performance characteristics. All tests were performed using methods that preserve NIST traceability for the instrument.

Instruments are temperature cycled from 0°C to 50°C for 48 hours minimum.

I. Zero and drift measurement

INPUT mV	READING AT 0°C	50°C	MAXIMUM ALLOWABLE COUNTS
00.000	A	B	A - B = ± 15
90.000	C	D	A + D - B - C = ± 9

II. Ground isolation, analog/digital/chassis ☐

III. Converter voltages ± 5, ± 10 ☐

IV. Calibrate low battery detection, 5.90V DC ± .03V DC ☐

V. Very low battery auto-shutdown ☐

VI. Power supply rejection, 1 count maximum ☐

VII. Calibrate preamp zero ☐

VIII. Calibrate zero and gains

INPUT mV	DISPLAY ERROR, COUNTS -2	-1	0	+1	+2
00.000					
+15.000					
-15.000					
+40.000					
-40.000					
+70.000					
-70.000					
+90.000					
-90.000					

A2-2701 REV O
SHEET 2 OF 3

Wahl

THERMOCOUPLE CALIBRATION STANDARD

Wahl Instruments, Incorporated
5750 Hannum Avenue
Culver City, California 90230 U.S.A.
(310) 641-6931 Telex 66-4406

IX. CMR > 140 dB, ± 300V peak at 60 Hz ☐

X. NMR > 50 dB, 60 Hz ☐

XI. Calibrate thermocouple input, ice point reference ☐

XII. Output adjust range ≥ (-12 to +80 mV) ☐

XIII. SELF-TEST Mode, display vs. range select

RANGE	DISPLAY
mV	....
All Thermocouples	☐

XIV. Display function

a) Segment Check ☐
b) Decimal point ☐
c) Polarity ☐
d) Annunciators °C, °F, E ☐
e) Blink, low battery ☐
f) OPEN ☐
g) LO ☐
h) HIGH ☐
i) Error ☐

XV. Charger operation ☐

Tested By:______________________ Date______________

Quality Assurance ACCEPTED ______________________ Q.A. Inspector

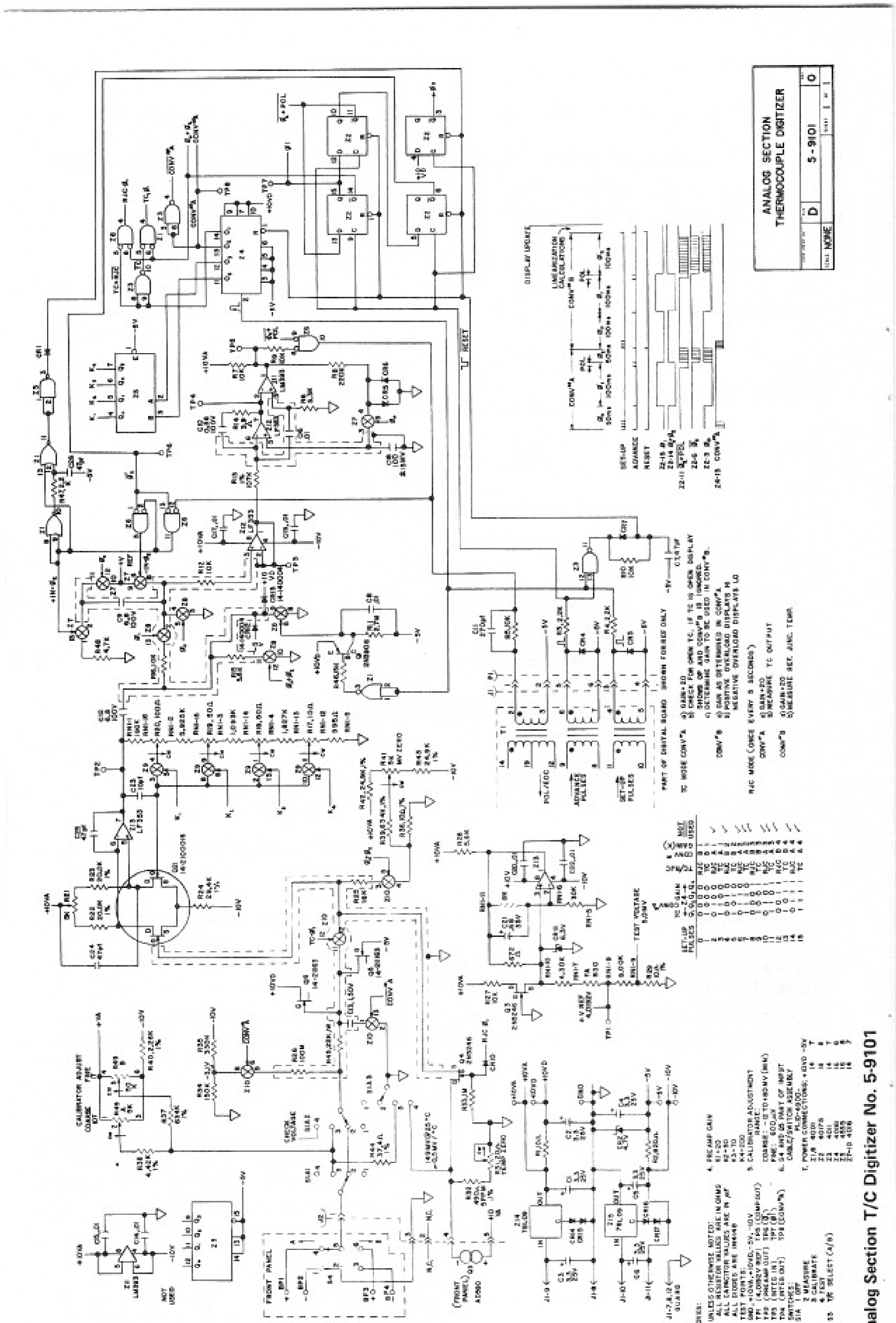
Date______________

A2-2701 REV 0
SHEET 3 OF 3

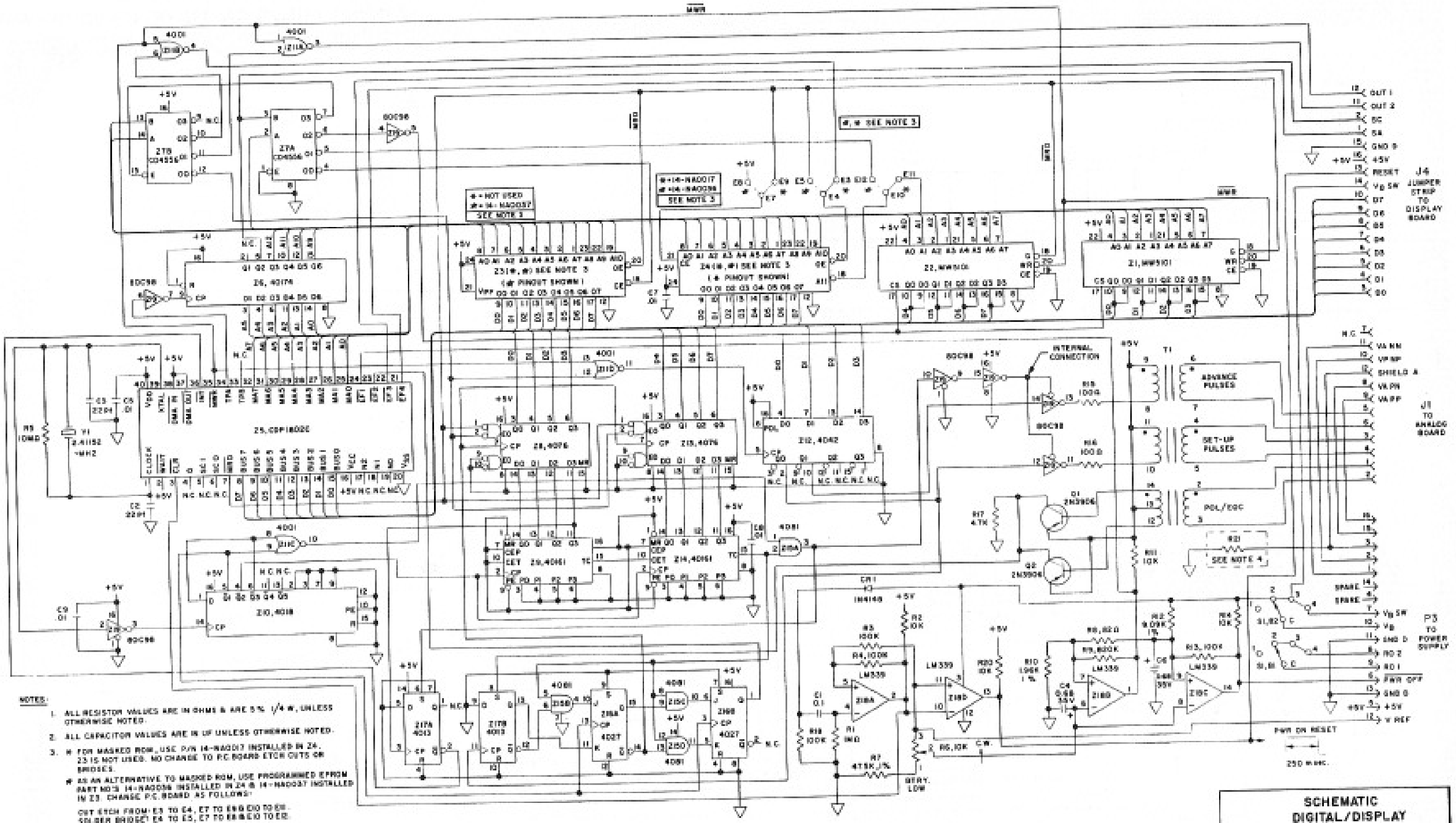
APPENDIX B

Schematic Drawings

1. Analog Section T/C Digitizer No. 5-9101
2. Schematic Digital Display No. 5-9100
   Sheet 1 and 2
3. Schematic Power Supply P.C. Board
   No. 5-9102



Analog Section T/C Digitizer No. 5-9101



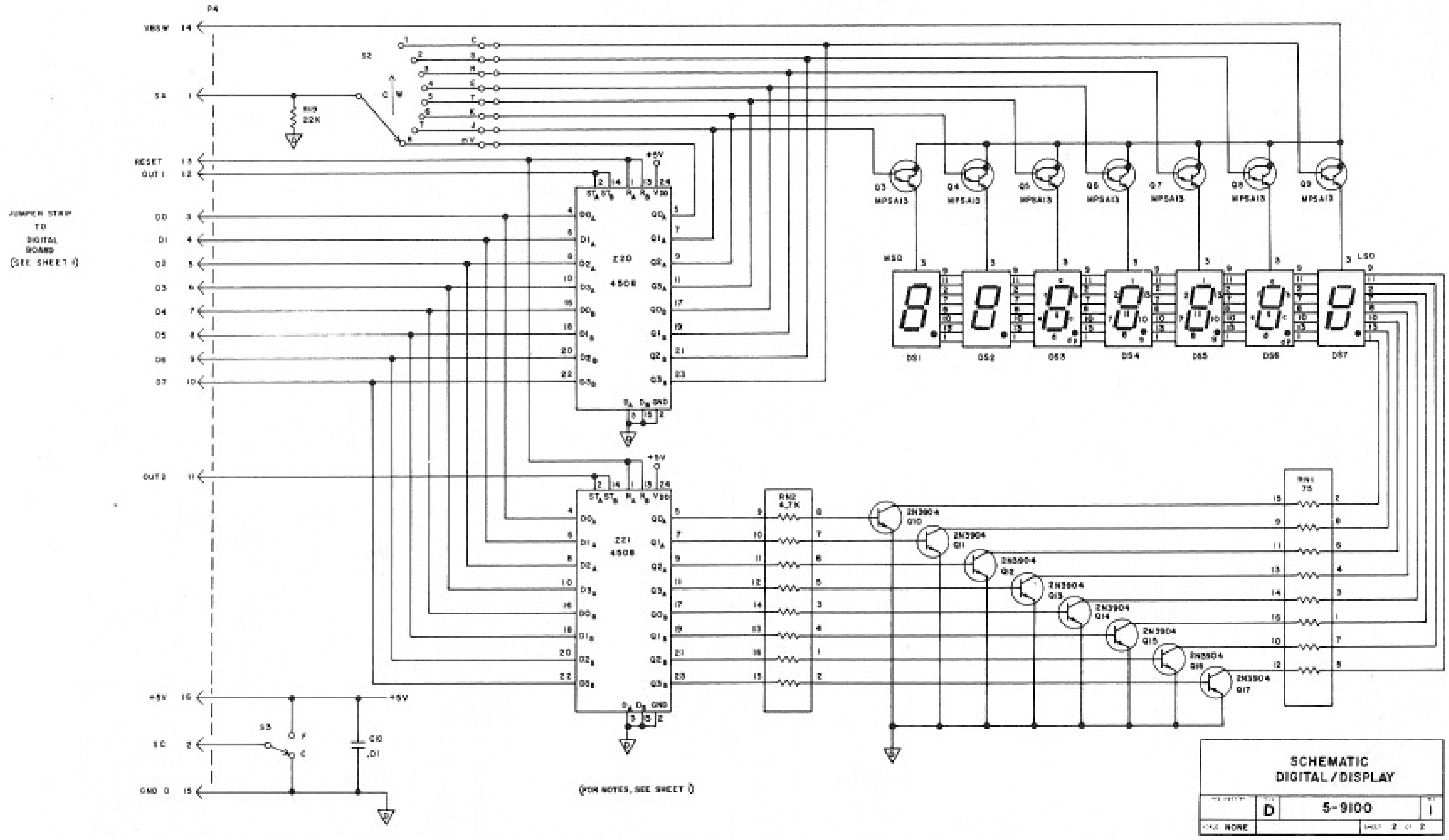
NOTES:

1. ALL RESISTOR VALUES ARE IN OHMS & ARE 5% 1/4 W, UNLESS OTHERWISE NOTED.
2. ALL CAPACITOR VALUES ARE IN UF UNLESS OTHERWISE NOTED.
3. \# FOR MASKED ROM, USE P/N 14-NA0017 INSTALLED IN Z4. Z3 IS NOT USED. NO CHANGE TO P.C. BOARD ETCH CUTS OR BRIDGES.
   * AS AN ALTERNATIVE TO MASKED ROM, USE PROGRAMMED EPROM PART NO'S 14-NA0036 INSTALLED IN Z4 & 14-NA0037 INSTALLED IN Z3. CHANGE P.C. BOARD AS FOLLOWS:
   CUT ETCH FROM: E3 TO E4, E7 TO E9 & E10 TO E11.
   SOLDER BRIDGE: E4 TO E5, E7 TO E8 & E10 TO E12.
4. R21 IS NOT USED.

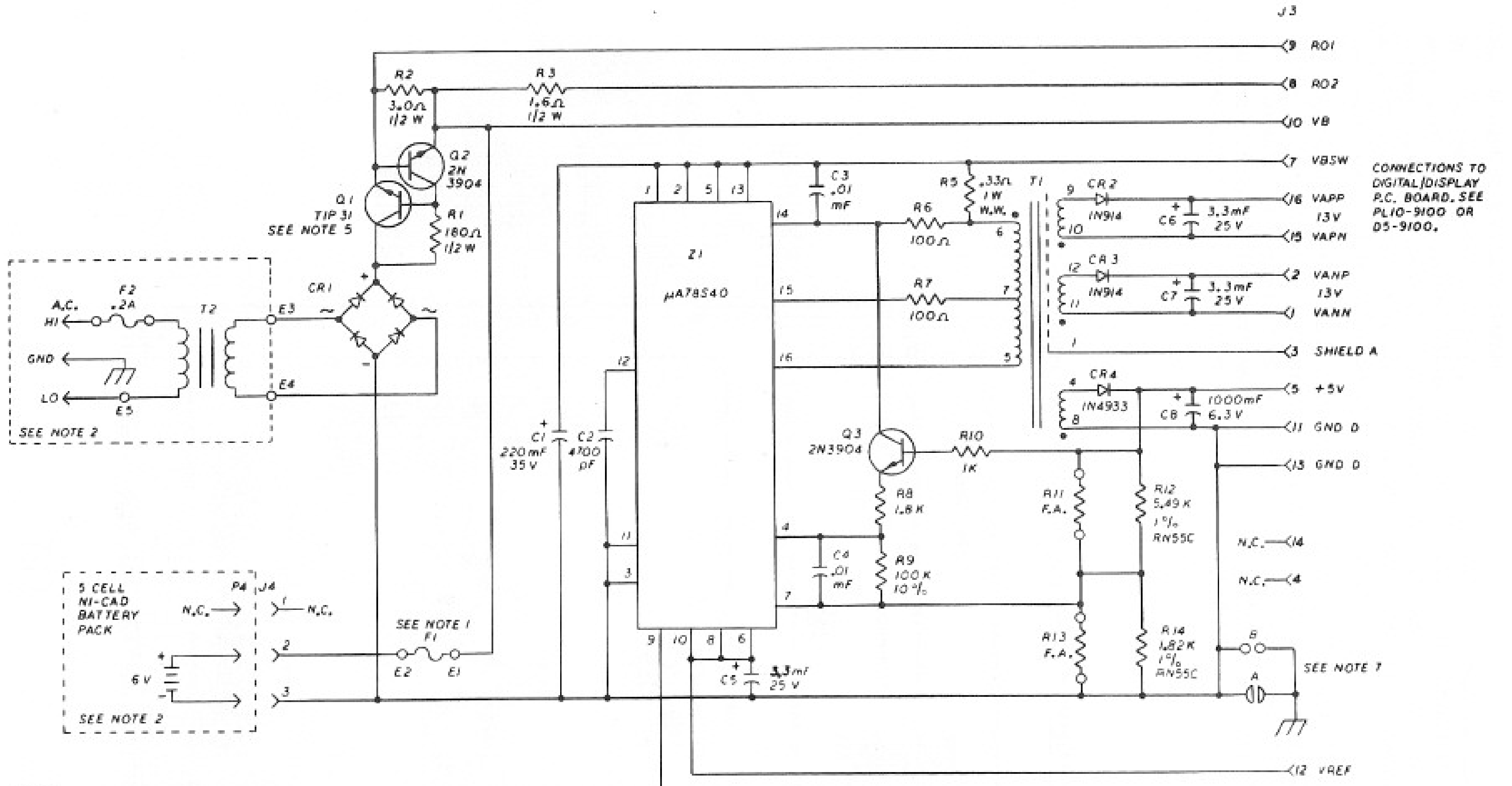
LAST USED/UNUSED REF. DESIGNATIONS

	Z	Q	CR	R	C	RN	T	S	J	P	E	Y
USED	21	16	1	20	10	2	1	3	4	3	12	1
UNUSED	—	—	—	—	—	—	—	—	2,3	1,2	1,2,6	—

Schematic Digital Display No. 5-9100 (Sheet 1)



Schematic Digital Display No. 5-9100 (Sheet 2)



NOTES

1. F1 IS AN "ETCH" FUSE. WHEN BLOWN, REPLACE WITH NO. 32 AWG BUSS WIRE, INSTALLED FROM E1 TO E2.
2. ITEMS WITHIN DOTTED OUTLINES ARE NOT ON PRINTED CIRCUIT BOARD.
3. FOR ASSEMBLY SEE DT-9102.
4. FOR PARTS LIST SEE PLIO-9102.
5. Q1 IS HEAT-SUNK ON CHASSIS.
6. UNLESS OTHERWISE SPECIFIED, RESISTORS ARE 1/4W, 5%.
7. FOR CHASSIS GROUND: BRIDGE "A" OR JUMPER "B".

SCHEMATIC POWER SUPPLY P.C. BOARD			
CODE IDENT NO	SIZE C	5-9102	REV OA
SCALE —			SHEET 1 OF 1

Schematic Power Supply P.C. Board No. 5-9102

APPENDIX C

Reference Tables, Type K, mV vs. Temp. °C

Reference Tables, Type B, mV vs. Temp. °C

REFERENCE TABLES TYPE K

THERMOELECTRIC VOLTAGE IN ABSOLUTE MILLIVOLTS

DEG C	0	1	2	3	4	5	6	7	8	9	10	DEG C
-270	-6.458											-270
-260	-6.441	-6.444	-6.446	-6.448	-6.450	-6.452	-6.453	-6.455	-6.456	-6.457	-6.458	-260
-250	-6.404	-6.408	-6.413	-6.417	-6.421	-6.425	-6.429	-6.432	-6.435	-6.438	-6.441	-250
-240	-6.344	-6.351	-6.358	-6.364	-6.371	-6.377	-6.382	-6.388	-6.394	-6.399	-6.404	-240
-230	-6.262	-6.271	-6.280	-6.289	-6.297	-6.306	-6.314	-6.322	-6.329	-6.337	-6.344	-230
-220	-6.158	-6.170	-6.181	-6.192	-6.202	-6.213	-6.223	-6.233	-6.243	-6.253	-6.262	-220
-210	-6.035	-6.048	-6.061	-6.074	-6.087	-6.099	-6.111	-6.123	-6.135	-6.147	-6.158	-210
-200	-5.891	-5.907	-5.922	-5.936	-5.951	-5.965	-5.980	-5.994	-6.007	-6.021	-6.035	-200
-190	-5.730	-5.747	-5.763	-5.780	-5.796	-5.813	-5.829	-5.845	-5.860	-5.876	-5.891	-190
-180	-5.550	-5.569	-5.587	-5.606	-5.624	-5.642	-5.660	-5.678	-5.695	-5.712	-5.730	-180
-170	-5.354	-5.374	-5.394	-5.414	-5.434	-5.454	-5.474	-5.493	-5.512	-5.531	-5.550	-170
-160	-5.141	-5.163	-5.185	-5.207	-5.228	-5.249	-5.271	-5.292	-5.313	-5.333	-5.354	-160
-150	-4.912	-4.936	-4.959	-4.983	-5.006	-5.029	-5.051	-5.074	-5.097	-5.119	-5.141	-150
-140	-4.669	-4.694	-4.719	-4.743	-4.768	-4.792	-4.817	-4.841	-4.865	-4.889	-4.912	-140
-130	-4.410	-4.437	-4.463	-4.489	-4.515	-4.541	-4.567	-4.593	-4.618	-4.644	-4.669	-130
-120	-4.138	-4.166	-4.193	-4.221	-4.248	-4.276	-4.303	-4.330	-4.357	-4.384	-4.410	-120
-110	-3.852	-3.881	-3.910	-3.939	-3.968	-3.997	-4.025	-4.053	-4.082	-4.110	-4.138	-110
-100	-3.553	-3.584	-3.614	-3.644	-3.674	-3.704	-3.734	-3.764	-3.793	-3.823	-3.852	-100
-90	-3.242	-3.274	-3.305	-3.337	-3.368	-3.399	-3.430	-3.461	-3.492	-3.523	-3.553	-90
-80	-2.920	-2.953	-2.985	-3.018	-3.050	-3.082	-3.115	-3.147	-3.179	-3.211	-3.242	-80
-70	-2.586	-2.620	-2.654	-2.687	-2.721	-2.754	-2.788	-2.821	-2.854	-2.887	-2.920	-70
-60	-2.243	-2.277	-2.312	-2.347	-2.381	-2.416	-2.450	-2.484	-2.518	-2.552	-2.586	-60
-50	-1.889	-1.925	-1.961	-1.996	-2.032	-2.067	-2.102	-2.137	-2.173	-2.208	-2.243	-50
-40	-1.527	-1.563	-1.600	-1.636	-1.673	-1.709	-1.745	-1.781	-1.817	-1.853	-1.889	-40
-30	-1.156	-1.193	-1.231	-1.268	-1.305	-1.342	-1.379	-1.416	-1.453	-1.490	-1.527	-30
-20	-0.777	-0.816	-0.854	-0.892	-0.930	-0.968	-1.005	-1.043	-1.081	-1.118	-1.156	-20
-10	-0.392	-0.431	-0.469	-0.508	-0.547	-0.585	-0.624	-0.662	-0.701	-0.739	-0.777	-10
0	0.000	-0.039	-0.079	-0.118	-0.157	-0.197	-0.236	-0.275	-0.314	-0.353	-0.392	0

DEG C	0	1	2	3	4	5	6	7	8	9	10	DEG C
0	0.000	0.039	0.079	0.119	0.158	0.198	0.238	0.277	0.317	0.357	0.397	0
10	0.397	0.437	0.477	0.517	0.557	0.597	0.637	0.677	0.718	0.758	0.798	10
20	0.798	0.838	0.879	0.919	0.960	1.000	1.041	1.081	1.122	1.162	1.203	20
30	1.203	1.244	1.285	1.325	1.366	1.407	1.448	1.489	1.529	1.570	1.611	30
40	1.611	1.652	1.693	1.734	1.776	1.817	1.858	1.899	1.940	1.981	2.022	40
50	2.022	2.064	2.105	2.146	2.188	2.229	2.270	2.312	2.353	2.394	2.436	50
60	2.436	2.477	2.519	2.560	2.601	2.643	2.684	2.726	2.767	2.809	2.850	60
70	2.850	2.892	2.933	2.975	3.016	3.058	3.100	3.141	3.183	3.224	3.266	70
80	3.266	3.307	3.349	3.390	3.432	3.473	3.515	3.556	3.598	3.639	3.681	80
90	3.681	3.722	3.764	3.805	3.847	3.888	3.930	3.971	4.012	4.054	4.095	90
100	4.095	4.137	4.178	4.219	4.261	4.302	4.343	4.384	4.426	4.467	4.508	100
110	4.508	4.549	4.590	4.632	4.673	4.714	4.755	4.796	4.837	4.878	4.919	110
120	4.919	4.960	5.001	5.042	5.083	5.124	5.164	5.205	5.246	5.287	5.327	120
130	5.327	5.368	5.409	5.450	5.490	5.531	5.571	5.612	5.652	5.693	5.733	130
140	5.733	5.774	5.814	5.855	5.895	5.936	5.976	6.016	6.057	6.097	6.137	140
150	6.137	6.177	6.218	6.258	6.298	6.338	6.378	6.419	6.459	6.499	6.539	150
160	6.539	6.579	6.619	6.659	6.699	6.739	6.779	6.819	6.859	6.899	6.939	160
170	6.939	6.979	7.019	7.059	7.099	7.139	7.179	7.219	7.259	7.299	7.338	170
180	7.338	7.378	7.418	7.458	7.498	7.538	7.578	7.618	7.658	7.697	7.737	180
190	7.737	7.777	7.817	7.857	7.897	7.937	7.977	8.017	8.057	8.097	8.137	190
200	8.137	8.177	8.216	8.256	8.296	8.336	8.376	8.416	8.456	8.497	8.537	200
210	8.537	8.577	8.617	8.657	8.697	8.737	8.777	8.817	8.857	8.898	8.938	210
220	8.938	8.978	9.018	9.058	9.099	9.139	9.179	9.220	9.260	9.300	9.341	220
230	9.341	9.381	9.421	9.462	9.502	9.543	9.583	9.624	9.664	9.705	9.745	230
240	9.745	9.786	9.826	9.867	9.907	9.948	9.989	10.029	10.070	10.111	10.151	240
250	10.151	10.192	10.233	10.274	10.315	10.355	10.396	10.437	10.478	10.519	10.560	250
260	10.560	10.600	10.641	10.682	10.723	10.764	10.805	10.846	10.887	10.928	10.969	260
270	10.969	11.010	11.051	11.093	11.134	11.175	11.216	11.257	11.298	11.339	11.381	270
280	11.381	11.422	11.463	11.504	11.546	11.587	11.628	11.669	11.711	11.752	11.793	280
290	11.793	11.835	11.876	11.918	11.959	12.000	12.042	12.083	12.125	12.166	12.207	290
300	12.207	12.249	12.290	12.332	12.373	12.415	12.456	12.498	12.539	12.581	12.623	300
310	12.623	12.664	12.706	12.747	12.789	12.831	12.872	12.914	12.955	12.997	13.039	310
320	13.039	13.080	13.122	13.164	13.205	13.247	13.289	13.331	13.372	13.414	13.456	320
330	13.456	13.497	13.539	13.581	13.623	13.665	13.706	13.748	13.790	13.832	13.874	330
340	13.874	13.915	13.957	13.999	14.041	14.083	14.125	14.167	14.208	14.250	14.292	340
350	14.292	14.334	14.376	14.418	14.460	14.502	14.544	14.586	14.628	14.670	14.712	350
360	14.712	14.754	14.796	14.838	14.880	14.922	14.964	15.006	15.048	15.090	15.132	360
370	15.132	15.174	15.216	15.258	15.300	15.342	15.384	15.426	15.468	15.510	15.552	370
380	15.552	15.594	15.636	15.679	15.721	15.763	15.805	15.847	15.889	15.931	15.974	380
390	15.974	16.016	16.058	16.100	16.142	16.184	16.227	16.269	16.311	16.353	16.395	390
400	16.395	16.438	16.480	16.522	16.564	16.607	16.649	16.691	16.733	16.776	16.818	400
410	16.818	16.860	16.902	16.945	16.987	17.029	17.072	17.114	17.156	17.199	17.241	410
420	17.241	17.283	17.326	17.368	17.410	17.453	17.495	17.537	17.580	17.622	17.664	420
430	17.664	17.707	17.749	17.792	17.834	17.876	17.919	17.961	18.004	18.046	18.088	430
440	18.088	18.131	18.173	18.216	18.258	18.301	18.343	18.385	18.428	18.470	18.513	440
450	18.513	18.555	18.598	18.640	18.683	18.725	18.768	18.810	18.853	18.895	18.938	450
460	18.938	18.980	19.023	19.065	19.108	19.150	19.193	19.235	19.278	19.320	19.363	460
470	19.363	19.405	19.448	19.490	19.533	19.576	19.618	19.661	19.703	19.746	19.788	470
480	19.788	19.831	19.873	19.916	19.959	20.001	20.044	20.086	20.129	20.172	20.214	480
490	20.214	20.257	20.299	20.342	20.385	20.427	20.470	20.512	20.555	20.598	20.640	490
500	20.640	20.683	20.725	20.768	20.811	20.853	20.896	20.938	20.981	21.024	21.066	500
510	21.066	21.109	21.152	21.194	21.237	21.280	21.322	21.365	21.407	21.450	21.493	510
520	21.493	21.535	21.578	21.621	21.663	21.706	21.749	21.791	21.834	21.876	21.919	520
530	21.919	21.962	22.004	22.047	22.090	22.132	22.175	22.218	22.260	22.303	22.346	530
540	22.346	22.388	22.431	22.473	22.516	22.559	22.601	22.644	22.687	22.729	22.772	540
550	22.772	22.815	22.857	22.900	22.942	22.985	23.028	23.070	23.113	23.156	23.198	550
560	23.198	23.241	23.284	23.326	23.369	23.411	23.454	23.497	23.539	23.582	23.624	560
570	23.624	23.667	23.710	23.752	23.795	23.837	23.880	23.923	23.965	24.008	24.050	570
580	24.050	24.093	24.136	24.178	24.221	24.263	24.306	24.348	24.391	24.434	24.476	580
590	24.476	24.519	24.561	24.604	24.646	24.689	24.731	24.774	24.817	24.859	24.902	590
600	24.902	24.944	24.987	25.029	25.072	25.114	25.157	25.199	25.242	25.284	25.327	600
DEG C	0	1	2	3	4	5	6	7	8	9	10	DEG C

REFERENCE TABLES TYPE K (Cont'd)

THERMOELECTRIC VOLTAGE IN ABSOLUTE MILLIVOLTS

DEG C	0	1	2	3	4	5	6	7	8	9	10	DEG C
600	24.902	24.944	24.987	25.029	25.072	25.114	25.157	25.199	25.242	25.284	25.327	600
610	25.327	25.369	25.412	25.454	25.497	25.539	25.582	25.624	25.666	25.709	25.751	610
620	25.751	25.794	25.836	25.879	25.921	25.964	26.006	26.048	26.091	26.133	26.176	620
630	26.176	26.218	26.260	26.303	26.345	26.387	26.430	26.472	26.515	26.557	26.599	630
640	26.599	26.642	26.684	26.726	26.769	26.811	26.853	26.896	26.938	26.980	27.022	640
650	27.022	27.065	27.107	27.149	27.192	27.234	27.276	27.318	27.361	27.403	27.445	650
660	27.445	27.487	27.529	27.572	27.614	27.656	27.698	27.740	27.783	27.825	27.867	660
670	27.867	27.909	27.951	27.993	28.035	28.078	28.120	28.162	28.204	28.246	28.288	670
680	28.288	28.330	28.372	28.414	28.456	28.498	2..540	28.583	28.625	28.667	28.709	680
690	28.709	28.751	28.793	28.835	28.877	28.919	28.961	29.002	29.044	29.086	29.128	690
700	29.128	29.170	29.212	29.254	29.296	29.338	29.380	29.422	29.464	29.505	29.547	700
710	29.547	29.589	29.631	29.673	29.715	29.756	29.798	29.840	29.882	29.924	29.965	710
720	29.965	30.007	30.049	30.091	30.132	30.174	30.216	30.257	30.299	30.341	30.383	720
730	30.383	30.424	30.466	30.508	30.549	30.591	30.632	30.674	30.716	30.757	30.799	730
740	30.799	30.840	30.882	30.924	30.965	31.007	31.048	31.090	31.131	31.173	31.214	740
750	31.214	31.256	31.297	31.339	31.380	31.422	31.463	31.504	31.546	31.587	31.629	750
760	31.629	31.670	31.712	31.753	31.794	31.836	31.877	31.918	31.960	32.001	32.042	760
770	32.042	32.084	32.125	32.166	32.207	32.249	32.290	32.331	32.372	32.414	32.455	770
780	32.455	32.496	32.537	32.578	32.619	32.661	32.702	32.743	32.784	32.825	32.866	780
790	32.866	32.907	32.948	32.990	33.031	33.072	33.113	33.154	33.195	33.236	33.277	790
800	33.277	33.318	33.359	33.400	33.441	33.482	33.523	33.564	33.604	33.645	33.686	800
810	33.686	33.727	33.768	33.809	33.850	33.891	33.931	33.972	34.013	34.054	34.095	810
820	34.095	34.136	34.176	34.217	34.258	34.299	34.339	34.380	34.421	34.461	34.502	820
830	34.502	34.543	34.583	34.624	34.665	34.705	34.746	34.787	34.827	34.868	34.909	830
840	34.909	34.949	34.990	35.030	35.071	35.111	35.152	35.192	35.233	35.273	35.314	840
850	35.314	35.354	35.395	35.435	35.476	35.516	35.557	35.597	35.637	35.678	35.718	850
860	35.718	35.758	35.799	35.839	35.880	35.920	35.960	36.000	36.041	36.081	36.121	860
870	36.121	36.162	36.202	36.242	36.282	36.323	36.363	36.403	36.443	36.483	36.524	870
880	36.524	36.564	36.604	36.644	36.684	36.724	36.764	36.804	36.844	36.885	36.925	880
890	36.925	36.965	37.005	37.045	37.085	37.125	37.165	37.205	37.245	37.285	37.325	890
900	37.325	37.365	37.405	37.445	37.484	37.524	37.564	37.604	37.644	37.684	37.724	900
910	37.724	37.764	37.803	37.843	37.883	37.923	37.963	38.002	38.042	38.082	38.122	910
920	38.122	38.162	38.201	38.241	38.281	38.320	38.360	38.400	38.439	38.479	38.519	920
930	38.519	38.558	38.598	38.638	38.677	38.717	38.756	38.796	38.836	38.875	38.915	930
940	38.915	38.954	38.994	39.033	39.073	39.112	39.152	39.191	39.231	39.270	39.310	940
950	39.310	39.349	39.388	39.428	39.467	39.507	39.546	39.585	39.625	39.664	39.703	950
960	39.703	39.743	39.782	39.821	39.861	39.900	39.939	39.979	40.018	40.057	40.096	960
970	40.096	40.136	40.175	40.214	40.253	40.292	40.332	40.371	40.410	40.449	40.488	970
980	40.488	40.527	40.566	40.605	40.645	40.684	40.723	40.762	40.801	40.840	40.879	980
990	40.879	40.918	40.957	40.996	41.035	41.074	41.113	41.152	41.191	41.230	41.269	990
1,000	41.269	41.308	41.347	41.385	41.424	41.463	41.502	41.541	41.580	41.619	41.657	1,000
1,010	41.657	41.696	41.735	41.774	41.813	41.851	41.890	41.929	41.968	42.006	42.045	1,010
1,020	42.045	42.084	42.123	42.161	42.200	42.239	42.277	42.316	42.355	42.393	42.432	1,020
1,030	42.432	42.470	42.509	42.548	42.586	42.625	42.663	42.702	42.740	42.779	42.817	1,030
1,040	42.817	42.856	42.894	42.933	42.971	43.010	43.048	43.087	43.125	43.164	43.202	1,040
1,050	43.202	43.240	43.279	43.317	43.356	43.394	43.432	43.471	43.509	43.547	43.585	1,050
1,060	43.585	43.624	43.662	43.700	43.739	43.777	43.815	43.853	43.891	43.930	43.968	1,060
1,070	43.968	44.006	44.044	44.082	44.121	44.159	44.197	44.235	44.273	44.311	44.349	1,070
1,080	44.349	44.387	44.425	44.463	44.501	44.539	44.577	44.615	44.653	44.691	44.729	1,080
1,090	44.729	44.767	44.805	44.843	44.881	44.919	44.957	44.995	45.033	45.070	45.108	1,090
1,100	45.108	45.146	45.184	45.222	45.260	45.297	45.335	45.373	45.411	45.448	45.486	1,100
1,110	45.486	45.524	45.561	45.599	45.637	45.675	45.712	45.750	45.787	45.825	45.863	1,110
1,120	45.863	45.900	45.938	45.975	46.013	46.051	46.088	46.126	46.163	46.201	46.238	1,120
1,130	46.238	46.275	46.313	46.350	46.388	46.425	46.463	46.500	46.537	46.575	46.612	1,130
1,140	46.612	46.649	46.687	46.724	46.761	46.799	46.836	46.873	46.910	46.948	46.985	1,140
1,150	46.985	47.022	47.059	47.096	47.134	47.171	47.208	47.245	47.282	47.319	47.356	1,150
1,160	47.356	47.393	47.430	47.468	47.505	47.542	47.579	47.616	47.653	47.689	47.726	1,160
1,170	47.726	47.763	47.800	47.837	47.874	47.911	47.948	47.985	48.021	48.058	48.095	1,170
1,180	48.095	48.132	48.169	48.205	48.242	48.279	48.316	48.352	48.389	48.426	48.462	1,180
1,190	48.462	48.499	48.536	48.572	48.609	48.645	48.682	48.718	48.755	48.792	48.828	1,190
1,200	48.828	48.865	48.901	48.937	48.974	49.010	49.047	49.083	49.120	49.156	49.192	1,200
1,210	49.192	49.229	49.265	49.301	49.338	49.374	49.410	49.446	49.483	49.519	49.555	1,210
1,220	49.555	49.591	49.627	49.663	49.700	49.736	49.772	49.808	49.844	49.880	49.916	1,220
1,230	49.916	49.952	49.988	50.024	50.060	50.096	50.132	50.168	50.204	50.240	50.276	1,230
1,240	50.276	50.311	50.347	50.383	50.419	50.455	50.491	50.526	50.562	50.598	50.633	1,240
1,250	50.633	50.669	50.705	50.741	50.776	50.812	50.847	50.883	50.919	50.954	50.990	1,250
1,260	50.990	51.025	51.061	51.096	51.132	51.167	51.203	51.238	51.274	51.309	51.344	1,260
1,270	51.344	51.380	51.415	51.450	51.486	51.521	51.556	51.592	51.627	51.662	51.697	1,270
1,280	51.697	51.733	51.768	51.803	51.838	51.873	51.908	51.943	51.979	52.014	52.049	1,280
1,290	52.049	52.084	52.119	52.154	52.189	52.224	52.259	52.294	52.329	52.364	52.398	1,290
1,300	52.398	52.433	52.468	52.503	52.538	52.573	52.608	52.642	52.677	52.712	52.747	1,300
1,310	52.747	52.781	52.816	52.851	52.886	52.920	52.955	52.989	53.024	53.059	53.093	1,310
1,320	53.093	53.128	53.162	53.197	53.232	53.266	53.301	53.335	53.370	53.404	53.439	1,320
1,330	53.439	53.473	53.507	53.542	53.576	53.611	53.645	53.679	53.714	53.748	53.782	1,330
1,340	53.782	53.817	53.851	53.885	53.920	53.954	53.988	54.022	54.057	54.091	54.125	1,340
1,350	54.125	54.159	54.193	54.228	54.262	54.296	54.330	54.364	54.398	54.432	54.466	1,350
1,360	54.466	54.501	54.535	54.569	54.603	54.637	54.671	54.705	54.739	54.773	54.807	1,360
1,370	54.807	54.841	54.875									1,370
DEG C	0	1	2	3	4	5	6	7	8	9	10	DEG C

REFERENCE TABLES TYPE B

THERMOELECTRIC VOLTAGE IN ABSOLUTE MILLIVOLTS

DEG C	0	1	2	3	4	5	6	7	8	9	10	DEG C
0	0.000	-0.000	-0.000	-0.001	-0.001	-0.001	-0.001	-0.001	-0.002	-0.002	-0.002	0
10	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.003	-0.003	-0.003	10
20	-0.003	-0.003	-0.003	-0.003	-0.003	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	20
30	-0.002	-0.002	-0.002	-0.002	-0.002	-0.001	-0.001	-0.001	-0.001	-0.001	-0.000	30
40	-0.000	-0.000	-0.000	0.000	0.000	0.001	0.001	0.001	0.002	0.002	0.002	40
50	0.002	0.003	0.003	0.003	0.004	0.004	0.004	0.005	0.005	0.006	0.006	50
60	0.006	0.007	0.007	0.008	0.008	0.009	0.009	0.010	0.010	0.011	0.011	60
70	0.011	0.012	0.012	0.013	0.014	0.014	0.015	0.015	0.016	0.017	0.017	70
80	0.017	0.018	0.019	0.020	0.020	0.021	0.022	0.022	0.023	0.024	0.025	80
90	0.025	0.026	0.026	0.027	0.028	0.029	0.030	0.031	0.031	0.032	0.033	90
100	0.033	0.034	0.035	0.036	0.037	0.038	0.039	0.040	0.041	0.042	0.043	100
110	0.043	0.044	0.045	0.046	0.047	0.048	0.049	0.050	0.051	0.052	0.053	110
120	0.053	0.055	0.056	0.057	0.058	0.059	0.060	0.062	0.063	0.064	0.065	120
130	0.065	0.066	0.068	0.069	0.070	0.071	0.073	0.074	0.075	0.077	0.078	130
140	0.078	0.079	0.081	0.082	0.083	0.085	0.086	0.088	0.089	0.091	0.092	140
150	0.092	0.093	0.095	0.096	0.098	0.099	0.101	0.102	0.104	0.106	0.107	150
160	0.107	0.109	0.110	0.112	0.113	0.115	0.117	0.118	0.120	0.122	0.123	160
170	0.123	0.125	0.127	0.128	0.130	0.132	0.133	0.135	0.137	0.139	0.140	170
180	0.140	0.142	0.144	0.146	0.148	0.149	0.151	0.153	0.155	0.157	0.159	180
190	0.159	0.161	0.163	0.164	0.166	0.168	0.170	0.172	0.174	0.176	0.178	190
200	0.178	0.180	0.182	0.184	0.186	0.188	0.190	0.192	0.194	0.197	0.199	200
210	0.199	0.201	0.203	0.205	0.207	0.209	0.211	0.214	0.216	0.218	0.220	210
220	0.220	0.222	0.225	0.227	0.229	0.231	0.234	0.236	0.238	0.240	0.243	220
230	0.243	0.245	0.247	0.250	0.252	0.254	0.257	0.259	0.262	0.264	0.266	230
240	0.266	0.269	0.271	0.274	0.276	0.279	0.281	0.284	0.286	0.289	0.291	240
250	0.291	0.294	0.296	0.299	0.301	0.304	0.307	0.309	0.312	0.314	0.317	250
260	0.317	0.320	0.322	0.325	0.328	0.330	0.333	0.336	0.338	0.341	0.344	260
260	0.317	0.320	0.322	0.325	0.328	0.330	0.333	0.336	0.338	0.341	0.344	260
270	0.344	0.347	0.349	0.352	0.355	0.358	0.360	0.363	0.366	0.369	0.372	270
280	0.372	0.375	0.377	0.380	0.383	0.386	0.389	0.392	0.395	0.398	0.401	280
290	0.401	0.404	0.406	0.409	0.412	0.415	0.418	0.421	0.424	0.427	0.431	290
300	0.431	0.434	0.437	0.440	0.443	0.446	0.449	0.452	0.455	0.458	0.462	300
310	0.462	0.465	0.468	0.471	0.474	0.477	0.481	0.484	0.487	0.490	0.494	310
320	0.494	0.497	0.500	0.503	0.507	0.510	0.513	0.517	0.520	0.523	0.527	320
330	0.527	0.530	0.533	0.537	0.540	0.544	0.547	0.550	0.554	0.557	0.561	330
340	0.561	0.564	0.568	0.571	0.575	0.578	0.582	0.585	0.589	0.592	0.596	340
350	0.596	0.599	0.603	0.606	0.610	0.614	0.617	0.621	0.625	0.628	0.632	350
360	0.632	0.636	0.639	0.643	0.647	0.650	0.654	0.658	0.661	0.665	0.669	360
370	0.669	0.673	0.677	0.680	0.684	0.688	0.692	0.696	0.699	0.703	0.707	370
380	0.707	0.711	0.715	0.719	0.723	0.727	0.730	0.734	0.738	0.742	0.746	380
390	0.746	0.750	0.754	0.758	0.762	0.766	0.770	0.774	0.778	0.782	0.786	390
400	0.786	0.790	0.794	0.799	0.803	0.807	0.811	0.815	0.819	0.823	0.827	400
410	0.827	0.832	0.836	0.840	0.844	0.848	0.853	0.857	0.861	0.865	0.870	410
420	0.870	0.874	0.878	0.882	0.887	0.891	0.895	0.900	0.904	0.908	0.913	420
430	0.913	0.917	0.921	0.926	0.930	0.935	0.939	0.943	0.948	0.952	0.957	430
440	0.957	0.961	0.966	0.970	0.975	0.979	0.984	0.988	0.993	0.997	1.002	440
450	1.002	1.006	1.011	1.015	1.020	1.025	1.029	1.034	1.039	1.043	1.048	450
460	1.048	1.052	1.057	1.062	1.066	1.071	1.076	1.081	1.085	1.090	1.095	460
470	1.095	1.100	1.104	1.109	1.114	1.119	1.123	1.128	1.133	1.138	1.143	470
480	1.143	1.148	1.152	1.157	1.162	1.167	1.172	1.177	1.182	1.187	1.192	480
490	1.192	1.197	1.202	1.206	1.211	1.216	1.221	1.226	1.231	1.236	1.241	490
500	1.241	1.246	1.252	1.257	1.262	1.267	1.272	1.277	1.282	1.287	1.292	500
510	1.292	1.297	1.303	1.308	1.313	1.318	1.323	1.328	1.334	1.339	1.344	510
520	1.344	1.349	1.354	1.360	1.365	1.370	1.375	1.381	1.386	1.391	1.397	520
530	1.397	1.402	1.407	1.413	1.418	1.423	1.429	1.434	1.439	1.445	1.450	530
540	1.450	1.456	1.461	1.467	1.472	1.477	1.483	1.488	1.494	1.499	1.505	540
550	1.505	1.510	1.516	1.521	1.527	1.532	1.538	1.544	1.549	1.555	1.560	550
560	1.560	1.566	1.571	1.577	1.583	1.588	1.594	1.600	1.605	1.611	1.617	560
570	1.617	1.622	1.628	1.634	1.639	1.645	1.651	1.657	1.662	1.668	1.674	570
580	1.674	1.680	1.685	1.691	1.697	1.703	1.709	1.715	1.720	1.726	1.732	580
590	1.732	1.738	1.744	1.750	1.756	1.762	1.767	1.773	1.779	1.785	1.791	590
600	1.791	1.797	1.803	1.809	1.815	1.821	1.827	1.833	1.839	1.845	1.851	600
610	1.851	1.857	1.863	1.869	1.875	1.882	1.888	1.894	1.900	1.906	1.912	610
620	1.912	1.918	1.924	1.931	1.937	1.943	1.949	1.955	1.961	1.968	1.974	620
630	1.974	1.980	1.986	1.993	1.999	2.005	2.011	2.018	2.024	2.030	2.036	630
640	2.036	2.043	2.049	2.055	2.062	2.068	2.074	2.081	2.087	2.094	2.100	640
650	2.100	2.106	2.113	2.119	2.126	2.132	2.139	2.145	2.151	2.158	2.164	650
660	2.164	2.171	2.177	2.184	2.190	2.197	2.203	2.210	2.216	2.223	2.230	660
670	2.230	2.236	2.243	2.249	2.256	2.263	2.269	2.276	2.282	2.289	2.296	670
680	2.296	2.302	2.309	2.316	2.322	2.329	2.336	2.343	2.349	2.356	2.363	680
690	2.363	2.369	2.376	2.383	2.390	2.396	2.403	2.410	2.417	2.424	2.430	690
700	2.430	2.437	2.444	2.451	2.458	2.465	2.472	2.478	2.485	2.492	2.499	700
710	2.499	2.506	2.513	2.520	2.527	2.534	2.541	2.548	2.555	2.562	2.569	710
720	2.569	2.576	2.583	2.590	2.597	2.604	2.611	2.618	2.625	2.632	2.639	720
730	2.639	2.646	2.653	2.660	2.667	2.674	2.682	2.689	2.696	2.703	2.710	730
740	2.710	2.717	2.724	2.732	2.739	2.746	2.753	2.760	2.768	2.775	2.782	740
750	2.782	2.789	2.797	2.804	2.811	2.818	2.826	2.833	2.840	2.848	2.855	750
760	2.855	2.862	2.869	2.877	2.884	2.892	2.899	2.906	2.914	2.921	2.928	760
770	2.928	2.936	2.943	2.951	2.958	2.966	2.973	2.980	2.988	2.995	3.003	770
780	3.003	3.010	3.018	3.025	3.033	3.040	3.048	3.055	3.063	3.070	3.078	780
790	3.078	3.086	3.093	3.101	3.108	3.116	3.124	3.131	3.139	3.146	3.154	790
800	3.154	3.162	3.169	3.177	3.185	3.192	3.200	3.208	3.215	3.223	3.231	800
810	3.231	3.239	3.246	3.254	3.262	3.269	3.277	3.285	3.293	3.301	3.308	810
820	3.308	3.316	3.324	3.332	3.340	3.347	3.355	3.363	3.371	3.379	3.387	820
830	3.387	3.395	3.402	3.410	3.418	3.426	3.434	3.442	3.450	3.458	3.466	830
840	3.466	3.474	3.482	3.490	3.498	3.506	3.514	3.522	3.530	3.538	3.546	840
850	3.546	3.554	3.562	3.570	3.578	3.586	3.594	3.602	3.610	3.618	3.626	850
860	3.626	3.634	3.643	3.651	3.659	3.667	3.675	3.683	3.691	3.700	3.708	860
870	3.708	3.716	3.724	3.732	3.741	3.749	3.757	3.765	3.773	3.782	3.790	870
880	3.790	3.798	3.806	3.815	3.823	3.831	3.840	3.848	3.856	3.865	3.873	880
890	3.873	3.881	3.890	3.898	3.906	3.915	3.923	3.931	3.940	3.948	3.957	890
DEG C	0	1	2	3	4	5	6	7	8	9	10	DEG C

REFERENCE TABLES TYPE B (Cont'd)

THERMOELECTRIC VOLTAGE IN ABSOLUTE MILLIVOLTS

DEG C	0	1	2	3	4	5	6	7	8	9	10	DEG C
900	3.957	3.965	3.973	3.982	3.990	3.999	4.007	4.016	4.024	4.032	4.041	900
910	4.041	4.049	4.058	4.066	4.075	4.083	4.092	4.100	4.109	4.117	4.126	910
920	4.126	4.135	4.143	4.152	4.160	4.169	4.177	4.186	4.195	4.203	4.212	920
930	4.212	4.220	4.229	4.238	4.246	4.255	4.264	4.272	4.281	4.290	4.298	930
940	4.298	4.307	4.316	4.325	4.333	4.342	4.351	4.359	4.368	4.377	4.386	940
950	4.386	4.394	4.403	4.412	4.421	4.430	4.438	4.447	4.456	4.465	4.474	950
960	4.474	4.483	4.491	4.500	4.509	4.518	4.527	4.536	4.545	4.553	4.562	960
970	4.562	4.571	4.580	4.589	4.598	4.607	4.616	4.625	4.634	4.643	4.652	970
980	4.652	4.661	4.670	4.679	4.688	4.697	4.706	4.715	4.724	4.733	4.742	980
990	4.742	4.751	4.760	4.769	4.778	4.787	4.796	4.805	4.814	4.824	4.833	990
1.000	4.833	4.842	4.851	4.860	4.869	4.878	4.887	4.897	4.906	4.915	4.924	1.000
1.010	4.924	4.933	4.942	4.952	4.961	4.970	4.979	4.989	4.998	5.007	5.016	1.010
1.020	5.016	5.025	5.035	5.044	5.053	5.063	5.072	5.081	5.090	5.100	5.109	1.020
1.030	5.109	5.118	5.128	5.137	5.146	5.156	5.165	5.174	5.184	5.193	5.202	1.030
1.040	5.202	5.212	5.221	5.231	5.240	5.249	5.259	5.268	5.278	5.287	5.297	1.040
1.050	5.297	5.306	5.316	5.325	5.334	5.344	5.353	5.363	5.372	5.382	5.391	1.050
1.060	5.391	5.401	5.410	5.420	5.429	5.439	5.449	5.458	5.468	5.477	5.487	1.060
1.070	5.487	5.496	5.506	5.516	5.525	5.535	5.544	5.554	5.564	5.573	5.583	1.070
1.080	5.583	5.593	5.602	5.612	5.621	5.631	5.641	5.651	5.660	5.670	5.680	1.080
1.090	5.680	5.689	5.699	5.709	5.718	5.728	5.738	5.748	5.757	5.767	5.777	1.090
1.100	5.777	5.787	5.796	5.806	5.816	5.826	5.836	5.845	5.855	5.865	5.875	1.100
1.110	5.875	5.885	5.895	5.904	5.914	5.924	5.934	5.944	5.954	5.964	5.973	1.110
1.120	5.973	5.983	5.993	6.003	6.013	6.023	6.033	6.043	6.053	6.063	6.073	1.120
1.130	6.073	6.083	6.093	6.102	6.112	6.122	6.132	6.142	6.152	6.162	6.172	1.130
1.140	6.172	6.182	6.192	6.202	6.212	6.223	6.233	6.243	6.253	6.263	6.273	1.140
1.150	6.273	6.283	6.293	6.303	6.313	6.323	6.333	6.343	6.353	6.364	6.374	1.150
1.160	6.374	6.384	6.394	6.404	6.414	6.424	6.435	6.445	6.455	6.465	6.475	1.160
1.170	6.475	6.485	6.496	6.506	6.516	6.526	6.536	6.547	6.557	6.567	6.577	1.170
1.180	6.577	6.588	6.598	6.608	6.618	6.629	6.639	6.649	6.659	6.670	6.680	1.180
1.190	6.680	6.690	6.701	6.711	6.721	6.732	6.742	6.752	6.763	6.773	6.783	1.190
1.200	6.783	6.794	6.804	6.814	6.825	6.835	6.846	6.856	6.866	6.877	6.887	1.200
1.210	6.887	6.898	6.908	6.918	6.929	6.939	6.950	6.960	6.971	6.981	6.991	1.210
1.220	6.991	7.002	7.012	7.023	7.033	7.044	7.054	7.065	7.075	7.086	7.096	1.220
1.230	7.096	7.107	7.117	7.128	7.138	7.149	7.159	7.170	7.181	7.191	7.202	1.230
1.240	7.202	7.212	7.223	7.233	7.244	7.255	7.265	7.276	7.286	7.297	7.308	1.240
1.250	7.308	7.318	7.329	7.339	7.350	7.361	7.371	7.382	7.393	7.403	7.414	1.250
1.260	7.414	7.425	7.435	7.446	7.457	7.467	7.478	7.489	7.500	7.510	7.521	1.260
1.270	7.521	7.532	7.542	7.553	7.564	7.575	7.585	7.596	7.607	7.618	7.628	1.270
1.280	7.628	7.639	7.650	7.661	7.671	7.682	7.693	7.704	7.715	7.725	7.736	1.280
1.290	7.736	7.747	7.758	7.769	7.780	7.790	7.801	7.812	7.823	7.834	7.845	1.290
1.300	7.845	7.855	7.866	7.877	7.888	7.899	7.910	7.921	7.932	7.943	7.953	1.300
1.310	7.953	7.964	7.975	7.986	7.997	8.008	8.019	8.030	8.041	8.052	8.063	1.310
1.320	8.063	8.074	8.085	8.096	8.107	8.118	8.128	8.139	8.150	8.161	8.172	1.320
1.330	8.172	8.183	8.194	8.205	8.216	8.227	8.238	8.249	8.261	8.272	8.283	1.330
1.340	8.283	8.294	8.305	8.316	8.327	8.338	8.349	8.360	8.371	8.382	8.393	1.340
1.350	8.393	8.404	8.415	8.426	8.437	8.449	8.460	8.471	8.482	8.493	8.504	1.350
1.360	8.504	8.515	8.526	8.538	8.549	8.560	8.571	8.582	8.593	8.604	8.616	1.360
1.370	8.616	8.627	8.638	8.649	8.660	8.671	8.683	8.694	8.705	8.716	8.727	1.370
1.380	8.727	8.738	8.750	8.761	8.772	8.783	8.795	8.806	8.817	8.828	8.839	1.380
1.390	8.839	8.851	8.862	8.873	8.884	8.896	8.907	8.918	8.929	8.941	8.952	1.390
1.400	8.952	8.963	8.974	8.986	8.997	9.008	9.020	9.031	9.042	9.053	9.065	1.400
1.410	9.065	9.076	9.087	9.099	9.110	9.121	9.133	9.144	9.155	9.167	9.178	1.410
1.420	9.178	9.189	9.201	9.212	9.223	9.235	9.246	9.257	9.269	9.280	9.291	1.420
1.430	9.291	9.303	9.314	9.326	9.337	9.348	9.360	9.371	9.382	9.394	9.405	1.430
1.440	9.405	9.417	9.428	9.439	9.451	9.462	9.474	9.485	9.497	9.508	9.519	1.440
1.450	9.519	9.531	9.542	9.554	9.565	9.577	9.588	9.599	9.611	9.622	9.634	1.450
1.460	9.634	9.645	9.657	9.668	9.680	9.691	9.703	9.714	9.726	9.737	9.748	1.460
1.470	9.748	9.760	9.771	9.783	9.794	9.806	9.817	9.829	9.840	9.852	9.863	1.470
1.480	9.863	9.875	9.886	9.898	9.909	9.921	9.933	9.944	9.956	9.967	9.979	1.480
1.490	9.979	9.990	10.002	10.013	10.025	10.036	10.048	10.059	10.071	10.082	10.094	1.490
1.500	10.094	10.106	10.117	10.129	10.140	10.152	10.163	10.175	10.187	10.198	10.210	1.500
1.510	10.210	10.221	10.233	10.244	10.256	10.268	10.279	10.291	10.302	10.314	10.325	1.510
1.520	10.325	10.337	10.349	10.360	10.372	10.383	10.395	10.407	10.418	10.430	10.441	1.520
1.530	10.441	10.453	10.465	10.476	10.488	10.500	10.511	10.523	10.534	10.546	10.558	1.530
1.540	10.558	10.569	10.581	10.593	10.604	10.616	10.627	10.639	10.651	10.662	10.674	1.540
1.550	10.674	10.686	10.697	10.709	10.721	10.732	10.744	10.756	10.767	10.779	10.790	1.550
1.560	10.790	10.802	10.814	10.825	10.837	10.849	10.860	10.872	10.884	10.895	10.907	1.560
1.570	10.907	10.919	10.930	10.942	10.954	10.965	10.977	10.989	11.000	11.012	11.024	1.570
1.580	11.024	11.035	11.047	11.059	11.070	11.082	11.094	11.105	11.117	11.129	11.141	1.580
1.590	11.141	11.152	11.164	11.176	11.187	11.199	11.211	11.222	11.234	11.246	11.257	1.590
1.600	11.257	11.269	11.281	11.292	11.304	11.316	11.328	11.339	11.351	11.363	11.374	1.600
1.610	11.374	11.386	11.398	11.409	11.421	11.433	11.444	11.456	11.468	11.480	11.491	1.610
1.620	11.491	11.503	11.515	11.526	11.538	11.550	11.561	11.573	11.585	11.597	11.608	1.620
1.630	11.608	11.620	11.632	11.643	11.655	11.667	11.678	11.690	11.702	11.714	11.725	1.630
1.640	11.725	11.737	11.749	11.760	11.772	11.784	11.795	11.807	11.819	11.830	11.842	1.640
1.650	11.842	11.854	11.866	11.877	11.889	11.901	11.912	11.924	11.936	11.947	11.959	1.650
1.660	11.959	11.971	11.983	11.994	12.006	12.018	12.029	12.041	12.053	12.064	12.076	1.660
1.670	12.076	12.088	12.099	12.111	12.123	12.134	12.146	12.158	12.170	12.181	12.193	1.670
1.680	12.193	12.205	12.216	12.228	12.240	12.251	12.263	12.275	12.286	12.298	12.310	1.680
1.690	12.310	12.321	12.333	12.345	12.356	12.368	12.380	12.391	12.403	12.415	12.426	1.690
1.700	12.426	12.438	12.450	12.461	12.473	12.485	12.496	12.508	12.520	12.531	12.543	1.700
1.710	12.543	12.555	12.566	12.578	12.590	12.601	12.613	12.624	12.636	12.648	12.659	1.710
1.720	12.659	12.671	12.683	12.694	12.706	12.718	12.729	12.741	12.752	12.764	12.776	1.720
1.730	12.776	12.787	12.799	12.811	12.822	12.834	12.845	12.857	12.869	12.880	12.892	1.730
1.740	12.892	12.903	12.915	12.927	12.938	12.950	12.961	12.973	12.985	12.996	13.008	1.740
1.750	13.008	13.019	13.031	13.043	13.054	13.066	13.077	13.089	13.100	13.112	13.124	1.750
1.760	13.124	13.135	13.147	13.158	13.170	13.181	13.193	13.204	13.216	13.228	13.239	1.760
1.770	13.239	13.251	13.262	13.274	13.285	13.297	13.308	13.320	13.331	13.343	13.354	1.770
1.780	13.354	13.366	13.378	13.389	13.401	13.412	13.424	13.435	13.447	13.458	13.470	1.780
1.790	13.470	13.481	13.493	13.504	13.516	13.527	13.539	13.550	13.562	13.573	13.585	1.790
1.800	13.585	13.596	13.607	13.619	13.630	13.642	13.653	13.665	13.676	13.688	13.699	1.800
1.810	13.699	13.711	13.722	13.733	13.745	13.756	13.768	13.779	13.791	13.802	13.814	1.810
1.820	13.814											1.820
DEG C	0	1	2	3	4	5	6	7	8	9	10	DEG C

WARRANTY

Wahl Instruments, Inc. hereinafter referred to as Wahl, warrants each instrument of it manufacture to be free from defects in material and workmanship under normal use and service for 12 months from the date of shipment. If our examination discloses that malfunction was caused by either poor workmanship or defective material, Wahl will repair or replace the components accordingly, providing these were forwarded to the factory within 12 months from the date of shipment, properly packaged and transportation prepaid. Wahl assumes no liability for damages of any kind, direct or indirect, as a result of the installation and/or use of the equipment. The purchaser by accepting the equipment will assume all liability for any damages, direct or consequential, to himself, his employees, agents or others, which may result from use of misuse of this equipment.

The above warranty also applies to instrument accessories manufactured by Wahl except thermocouples, probes, thermocouple extension wire (bare, insulated or cabled), which, due to the environmental nature of their use, cannot be replaced unless returned unused. In addition, Wahl assumes no liability for any costs resulting from removing and reinstalling any of its product for replacement under the terms of the above warranty.

CALIBRATION

Wahl Instruments certifies that this instrument was tested against a standard temperature source at the factory immediately prior to shipment. The instrument should be recalibrated at intervals no less than one year.