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MAGTROL

Model 5100

Single Phase Power Analyzer



User's Manual

MAGTROL, INC.

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02/07/00	Added External Shunt Connection Drawing	5

1 - Introduction

ABBREVIATIONS

PA	Model 5100 Power Analyzer
GPIB	IEEE-488 Instrument Bus Standard
LED	front panel indicator light
A,V, W, PF and VA	Amperes, Volts, Watts, Power Factor and Volt Amperes, respectively
MPU	microprocessor unit
LSD, LSB	least significant digit or bit
CMRR	common mode rejection ratio

UNPACKING

The Model 5100 is packed in reusable, shock resistant packing material that will protect the instrument during normal handling. In the event of shipping damage, immediately notify the carrier and MAGTROL Customer Service Dept.

Save all shipping materials for reuse when returning the instrument for calibration or servicing.

POWER

The 5100 PA is factory wired for either 120 or 240 Vrms, 50/60 Hz, power at 40 volt amps, max. The line cord is a detachable NEMA standard 3 wire which plugs into the rear access power entry and filter module of the 5100 PA. The line cord must be detached from the PA during servicing.

NOTE: The standard 5100 is factory wired for 120 Vrms power. Wiring for 240 Vrms is available on special order.

FUSE REPLACEMENT

Remove the line cord and carefully pry up and remove the fuse holder. Use a 1/2 Amp slow blow fuse for 120 Vrms or a 1/4 Amp slow blow fuse for 240 Vrms power.

SAFETY

SECURELY GROUND the 5100 PA case by connecting a good earth ground at the ground stud that is located on the rear panel. Use a number 12 AWG, or larger wire.

CONNECTORS

Plugs that mate with 5100 PA connectors:

Superior Electric Supercon®

INPUT (plug, white, female) - PS50GWT

OUTPUT (plug, white, male) - PP50GWT

VOLTS HIGH (plug, black, female) - PS25GB

VOLTS LOW (plug, white, female) - PS25GWT

For your convenience, the above connectors are supplied with your 5100 PA.



CAUTION

Use only the above connectors.

NOTE: GPIB (IEEE-488) - 24 Pin bus standard. Not included, must be ordered separately.

MAXIMUM RATINGS

LOAD voltage: line to line, or line to common is 600 Vrms.

LOAD current: 50 Amperes rms, continuous.
100 Amperes rms, 30 sec. max.

REMOTE VOLTAGE SENSE: Line to line is 600 Vrms. Also, do not exceed 600 Vrms differential between the VOLTS INPUT and AMPS OUTPUT terminals.

INSTALLATION

ORIENTATION

The 5100 PA must be mounted within ± 20 degrees from horizontal. This insures proper operation of the mercury shunt bypass relay.

ELECTRICAL LOAD

Use wire rated for the maximum load current and voltage expected.

Hint - use wire gauge large enough to insure good connector set screw compression on the wire leads. Soldering may be used instead of, or in addition to the set screw.

IEEE-488 (GPIB)

Use only high quality shielded cable conforming to the bus standards.

INITIAL CHECKOUT

Make sure the circuit is completely de-energized by removing all voltage sources.

Plug the 5100 PA into the 50/60 Hz power mains. Switch the POWER rocker switch (red) to ON and observe that the digit readouts flash on-off-on and then indicate zero or a small number. The VOLTS and AMPERES range switch indicator lights will all illuminate. The voltage ranges sequence down from 600 through 15 and current ranges sequence down from 50 through 2. The 15 Volt, 2 Amp and AUTO indicators will remain illuminated. The MODE indicators do not light during this power-on sequencing.

Your 5100 PA has passed the initial check.

TRANSIENT OVERLOADS

Connect an appropriate transient suppressor in parallel with all inductive loads. Consult the suppressor vendors application literature for proper selection and sizing.



Damage to the 5100 can result from excessive voltage transients generated by unsuppressed inductive loads.

This damage is not within the scope of the normal instrument service and is not covered by the MAGTROL WARRANTY.

CURRENT OVERLOAD

NO FUSES are in the 5100 PA measuring circuits. Therefore, excessive current passed through the AMPS terminals will cause excessive internal heating and possible unit damage.



This overload abuse is not covered by the MAGTROL WARRANTY.

Know your load conditions and double check all connections. If an overload should occur, immediately remove all power , locate and correct the problem before re-energizing your circuit. If a circuit breaker is installed, it must be installed on the LOAD side of the 5100 (downstream). This will keep the low impedance of the input line connected to the 5100 PA for surge suppression. If the line side must also contain a breaker, it should be delayed in operation to open after the load side breaker has opened.

2 - Specifications

VOLTAGE

Five DC and AC Ranges:

- 15, 30, 150, 300 & 600 Volts DC & Volts rms.

Remote Voltage Sensing:

- Differential input - 110 dB CMRR.
- Maximum of 30 Volts peak, volts low terminal to amps output terminal.

CURRENT

Five DC and AC Ranges:

- 2, 5, 10, 20 and 50 Amps DC and Amps rms.

METER IMPEDANCE

Voltage, DC or AC:

- 3 Megohm load on each voltage range.

Current, DC or AC Ranges:

- 0.011 Ohm shunt resistance in the 2, 5, 10 and 20 Amp ranges.
- 0.001 Ohm shunt resistance in the 50 Amp range.

RESOLUTION

Processing resolution is 16 binary bits.

Voltage Display:

- All ranges $\leq$ 9.999 V is $\pm$ 0.001 Volt.
- Ranges $\geq$10 V and $\leq$ 99.9 V is $\pm$ 0.01 Volt.
- Ranges $\geq$ 100 V is $\pm$ 0.1 Volt.

Current Display:

- All ranges $\leq$ 9.999 A is $\pm$ 0.001 Amp.
- Ranges $\geq$ 10 A and $\leq$ 50 A is $\pm$ 0.01 Amp.

Power Display:

- $\pm$ 0.01% of active Volts and Amps range
- GPIB - Amps, Volts and Watts
  Same as display resolution.

ISOLATION

1500 Vrms break down from input circuit to chassis (ground).

DISPLAY AUTO ZERO

When the A and V, display indication is less than 0.5 % of range, the displayed value is set to ZERO.
Refer to SECTION 5 - SPECIAL FUNCTIONS to disable the AUTO ZERO function.

ANALOG OUTPUTS

This is an optional feature.

Analog AMPS, VOLTS and WATTS output signals are a relative value of approximately 5 Volts DC for full scale on each range selected. These outputs are calibrated to 5.00 Volts DC $\pm$ 0.2% for full scale input on the 10 Amp current range and 150 Volt voltage range (1500 Watt range). Ripple is less than 5 mV.

The outputs are operational amplifiers with an impedance of < 1 Ohm and current capacity of < 4 mA. Each output signal and common is electrically isolated from the measured circuit by 750 Volts continuous and 2500 Volts test breakdown. Leakage current is less than 0.3 µA at 240 Vrms, 60 Hz.

DATA ACQUISITION

ANALOG

The conversion of true rms to DC is expressed as:

$$V_{rms} \equiv \sqrt{\frac{1}{T}\int_0^T v^2(t)\ dt}$$

- Rms to DC conversion averaging time constant:
  Volts and Amps time constant TC $\cong$ 60 msec.
  Watts time constant TC $\cong$ 120 msec.
  Watts = V $\times$ I $\times$ cos θ (instantaneous)

DIGITAL

- Processing:
  Integration period = 0.10 second.
  Display update time = 2 readings per second.
- IEEE-488 (GPIB):
  Synchronized = 0.1 sec. per reading
  Non-synchronized is 0.04 to 0.07 sec per reading.

MEASUREMENT ACCURACY

Specified test conditions: Ambient temperature of 72° ± 10°F and power factor of 0.1 to 1.0, lead or lag.

VOLTAGE - DC	± (0.1% of reading + 0.2% of range)
VOLTAGE - AC:	
10 Hz to < 20 Hz	± 1.0% of range
20 Hz to < 45 Hz	± (0.2% of reading + 0.3% of range)
45 Hz to < 10 kHz	± (0.1% of reading + 0.2% of range)
10 kHz to 20 kHz	± (0.2% of reading + 0.3% of range)
CURRENT - DC	**2, 5, 10, 20 and 50 Amp Ranges**
	± (0.1% of reading + 0.2% of range)
CURRENT - AC:	**2, 5, 10 and 20 Amp Ranges**
10 Hz to < 20 Hz	± 1.0% of range
20 Hz to < 45 Hz	± (0.2% of reading + 0.3% of range)
45 Hz to < 1 kHz	± (0.1% of reading + 0.2% of range)
1 kHz to < 5 kHz	± (0.2% of reading + 0.3% of range)
5 kHz to < 10 kHz	± 1.0% of reading
10 kHz to 20 kHz	± 2.0% of reading
	50 Amp Range
10 Hz to < 1 kHz	same as 20 Amp range
1 kHz to 2 kHz	± 2.0% of range
POWER - DC	± (0.1% of reading + 0.3% of VA range)
POWER - AC	± (0.1% of reading + 0.2% of VA range)
POWER FACTOR	± (VA error ± W error)
DISPLAY	Digital display error ± 1 LSB
CREST FACTOR	Exceeds 3:1 (at 50% of range full scale)
TEMPERATURE COEFFICIENT	± 0.01% of range per deg. C. max

ACCURACY CERTIFICATION

All instruments are shipped with a CERTIFICATE of CALIBRATION from MAGTROL Inc. Magtrol policies and procedures comply with MIL-STD-45662A. Measurement standards are traceable to the National Institute of Standards and Technology (NIST).

Instrument calibration every six calendar months is necessary to maintain full compliance with all specifications.

If a one year calibration cycle is used, all accuracy specifications are reduced by 0.1%. After one calendar year, the instrument is considered to be out of calibration.

3 - Connecting the 5100

CAUTION

Always install a properly rated circuit breaker or fuse between the 5100 analyzer and the load. Also, make sure that your power source has it's own disconnect and overload protection that has an operating time lag that insures the load breaker always operates first.

Wire according to all applicable wiring codes, making sure the wire gauge and insulation ratings are adequate for your application.

SURGE PROTECTION

Use Metal Oxide Varistors (MOV) or other PROTECTION:equivalent transient suppressors connected between lines at the load (across the load). These suppressors are an absolute necessity when inductive loads are used. In three phase systems, each load must have a suppressor.

EXTERNAL SHUNTS

100	All watts
150	EXT-600V-KW
200	EXT-600-KW
250	EXT-300 & 600-KW
400	EXT-300 & 600
750	EXT-150, 300 & 600-KW
1000A	EXT-150, 300 & 600

- EXT Shunt must be plugged in (even if not in use) or 5100 will display “HELP.”
- EXT Shunt is calibrated with one 5100. Calibration will be off if used with a different 5100.
- Sense leads to shunt should not be disconnected or calibration will be off.
- Shunt must be sent back with 5100 for recalibration.

CONNECTORS

Use the supplied Supercon® connectors.

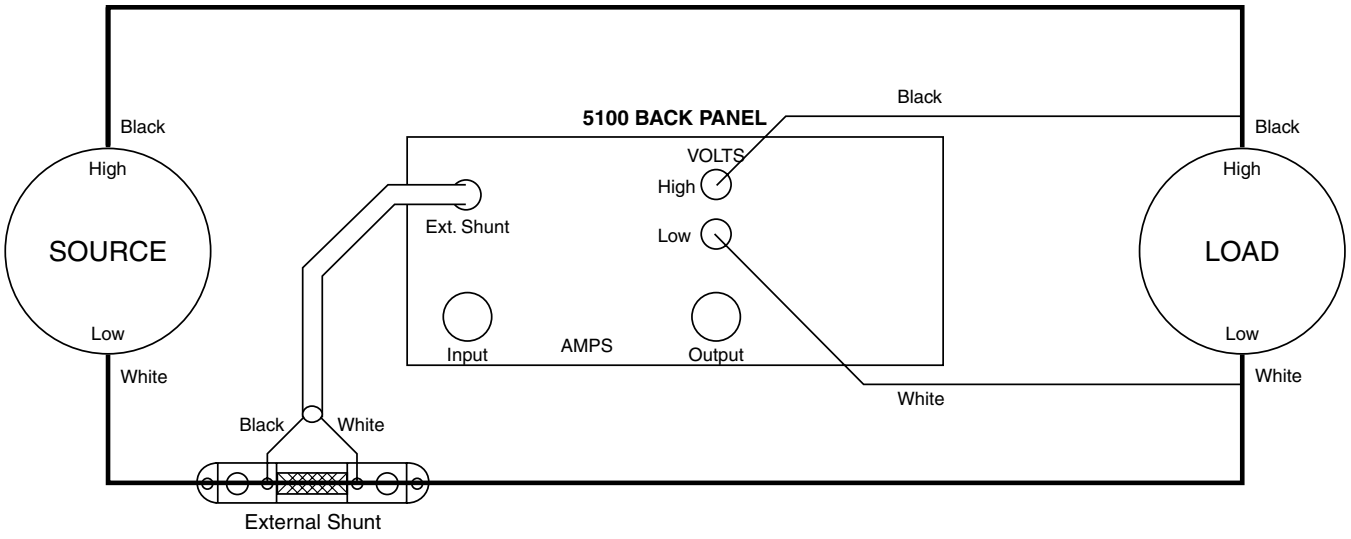
AMPS:

INPUT - PLUG, WHITE, FEMALE-(PS50GWT)
OUTPUT - PLUG, WHITE, MALE-(PP50GWT)

VOLTS:

HIGH - PLUG, BLACK, FEMALE-(PS25GB)
LOW - PLUG, WHITE, FEMALE-(PS25GWT)

Figure 1. External Shunt Connection



SINGLE PHASE AC OR DC CONNECTIONS

This circuit utilizes the 5100 PA REMOTE VOLTAGE SENSE feature by measuring the voltage at the load. This increases measurement accuracy by eliminating line voltage drop from the power measurement. For safety, an overload circuit breaker (CB) removes all load voltage during an over current condition. Make sure that connections from the remote voltage sense lines are connected very close to the circuit breaker and the lines from the breaker to load are as short as possible.

CAUTION

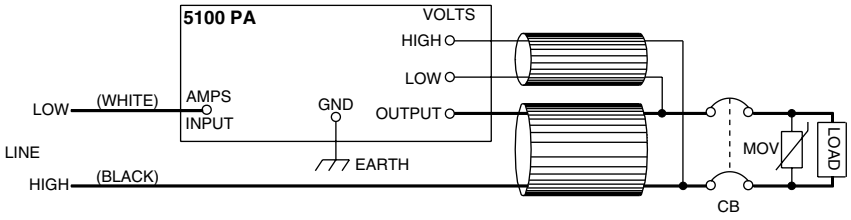
If a circuit breaker is used in the input line to the 5100 PA, a circuit should be used that prevents the breaker from opening until after the load side breaker has operated. Otherwise, potentially damaging inductive transients will be applied to the 5100 PA. Damage caused by these transients are outside the scope of the MAGTROL WARRANTY.

For voltage sense lines less than 25 feet in length, a twisted pair of #20 gauge (or larger) wire can be used. For lines longer than 25 feet or lines grouped with other AC conductors, shielded cable should be used. Connect the shield at the 5100 PA GND terminal. If the wires connecting the load to the 5100 PA OUTPUT are short and the resulting voltage drop is insignificant, the voltage sense connections can be made at the rear panel of the 5100 PA.

WARNING

Connect the chassis ground terminal to a good earth ground. Use at least #12 gauge insulated copper wire.

Figure 2. Single Phase AC or DC with Remote Voltage Sense

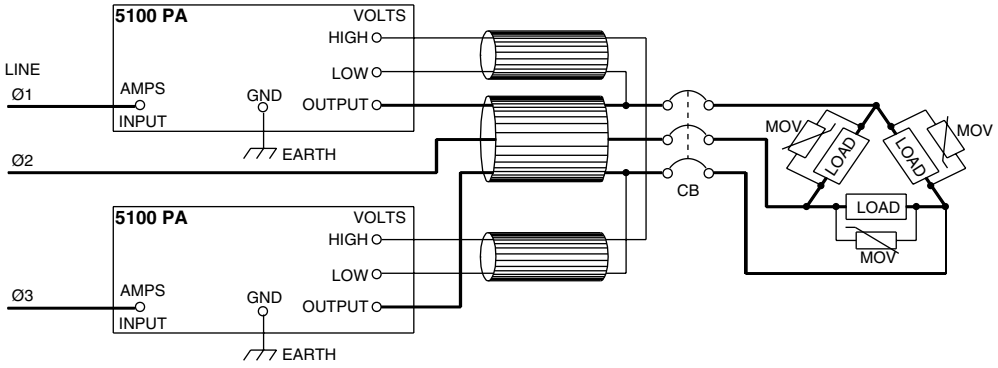


THREE PHASE, 3 WIRE DELTA CONNECTIONS

Load true power is the algebraic sum of the two wattmeter readings (W = W1 × W2) regardless of load power factor or balance. The general discussion from Figure 2 applies.

NOTE: For load power factor = 0.5, one wattmeter reads zero, as the power factor goes less than 0.5 it's power is negative and is subtracted in the algebraic watts summation. The 5100 PA will not display a minus sign for this condition. If your 5100 has the Analog Output Option, the watts (relative) polarity is available by measuring both analog watts outputs. For power factors greater than 0.5, the polarity of both wattmeters will be the same therefore, true power in watts is simply the unsigned sum of the wattmeter readings.

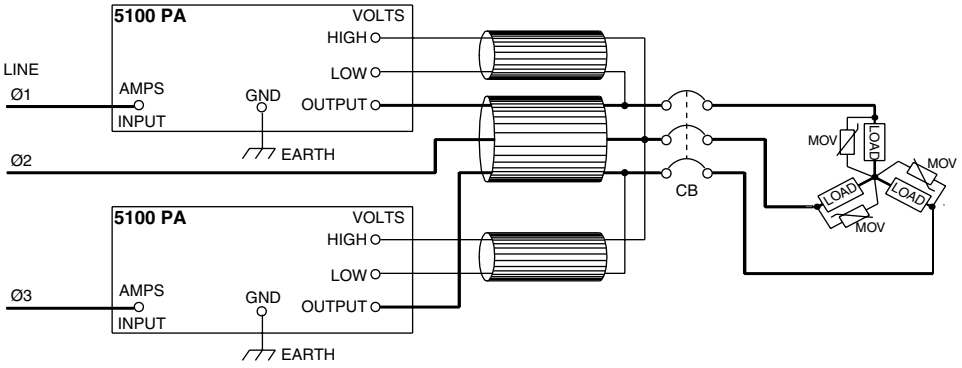
Figure 3. Three Phase, 3 Wire Delta, 2 Wattmeter with Remote Voltage Sense



THREE PHASE, 3 WIRE WYE, 2 WATTMETER CONNECTIONS

True power is the algebraic sum of the two wattmeter readings regardless of power factor and degree of load balance - see NOTE for Figure 3, concerning power factors less than 0.5. Also, the general discussion from Figure 2 applies.

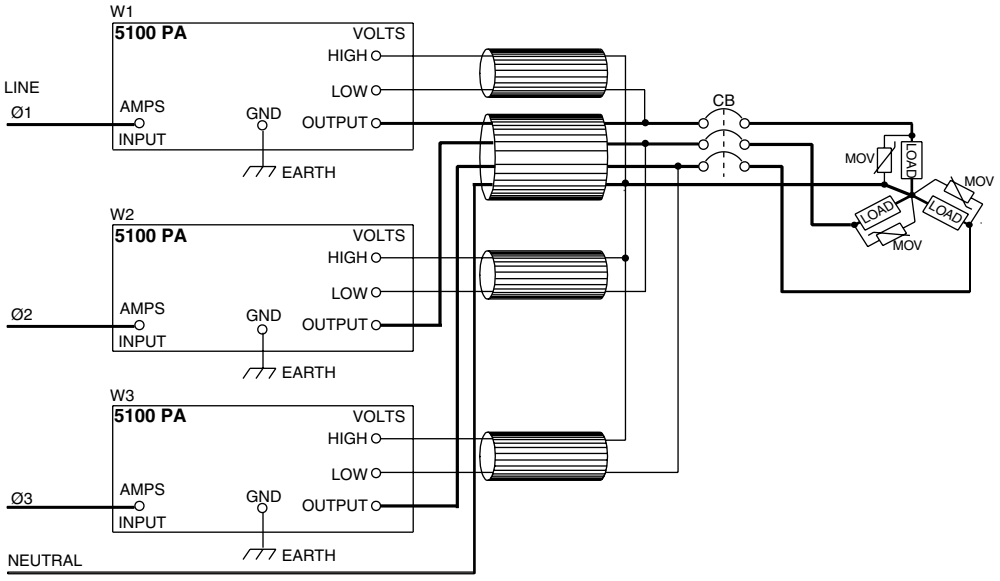
Figure 4. Three Phase, 3 Wire Wye, 2 Wattmeter with Remote Voltage Sense



THREE PHASE, 4 WIRE WYE, 3 WATTMETER CONNECTIONS

Three wattmeters are required for unbalanced loads. Total power is the algebraic sum of the three wattmeter readings. The general discussion from Figure 2 and the power factor discussion of Figure 3 applies.

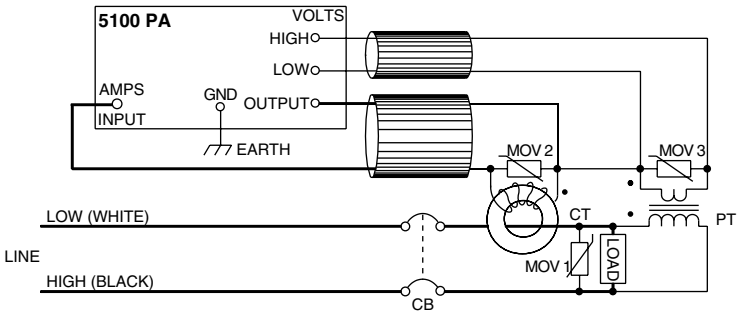
Figure 5. Three Phase, 4 Wire Wye, 3 Wattmeter with Remote Voltage Sense



SINGLE PHASE CURRENT & POTENTIAL TRANSFORMER CONNECTIONS

Voltage and current measurement ranges can be extended by using current and potential transformers. Frequency response will be determined by the characteristics of the transformers used. The general discussion from Figure 2 applies. Three phase lines can be measured by using the two or three wattmeter techniques previously illustrated.

Figure 6. Current & Potential Transformer - Single Phase



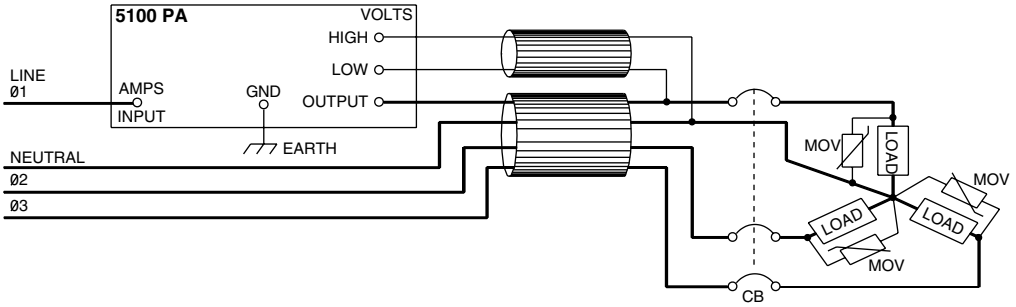
THREE PHASE, 4 WIRE BALANCED LOAD, 1 WATTMETER CONNECTIONS

With a balanced load, one wattmeter connected in one phase reads 1/3 of the total power consumed.

$WATTS_{TOTAL} = 3 \times$ WATTMETER READING

The general discussion from Figure 2 applies. The three load impedances are equal for balanced loads.

Figure 7. Three Phase, 4 Wire Wye, Balanced Load, 1 Wattmeter

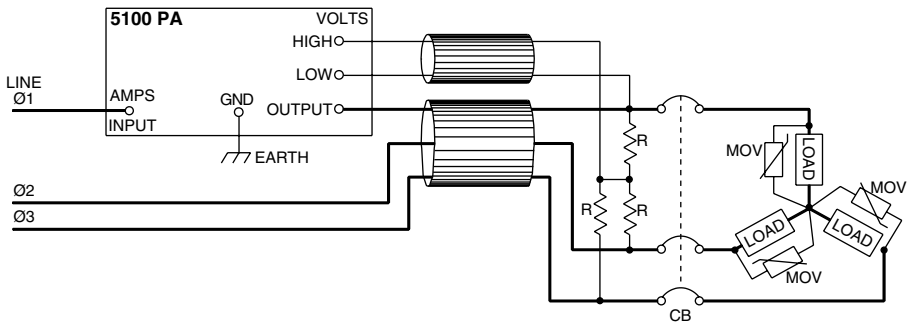


THREE PHASE, 3 WIRE BALANCED LOAD, 1 WATTMETER CONNECTIONS

$WATTS_{TOTAL} = 3 \times$ WATTMETER READING

An artificial neutral is formed by a star connection of three identical resistors (R). The value of these resistors should be high enough to avoid loading the lines and affecting the power measurement. The general discussion from Figure 2 applies. The three load impedances are equal for a balanced load.

Figure 8. Three Phase, 3 Wire, Balanced Load, 1 Wattmeter



4 - Operation

GENERAL

Using Sections 1 and 3 as a guide, connect the 5100. Before connecting the power mains, double check all connections using an Ohmmeter.

Verify that the overcurrent circuit breaker is open and connect the power mains.

Observing the 5100 front panel indicators. Turn the 5100 power switch ON and confirm proper operation - refer to *"Initial Checkout" under Chapter 1 - Introduction.*

Energize the power mains and apply power to the load by closing circuit breaker CB. If improper operation occurs, immediately disconnect power mains, locate and correct the problem.

The 5100 has three MODES - HOLD; PF (power factor) and AVG (averaging); five AMPS ranges plus AUTO (autoranging); and five VOLTS ranges plus AUTO. All have adjacent red LED's indicating the active mode and measurement range.

AMPERES DISPLAY

The AMPS display is a four digit, floating point display of true AC rms or DC current flowing into the AMPS INPUT connector (white) on the rear panel. For detailed specifications refer to *Chapter 2 - Specifications*.

The 5100 defaults to AUTO (auto ranging) at turn on. AUTO up-ranging occurs if the rms current exceeds the top of the range value plus about 5% or, if a peak value exceeds full range rms value × 1.414 plus approximately 5%.

AUTO down ranging occurs when the current is just less than full range value of the next lower range.

Selection of any amps range pushbutton activates the selected range by overriding the AUTO- range selection - AUTO LED goes off and selected AMPS LED illuminates. However, the AUTO up-range function is always silently monitoring the current and is ready to up-range the instrument if the current increases above the range full scale. If the current falls below the value of the originally selected range, that range will then re-activate. The instrument will automatically up-range from the measured current but will down-range only to the selected range. The display will show "HELP" when the 5100 PA maximum current is exceeded.

VOLTAGE DISPLAY

The VOLTS display is a four digit, unsigned floating point display of AC rms or DC voltage between the rear panel HIGH (black) and LOW (white) terminals.

The voltage input is differential (neither terminal tied to common) allowing connection at a remotely located load. This remote connection removes the voltage drop in the load connection wires from the power measurement. The VOLTS - LOW terminal (WHITE) must be connected to the AMPS - OUTPUT line at the load - see *Figure 1*.

The AUTO and manual VOLTS range selection is identical in operation to the AMPS as described above.

WATTS OR POWER FACTOR

The WATTS display is five digit, unsigned floating point display of power in WATTS or POWER FACTOR as a decimal number.

WATTS is the power ON default MODE, press the MODE - PF button for POWER FACTOR MODE. Watts measurements are from milliwatts through 30 kilowatts, and Power Factors from 0.0001 through 0.9999.

$$\text{WATTS} = V \times I \times \cos\theta = \text{TRUE POWER}$$

The WATTS range is set by the AMPS and VOLTS active ranges.

$$\text{Power Factor} \equiv \frac{\text{True Power}}{V \times I}$$

MODE HOLD

The HOLD pushbutton may be depressed at any time. When depressed, all internal machine functions are halted except auto ranging. If the AVG (averaging) function is active when the HOLD button is depressed, the last running average value of AMPS, VOLTS and WATTS will be latched on the display.

The HOLD and AVG functions can be combined. See the MODE AVG paragraph, below.

MODE AVG

AVG is an integration or averaging function on VOLTS , AMPS and WATTS.

Averaging remains active across manual or auto range changes.

The averaging function is useful in stabilizing the display when digits are changing because of slowly varying values. Integration periods from seconds to minutes may be needed.

The HOLD and AVG functions work together. When entering AVG with HOLD off, the averaging registers are cleared and integration starts from the current value. With the HOLD function active first, pressing AVG starts the integration point from the last stored values of AMPS, VOLTS or WATTS. When AVG is turned off, non-averaged values are displayed and the values at that instant are stored in non-volatile RAM and upon reentering the AVG mode will be returned as the new averaging starting points. Also, when the Analyzer power is turned off, the last averaged values stored will be held and returned when the AVG function is reactivated.

The HOLD - AVG function permits truly integrated power measurements where power is applied intermittently or, where a combination of devices require integrated measurements with interruptions between measurements.

NOTE: WATTHOURS can be determined by using the AVG function and a timing clock.

Watthours = (watts avg × time in hours)

Power Factor (PF) is not averaged.

ANALOG OUTPUT OPTION

This option provides analog output signals for AMPS, VOLTS and WATTS. These three analog outputs with their common are isolated from the measured circuits by 750 Volts continuous and 2500 Volts test breakdown.

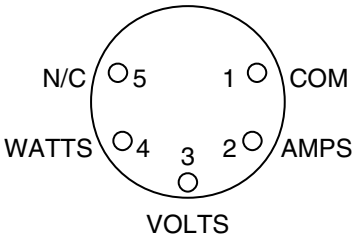
The outputs are provided through a standard 5 pin DIN style connector that is located on the rear panel of the 5100 - see figure 9 for connections.

The analog output voltage is calibrated to 5.00 Volts DC for full scale input on the 10 Amp current range and the 150 Volt voltage range (1500 Watt range). The actual output on other ranges will be a relative value close to 5 Volts due to tolerances in gain resistors and instrumentation amplifiers. For example: Full scale output on the 15 Volt range may be 4.95 Volts DC. The analog output at 12 Volts input would be FS / Rng × Rdg or 4.95 / 15 × 12 = 3.96 Volts DC.

NOTE: Analog output of POWER FACTOR is not provided

See Chapter 2 - Specifications.

Figure 9. Analog Output Connections



5 - GPIB Communication

GPIB (IEEE-488)

The IEEE-488 or GPIB (General Purpose Interface Bus) provides direct connection and control of the 5100 from any appropriately equipped computer for the purpose of data acquisition and display. MAGTROL factory assistance is available.

HARDWARE INSTALLATION

A GPIB interface requires installation of an interface card in the host computer and driver software resident on the PC's hard disk. MAGTROL can supply the National Instruments Corp. GPIB-PC2A® interface, for IBM® or compatible PC's.

SOFTWARE INSTALLATION

Formatting and initialization assistance is available from MAGTROL Customer Service.

All GPIB data acquisition systems require the use of termination characters to signal the conclusion of a data exchange. The 5100 uses the Hewlett Packard - HPIB™ standard ASCII termination characters "Carriage Return (CR) and Line Feed (LF)", in that order. On a write cycle, the 5100 looks for the CR-LF to signal completion of an instruction and transmits these characters upon conclusion of a data read cycle.

PRIMARY ADDRESS

All instruments serviced on the bus have a separate primary address code. The factory setting for the 5100 is twelve (12). This code can be changed by changing the DIP switch settings that are located on the rear panel and above the GPIB connector. Change this address only if there is an addressing conflict with other instrumentation on the bus. Refer to the table in Figure 10 to set the DIP switch pattern.

Figure 10. GPIB Address Selection

(Address 12 shown)

SWITCH SEGMENT					ADDRESS
1 LSB	2	3	4	5 MSB	
0	0	0	0	0	0
1	0	0	0	0	1
0	1	0	0	0	2
1	1	0	0	0	3
0	0	1	0	0	4
1	0	1	0	0	5
0	1	1	0	0	6
1	1	1	0	0	7
0	0	0	1	0	8
1	0	0	1	0	9
0	1	0	1	0	10
1	1	0	1	0	11
0	0	1	1	0	12
1	0	1	1	0	13
0	1	1	1	0	14
1	1	1	1	0	15
0	0	0	0	1	16
1	0	0	0	1	17
0	1	0	0	1	18
1	1	0	0	1	19
0	0	1	0	1	20
1	0	1	0	1	21
0	1	1	0	1	22
1	1	1	0	1	23
0	0	0	1	1	24
1	0	0	1	1	25
0	1	0	1	1	26
1	1	0	1	1	27
0	0	1	1	1	28
1	0	1	1	1	29
0	1	1	1	1	30
1	1	1	1	1	31



IBM® AND COMPATIBLES INSTRUCTIONS

The 5100 PA is configured for the Hewlett Packard standard termination characters of CARRIAGE RETURN (CR hex OD) and LINE FEED (LF hex OA). On a read cycle (5100 to PC), the 5100 expects the standard IEEE-488 read protocols and primary address. It responds with a data string followed by a CR and LF. This signals the end of a transmission. Upon receipt of these characters, the PC must be configured to terminate GPIB communications and proceed with its own program execution. On a write cycle (PC to 5100), the 5100 expects to receive: (1) the PRIMARY ADDRESS; (2) INSTRUCTIONAL DATA STRING (3); the TERMINATION CHARACTERS of CR and LF. If

these characters are not forthcoming, the 5100 has no way of knowing when to terminate handshaking, reset the GPIB and continue with its program loop. If omitted, the only way to restore operation is to cycle power OFF-ON or, force a GPIB interface reset - if available.

READ CYCLE

In read (5100 to PC) command mode, the 5100 will output a data string containing the information on the AMPS, VOLTS and WATTS display.

The ASCII output format is:

A= aa.aaV=vvv.vW=ww.www<CR><LF>

aa.aa is the CURRENT value as displayed on the AMPS display.

vvv.v is the VOLTAGE value as displayed on the VOLTS display.

ww.www is the WATTS value as displayed on the WATTS display.

The string length is always 24 characters. Most PC's will require that the input string length be dimensioned.

If the 5100 is in PF (power factor) MODE instead of WATTS, the "W" changes to "P".

QUICKBASIC® EXAMPLE

The following QuickBASIC ® program provides bus control and data transfer.

```
'$INCLUDE: 'c:\gpib-pc\qbasic\qbdecl.bas'
rd$ = SPACE$(24)
eos$ = CHR$(13) + CHR$(10)
CALL IBFIND("gpib0", gpib0%)
CALL IBFIND("dev12", dev12%)
CALL IBSIC(gpib0%)
start:
    CLS
    LOCATE 23, 1: PRINT "Press any key ..."
    LOCATE 1, 1: INPUT "Enter the function character(s)"; f$
    f$ = UCASE$(f$)
    wrt$ = f$ + eos$
    CALL IBWRT(dev12%, wrt$)
    DO
        CALL IBRD(dev12%, rd$)
        LOCATE 12, 29: PRINT rd$
    LOOP WHILE INKEY$ = ""
    GOTO start
```

GPIB INSTRUCTION SET

AA	Sets AMPS AUTO ranging on.
A2	Sets AMPS range to 2, AUTO o
A5	Sets AMPS range to 5, AUTO o
A10	Sets AMPS range to 10, AUTO o
A20	Sets AMPS range to 20, AUTO o
A50	Sets AMPS range to 50, AUTO o
AZ	Sets AUTO zero o Cycle POWER off/on to set AUTO zero on.
CAL	Uncalibrated data
CALC	Calibrated data
DEV	Shifts GPIB operation to DEBUG.
DEVC	Shifts from DEBUG to standard GPIB.
H	Sets HOLD function on.
HC	Sets HOLD function off.
I	Sets the AVG function on.
IC	Sets the AVG function off.
L	Locks out all front panel controls
LC	Clears front panel lockout.
OPEN	Allows GPIB data access at random.
P	Sets WATTS display to show PF.
SYNC	Sync's data access to 0.1 sec
VA	Sets VOLTS AUTOranging on.
V15	Sets VOLTS range to 15, AUTOzero o
V30	Sets VOLTS range to 30, AUTOzero o
V150	Sets VOLTS range to 150, AUTOzero o
V300	Sets VOLTS range to 300, AUTOzero o
V600	Sets VOLTS range to 600, AUTOzero o
W	Switches from PF display to WATTS.
ZNV	Sets all nonvolatile memory to zero.

SPECIAL FUNCTIONS

Three special functions are available at power turn on:

(1) To disable autozero display function:

Turn 5100 power off; depress and simultaneously hold the MODE-HOLD and the 2 AMPS range buttons as POWER is switched ON. All least significant digit (LSD) changes around zero will display. Normal operation suppresses ± several counts around zero.

(2) To remove the factory set calibration factors:

Turn the 5100 power off, depress and simultaneously hold the MODE-PF and the 2 AMPS range buttons as POWER is switched ON. Uncalibrated values (without factory programmed calibration factors) are displayed.

(3) To remove all programmed calibration factors and display the basic input binary word (integer BCD format):

Turn the 5100 power off, depress and simultaneously hold the MODE-AVG and the 2 AMPS range buttons as POWER switch ON.

NOTE: These functions are provided for the 5100 PA performance evaluation and are not of use to the average user.

6 - Operating Principles

AMPERES TRANSDUCING

Current measuring is accomplished using two calibrated manganin meter shunts. For the 2 ,5, 10 and 20 Amp ranges, 0.011 Ohms resistance from two series connected metering shunts provide a voltage to a differential input calibration amplifier. In the 50 Amp range, the low current section of the shunt is bypassed by a low resistance mercury relay leaving 0.001 Ohm of active shunt. *See Figure 10.*

This autorange activated shunt bypass relay protects the metering shunts from overheating for overloads up to 100 amps for about 30 seconds.

VOLTAGE SENSING

The VOLTS input terminal connects a 1.5 megohm resistive voltage divider to a differential input amplifier to provide scaled voltage for measurements.

See Figure 11.

ANALOG PROCESSING

Input signals proportional to AMPS and VOLTS are amplified and scaled for each range. These scaled signals pass through a true rms to DC converter, a voltage to frequency converter and an optical isolation coupler. The resulting signals represent true rms current and voltage as a function of frequency (AF_0 and VF_0, respectively).

Also, scaled AMPS and VOLTS signals are input to a precision four quadrant X-Y multiplier, averaged by passing through an active two pole Butterworth filter, converted to frequency in a voltage to frequency converter and isolated through an optical coupler. The resulting signal, WF0, represents true power - ($V \times I \times \text{Cos } \theta$) in WATTS as a function of frequency.

There is 2500 volts isolation between the measured circuit and the AF_0, VF_0 and WF_0 frequency signals.

See Figure 12 for a block diagram.

Figure 11. 5100 Input Circuits

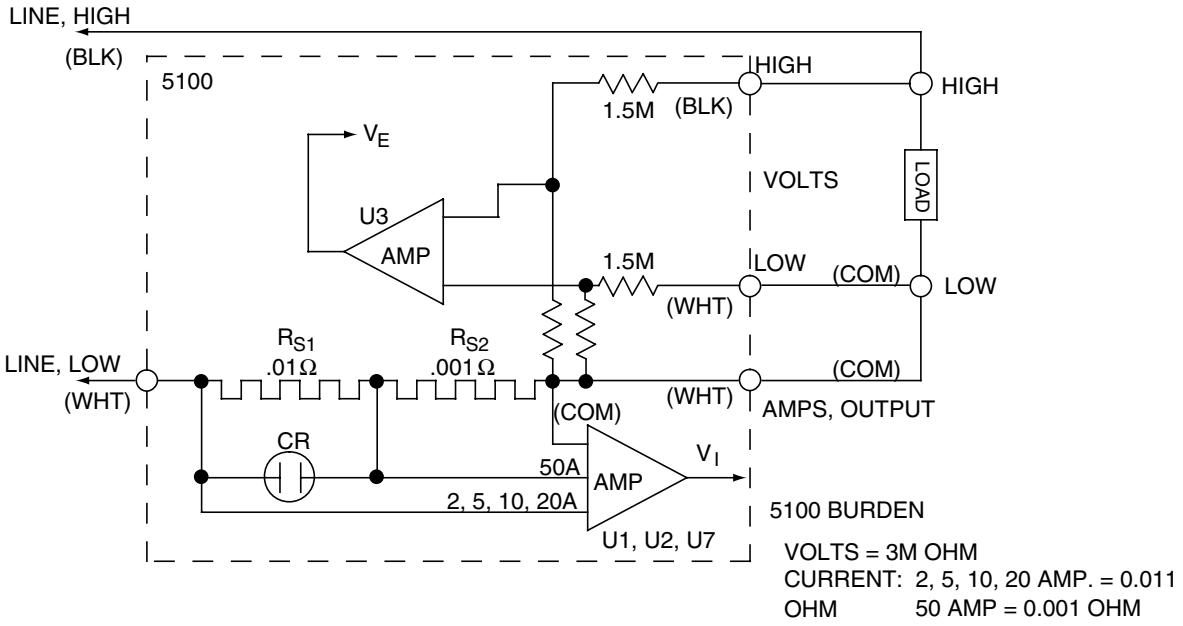
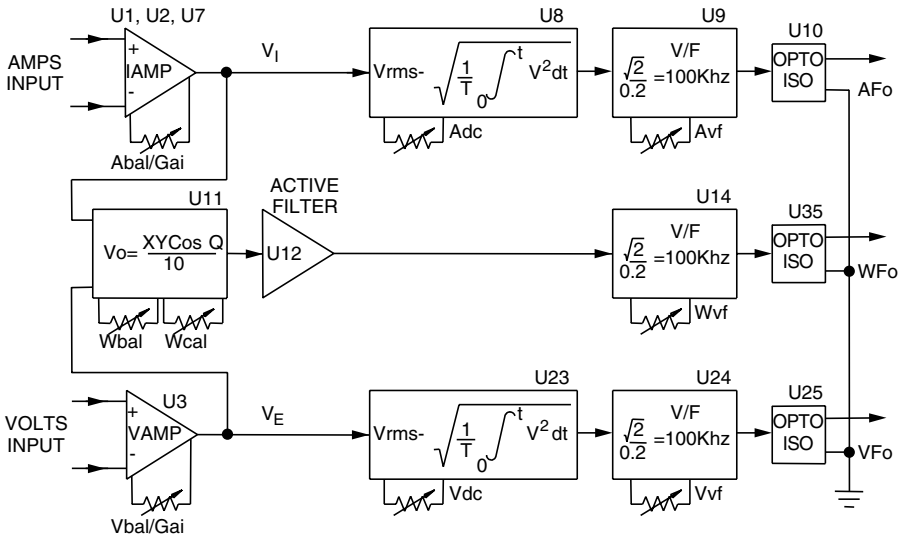


Figure 12. Block Diagram



DIGITAL PROCESSING

Frequency proportional signals of AMPS, VOLTS and WATTS (AF_0, VF_0 and WF_0, respectively) are integrated for a precise period of 0.1 seconds for digital conversion and processing via an eight bit microcomputer. The MPU controls functions of range control, auto-zero, calibration, BCD conversion, parameter display and GPIB transmission.

The MPU acquisition and conversion rate is 100 milliseconds (10 readings per second) and the display updates at 500 milliseconds (2 updates per second). The MPU scans all front panel pushbutton control inputs 25 times per second. When a pushbutton is depressed, the appropriate program loop is entered and the function is executed on the next program cycle. No damage will result to the 5100 PA from any combination of pushbutton selections.

In the AVG MODE (averaging), the 5100 PA integrates the 10 data readings per second (AMPS, VOLTS and WATTS) and then samples the averaged value for display. As the sampled readings accumulate, the changing display digits will steady down to provide a stable measurement of true power (computed from average VOLTS and AMPS). This technique works well when the displayed digits are changing too fast to be recognized resulting from changing power consumption.

7 - Calibration

GENERAL

Complete calibration of the 5100 PA is beyond the capabilities of most users. MAGTROL Inc. recommends that the 5100 PA should be returned to the factory for calibration certifying the instrument to full specifications.

NOTE: breaking the factory CAL VOID sticker voids the MAGTROL WARRANTY - Please call the MAGTROL Service Department before you break this seal.

However, this section includes CALIBRATION ACCURACY VERIFICATION procedures and steps to make minor trim-ups of calibration.

NOTE: Performing these steps VOIDS the factory CALIBRATION CERTIFICATION that comes with the 5100 PA., the factory seal will be broken.

TEST SETUP

The recommended test setup is shown by Figure 13.

The accuracy of the voltage and current standards used for calibration should be at least four times the accuracy of the 5100 PA specifications. The equipment shown in this test setup meets this requirement.

To accurately measure AC power it is important that the current source have a phase shifting control. With such a phase adjustment, phase shift caused by incidental circuit inductances can be compensated for by adjusting the phase of the current wave form to be exactly in phase (zero phase shift) with the voltage wave form.

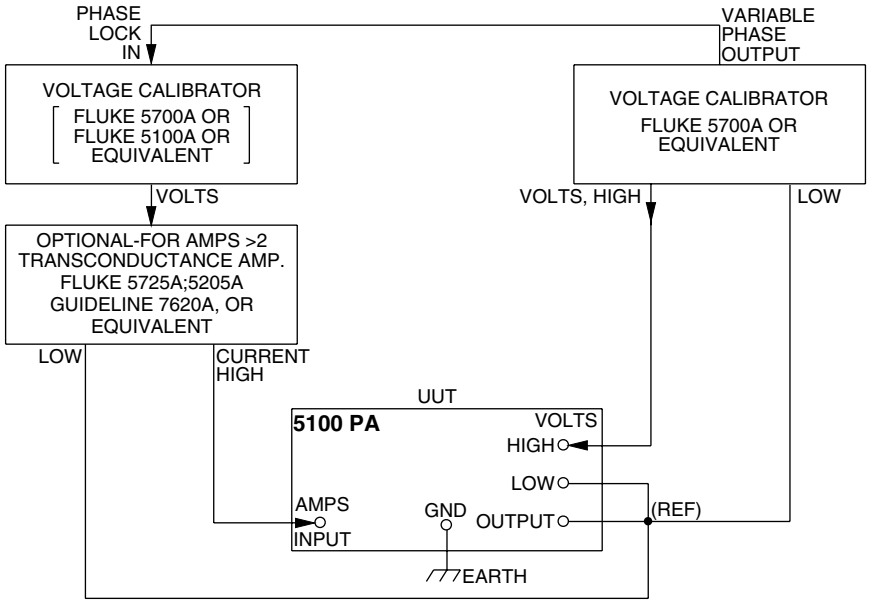
Sources of incidental circuit inductance include the current shunts within the 5100, output impedance of the calibrators, impedance of the load and wiring inductance.

Since the current calibrator output is usually a low impedance with low compliance voltage, the 5100's current measuring shunts are the circuits major resistance. Let's take a representative example and compute the resulting phase shift:

Let L = 10 μhenries (total of shunt, wiring, etc.)
Let R_{SHUNT} = 0.011 Ohm; R_{WIRING} = 0.01 Ohm
R = 0.011 + 0.01 = 0.021 Ohms
Let F = 60 Hz $\therefore$ 2π F L $\approx$ 0.004
θ = Arctan (2π FL / R) = Arctan (0.004 / 0.021)
$\theta \approx$ 11 degrees, or about 1.8 % measurement error.

This error can be eliminated by adjusting the calibrators variable phase shift control. This demonstrates the need for care in making power analyzer calibration measurements.

Figure 13. Calibration Verification Test Setup



CALIBRATION VERIFICATION

Refer to Figure 13, for the recommended test setup.

If other test equipment is used, appropriately modify the test steps for your equipment.

WARNING

Potentially lethal voltages are used in the following test steps.- avoid electrical shock. Refer to your calibrator operator manual for operating instructions - these calibrators generate lethal voltages, extreme care is necessary.

The three steps of the calibration verification are as follows:

1. Volts Calibration Check
2. Amperes Calibration Check
3. Watts Calibration

Set both the VOLTS and AMPERES calibrators to standby mode.

VOLTS CALIBRATION CHECK

DC:

1. On the 5100 PA, depress the 15 volts range pushbutton.
2. Set the volts calibrator for zero volts DC and operate mode.

   The 5100 VOLTS display should read zero + 0.0001% max of volts full scale range.
3. Set volts calibrator for + 15 volts DC.

   The 5100 VOLTS display should read 15.00 volts.
4. Record the VOLTS readings.
5. Set the calibrator for -15 volts DC and repeat the above step.
6. Record the VOLTS readings.
7. Repeat the above 6 steps for the 30, 150, 300 and 600 volts ranges.

WARNING

Lethal Voltages are Used!

8. Compare the above readings to the 5100 PA ACCURACY SPECIFICATIONS in Chapter 2 of this manual.

   The (+) and (-) readings should be within ± 2 least significant digit (LSD) of each other.

AC:

1. Set the volts calibrator for 60 Hz and repeat the volts checks as outlined in the DC test above.

   NOTE: If a beat frequency effect is experienced between the calibrator output and the 60 Hz power line frequency, try setting the calibrator for 80 Hz instead of 60 Hz.
2. Set the volts calibrator to standby mode.

AMPERES CALIBRATION CHECK

DC:

1. On the 5100, depress the 2 AMPERES range pushbutton.
2. Set the current calibrator for zero amperes and operate mode.

   The AMPERES display should read zero + 0.0001% max of range full scale.
3. Set the current calibrator for + 2 Amperes DC.

   The AMPERES display should read 2.000 Amps.
4. Record the current readings.
5. Set the current calibrator for -2 Amperes.

   The AMPERES display should read 2.000.
6. Repeat the above 5 steps for the 5, 10, 20 and 50 Amp ranges.
7. Compare the above readings to the 5100 PA ACCURACY SPECIFICATIONS in Chapter 2 of this manual.

The (+) and (-) readings should be within ± 2 LSD of each other.

AC:

1. Set the current calibrator for 60 Hz and repeat the current checks outlined above.

   NOTE: If a beat frequency effect is experienced between the calibrator output and the 60 Hz power line frequency, try setting the calibrator for 80 Hz instead of 60 Hz.

2. Set the current calibrator to standby mode.

WATTS CALIBRATION CHECK

This step calls for the simultaneous application of voltage and current to the 5100 PA.

DC:

1. On the 5100, select a VOLTS and AMPERES range.
2. Set the volts and current calibrators for a voltage and current near the center of each selected range.
3. Switch the CALIBRATORS to operate mode.

   The WATTS readout should show a power that is the product of the VOLTS and AMPS indications (POWER = V × I).
4. Compare the 5100 PA WATTS readout to the product of VOLTS and AMPS from the CALIBRATORS output. This difference is the WATTS error.

AC:

POWER = V × I × Cos θ
where θ = phase angle between volts and amps.

NOTE: maximum true power is delivered only when θ = zero degrees (cos θ = 1). Therefore, the volts calibrator variable phase adjustment is set for zero phase between the volts and amps at the input to the 5100 PA. Refer to the calibrator instruction manuals for this adjustment procedure.

1. The phase shift control should be carefully set to provide a peak 5100 PA WATTS indication, this corresponds to zero volts to amps phase angle.
2. Repeat the procedure as used for the DC power verification and record readings.
3. Compare the recorded reading to the 5100 PA. ACCURACY SPECIFICATIONS in Chapter 2 of this manual.

MINOR ADJUSTMENT (IF NEEDED)

NOTE: All trim pot adjustments are located on the 78B143 circuit board of the 5100 - see *Chapter 8 - Schematics*.



WARNING

Lethal Voltages are Used!

VOLTS ZERO

1. Disable the autozero function, refer to "Special Functions" under *Chapter 5 - GPIB Communication*.
2. Go to the 5100 VOLTS range that needs zero adjustment.
3. Set the volts calibrator for zero volt DC output.
4. Adjust trim pot R16 for zero (+ 0.0001% max) VOLTS display reading. This sets all voltage ranges - all ranges should be zero + 0.0001% of range full scale.

AMPERES ZERO

1. Disable the autozero function, refer to "Special Functions" in *Chapter 5 - GPIB Communication*.
2. Go to the 5100 AMPERES range(s) that need adjustment.
3. Set the current calibrator for zero amp DC output.
4. For the 2, 5, 10, and 20 amp ranges, adjust trim pot R_9, for zero AMPERES display indication.

   For the 50 amp range, adjust trim pot R_{13} for zero AMPERES display indication.

Volts Scale Factor

1. Go to the 5100 VOLTS range(s) that need adjustment.
2. Set the volts calibrator for an output equal to the range maximum voltage.
3. Adjust the trim pot(s) so the VOLTS display reads the full scale voltage as shown below:

   For the 15 volt range, adjust R_{17}

   For the 30 volt range, adjust R_{19}

   For the 150 volt range, adjust R_{21}

   For the 300 volt range, adjust R_{23}

   For the 600 volt range, adjust R_{25}

Amperes Scale Factor

1. Go to the AMPERES range(s) that need adjustment.
2. Set the current calibrator DC output to the range maximum current and adjust trim pot(s) so the AMPERES display reads the full scale current:

   For the 2 Amp. range, adjust R_{27}

   For the 5 Amp. range, adjust R_{29}

   For the 10 Amp. range, adjust R_{31}

   For the 20 Amp. range, adjust R_{33}

   For the 50 Amp. range, adjust R_{35}

Note:	Calibration on the 20 and 50 Amps ranges may have to be done at less than full range scale, depending on your calibration equipment.

Volts Balance

1. Go to the 5100 PA 150 VOLTS range.
2. Set the voltage calibrator for + 150 volts DC. output.
3. Note the VOLTS display reading.
4. Reverse the calibrator polarity to -150 volts DC.

   If the plus to minus display readings differ by more than ± 2 LSD, connect a digital voltmeter at amplifier U_{23} pin 14 and adjust trim pot R_{67}, for zero ± 0.1 millivolt DC.

Current Balance

1. Go to the 5100 PA 2 Amp. range.
2. Set the current calibrator for + 2 Amps DC output.
3. Note the AMPERES display reading.
4. Reverse the calibrator polarity to - 2 Amps DC.

   If the plus and minus display readings differ by more than ± 2 LSD, connect digital voltmeter at amplifier U_8 pin 14 and adjust trim pot R_{41}, for zero ± 0.1 millivolt.

Watts Scale Factor

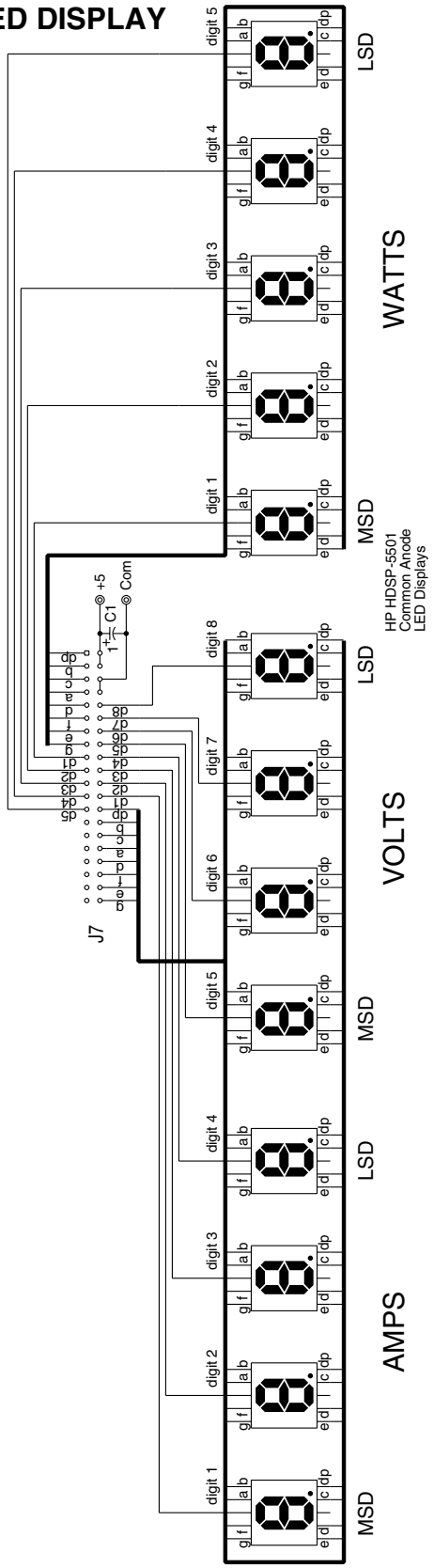
1. Set the volts and current calibrators for 150 VDC and 2 Amp DC output.
2. Adjust trim pot R_{48}, for 300.00 WATTS display reading.
3. Confirm AC measurement accuracy by setting the calibrators for 150 VRMS and 2 Amps RMS at 60 Hz. The WATTS display should read close to 300.00 watts and be within the specification accuracy.

   See “Accuracy Specifications” in *Chapter 2 - Specifications*.

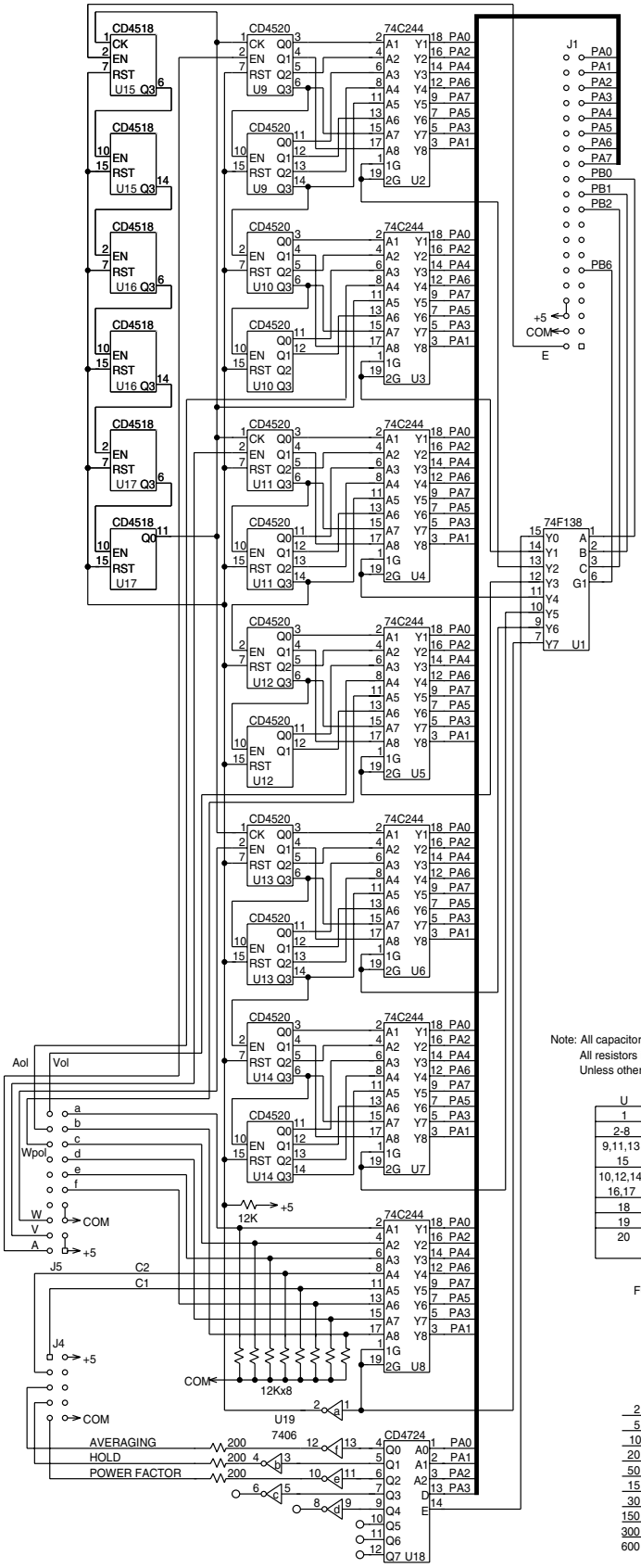
NOTE:	Adjust current calibrator's phase shift control for zero phase angle between volts and amps (peak the watts indication) - see “Calibration Verification” step 3 for AC.

Appendix A: Schematics

CIRCUIT BOARD 78B128 - LED DISPLAY



CIRCUIT BOARD 78B141



Note: All capacitors in uF
All resistors in OHMS
Unless otherwise noted

U	+5	COM
1	16	4,5,8
2-8	20	10
9,11,13 15	16	8,9
10,12,14 16,17	16	1,8,9
18	16	8,15
19	14	7
20	3,11 16	1,8,9

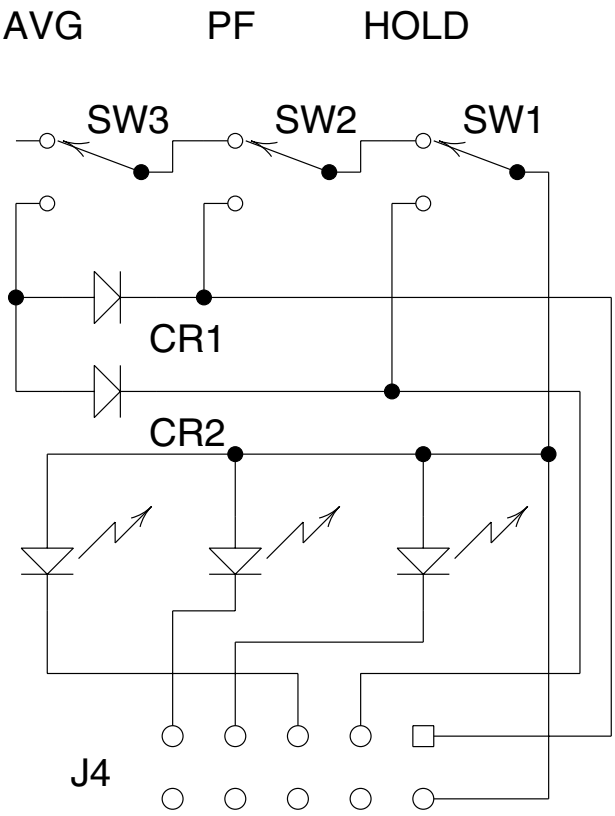
FUNCTION	C1	C2
HOLD	0	1
PF	1	0
AVG	1	1

RANGE SWITCH

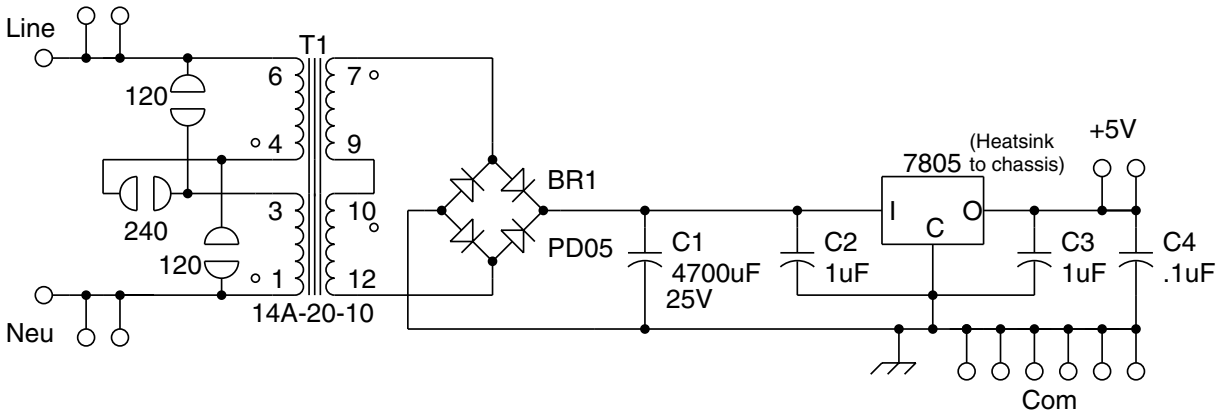
	a	b	c	d	e	f
2	1	0	0	x	x	x
5	0	1	0	x	x	x
10	1	1	0	x	x	x
20	0	0	1	x	x	x
50	1	1	1	x	x	x
15	x	x	x	1	0	0
30	x	x	x	0	1	0
150	x	x	x	1	1	0
300	x	x	x	0	0	1
600	x	x	x	1	1	1

x=don't care

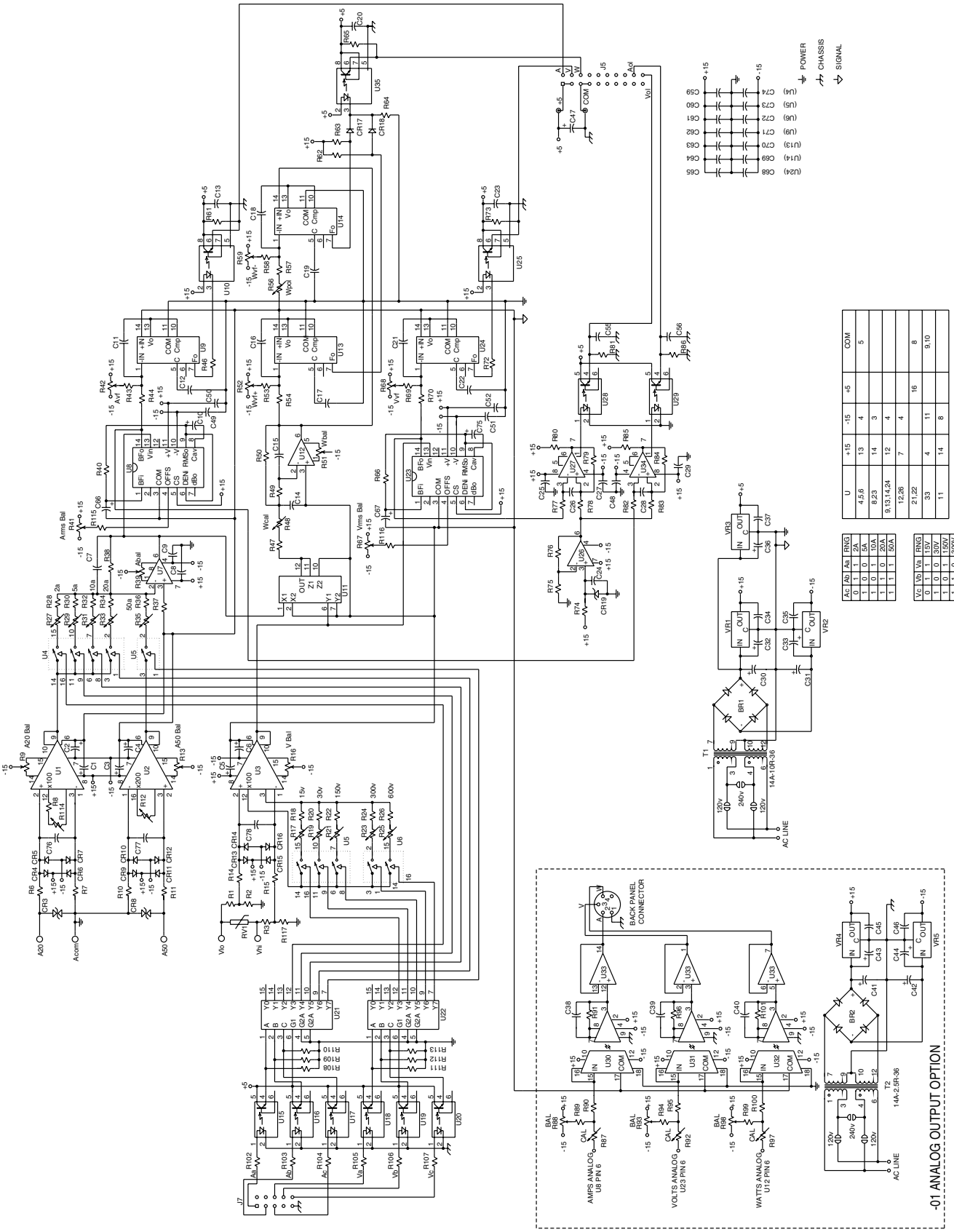
CIRCUIT BOARD 78B142



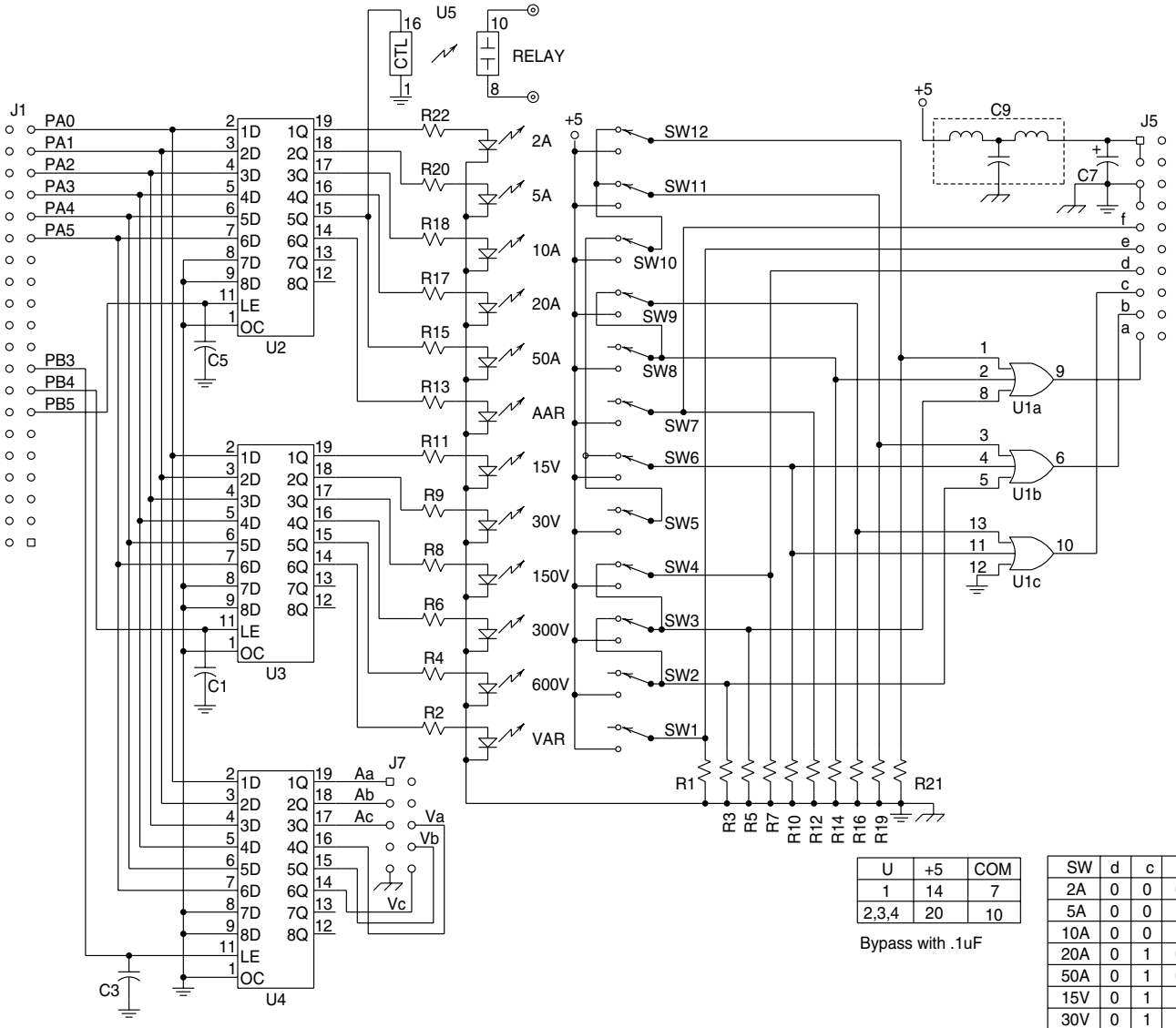
CIRCUIT BOARD 78B175



CIRCUIT BOARD 78B143



CIRCUIT BOARD 78B144

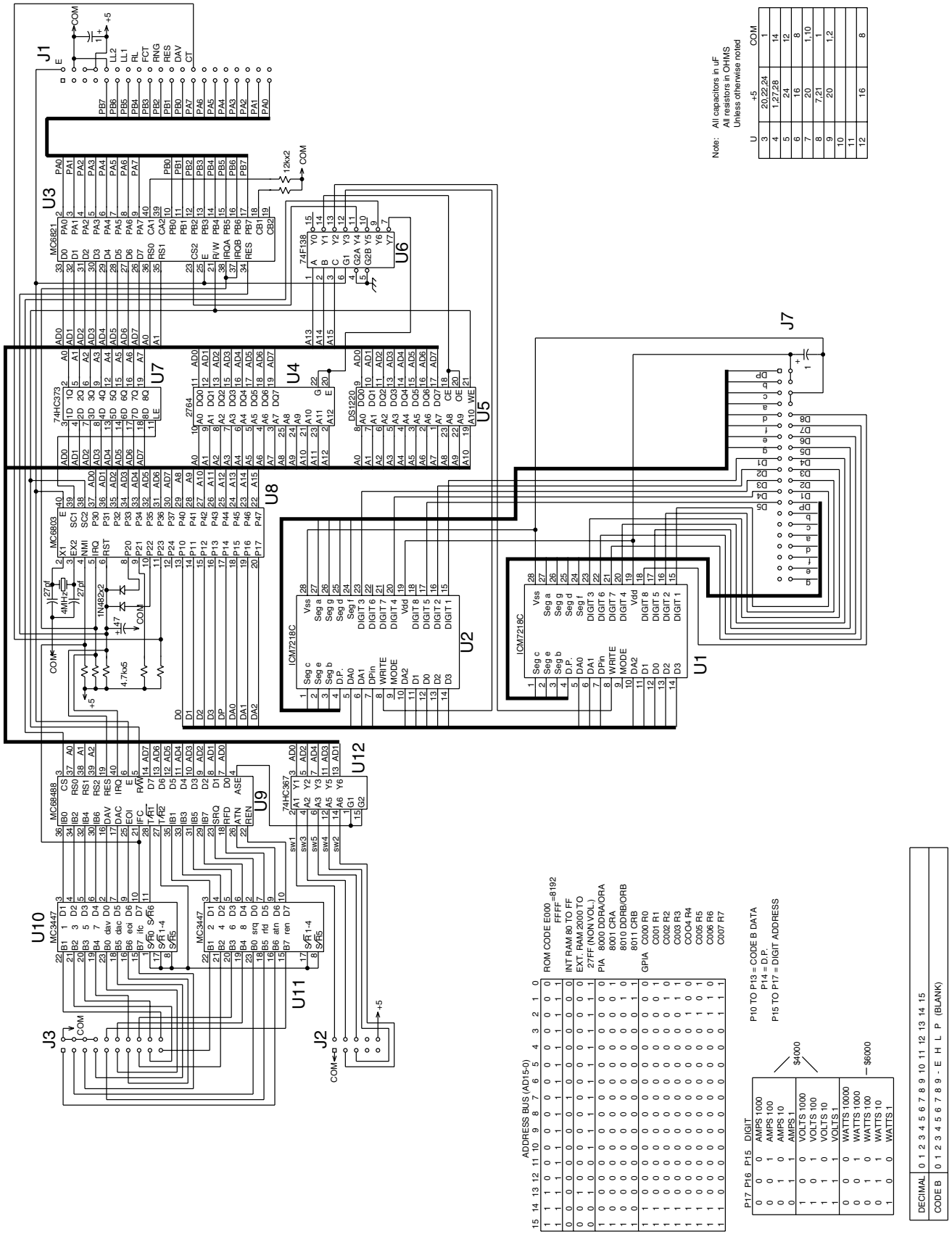


U	+5	COM
1	14	7
2,3,4	20	10

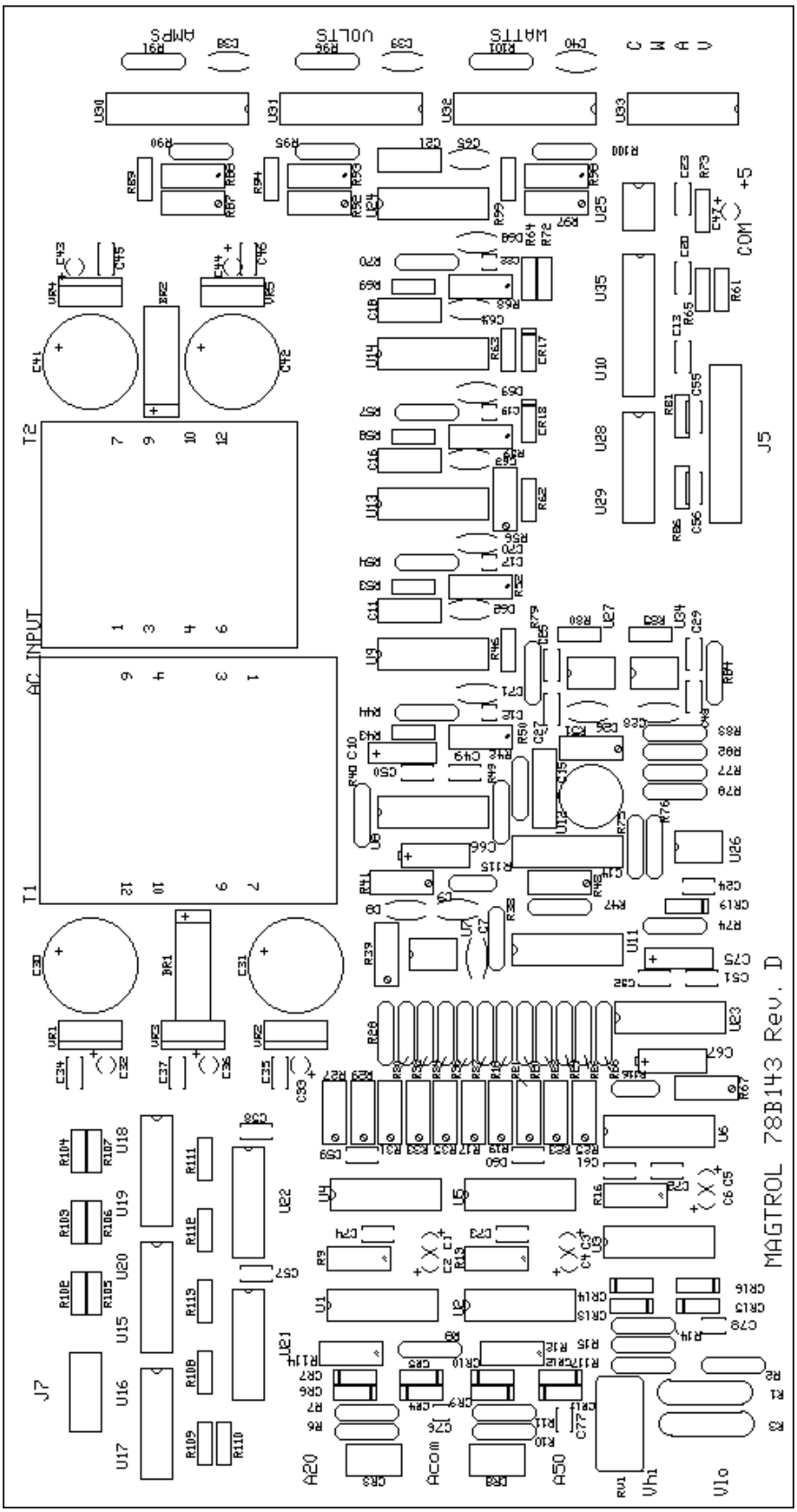
Bypass with .1uF

SW	d	c	b	a
2A	0	0	0	1
5A	0	0	1	0
10A	0	0	1	1
20A	0	1	0	0
50A	0	1	0	1
15V	0	1	1	0
30V	0	1	1	1
150V	1	0	0	0
300V	1	0	0	1
600V	1	0	1	1

CIRCUIT BOARD 78B145 - DIGITAL READOUT & MPU



PARTS LOCATION FOR CIRCUIT BOARD 78B143



Magtrol Limited Warranty

Magtrol, Inc. warrants its products to be free from defects in material and workmanship under normal use and service for a period of one (1) year from the date of shipment. Software is warranted to operate in accordance with its programmed instructions on appropriate Magtrol instruments. This warranty extends only to the original purchaser and shall not apply to fuses, computer media, or any other product which, in Magtrol's sole opinion, has been subject to misuse, alteration, abuse or abnormal conditions of operation or shipping.

Magtrol's obligation under this warranty is limited to repair or replacement of a product which is returned to the factory within the warranty period and is determined, upon examination by Magtrol, to be defective. If Magtrol determines that the defect or malfunction has been caused by misuse, alteration, abuse or abnormal conditions of operation or shipping, Magtrol will repair the product and bill the purchaser for the reasonable cost of repair. If the product is not covered by this warranty, Magtrol will, if requested by purchaser, submit an estimate of the repair costs before work is started.

To obtain repair service under this warranty, purchaser must forward the product (transportation prepaid) and a description of the malfunction to the factory. The instrument shall be repaired at the factory and returned to purchaser, transportation prepaid. **MAGTROL ASSUMES NO RISK FOR IN-TRANSIT DAMAGE.**

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CLAIMS

Immediately upon arrival, purchaser shall check the packing container against the enclosed packing list and shall, within thirty (30) days of arrival, give Magtrol notice of shortages or any nonconformity with the terms of the order. If purchaser fails to give notice, the delivery shall be deemed to conform with the terms of the order.

The purchaser assumes all risk of loss or damage to products upon delivery by Magtrol to the carrier. If a product is damaged in transit, PURCHASER MUST FILE ALL CLAIMS FOR DAMAGE WITH THE CARRIER to obtain compensation. Upon request by purchaser, Magtrol will submit an estimate of the cost to repair shipment damage.

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