MAGTROL

Model 5300

Three Phase Power Analyzer

User's Manual

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Manufacturers of:

Motor Test Equipment
◆
Hysteresis Brakes and Clutches

Trademark Acknowledgments

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1 - Introduction

ABBREVIATIONS

PA - Model 5300 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 5300 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 5300 PA is factory wired for either 120 or 240 Vrms, 50/60 Hz, power at 120 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 5300 PA. The line cord must be detached from the PA during servicing.

NOTE: The standard 5300 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 2 Amp slow blow fuse for 120 Vrms or a 1 Amp slow blow fuse for 240 Vrms power.

SAFETY

Securely ground the 5300 PA case by connecting a good earth ground at the ground stud that is located on the rear panel. Use a number 12 AWG wire, or larger.

CONNECTORS

The following plugs mate with 5300 PA connectors:

Superior Electric Supercon®

INPUT (plug, red, female) - PS100GR

OUTPUT (plug, red, male) - PP100GR

VOLTS HIGH (plug, black, female) - PS25GB

VOLTS LOW (plug, white, female) - PS25GWT

For your convenience, the above connectors are supplied with your 5300 PA.

CAUTION

Use only the above connectors.

NOTE : GPIB (IEEE-488) 24 Pin bus standard cable is not included with the 5300 PA and must be ordered separately.

MAXIMUM RATINGS

LOAD current: 100 Amperes rms, continuous.

200 Amperes rms, 5 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 5300 PA must be mounted within ± 20 degrees from horizontal. This ensures proper operation of the mercury shunt bypass relays.

Electrical Load

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

Hint: Use wire gauge large enough to ensure 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

1. Make sure the circuit is completely de-energized by removing all voltage sources.
2. Plug the 5300 PA into the 50/60 Hz power mains.
3. 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.
4. The VOLTS and AMPERES range switch indicator lights will all illuminate. The voltage ranges will sequence down from 600 through 150, and the current ranges will sequence down from 100 through 5.
5. The 150 Volt and 5 Amp and AUTO indicators remain illuminated. The MODE indicators will not light during this power-on sequencing.
6. Your 5300 PA has passed the initial check.

TRANSIENT OVERLOADS

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

CAUTION

Damage to the 5300 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

There are no fuses in the 5300 PA measuring circuits. Therefore, excessive current passed through the AMPS terminals will cause excessive internal heating and possible unit damage.

CAUTION

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, and 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 5300 (downstream). This will keep the low impedance of the input line connected to the 5300 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

Three DC and AC Ranges:

- 150, 300, and 600 Volts DC and Volts rms.

Remote Voltage Sensing:

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

CURRENT

Three DC and AC Ranges:

- 5, 25 and 100 Amps DC and Amps rms.

METER IMPEDANCE

Voltage, DC or AC:

- 3 Megohm load on each voltage range.

Current, DC or AC Ranges:

- 0.016 Ohm shunt resistance for 5 Amp range.
- 0.003 Ohm shunt resistance for 25 Amp ranges.
- 0.001 Ohm shunt resistance for 100 Amp range.

RESOLUTION

Processing resolution is 16 binary bits.

Voltage Display Resolution:

- 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 Resolution:

- 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 Resolution:

- Better than 0.015 % of the product of the active Voltage and Amperes ranges.

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 - CT/PT Installation* to disable the AUTO ZERO function.

ANALOG OUTPUTS

This is an optional feature.

Analog AMPS, VOLTS and WATTS output signals are DC proportional signals of 5.00 volts at full scale, for each AMPS, VOLTS and WATTS range. Ripple is less than 5 millivolts. The outputs are low impedance operational amplifiers <1 Ohm and <4 milliamperes current capacity. Each monitor signal and the common are electrically isolated from the monitored circuits. Isolation voltage is 750 Volts continuous and 2500 Volts test breakdown. Leakage current is less than 0.3 micro Amps at 240 Vrms, 60 Hz. Vrms

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 + 0.5% of range)
CURRENT - DC	**25 and 100 Amp Ranges**
	± (0.1% of reading + 0.2% of range)
CURRENT - AC:	**5 Amp Range**
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 + 1.0% of range)
10 kHz to 20 kHz	± (2.0% of reading + 2.0% of range)
	25 Amp Range
10 Hz to < 5 kHz	same as 5 Amp range
5 kHz to 10 kHz	± (2.0% of reading + 2.0% of range)
	100 Amp Range
10 Hz to < 1 kHz	± 0.5% of rng
1 kHz to 2 kHz	± (2.0% of reading + 2.0% of range)
POWER - DC	± (0.1% of reading + 0.2% of VA range)
POWER - AC	± [(0.1% of reading + 0.2% of (Amps range × Volts range)]
POWER FACTOR	± (VA error ± W error)
CREST FACTOR	Exceeds 3:1 (at 50% of range full scale)
TEMPERATURE COEFFICIENT	± 0.01% of range per deg. C maximum
DISPLAY	Digital display error ± 1 LSB.

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 5300

C A U T I O N

Always install a properly rated circuit breaker or fuse between the 5300 analyzer and the load. Also, make sure that your power source has its own fast-acting disconnect and overload protection. *See "Current Overload" in Chapter 1 - Introduction.* 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 equivalent transient suppressors connected between lines at the load (across the load). These suppressors are an absolute necessity when inductive loads are used. In 3-phase systems, each load must have a suppressor. See Figure 1 below.

CONNECTORS

Use the supplied Supercon® connectors.

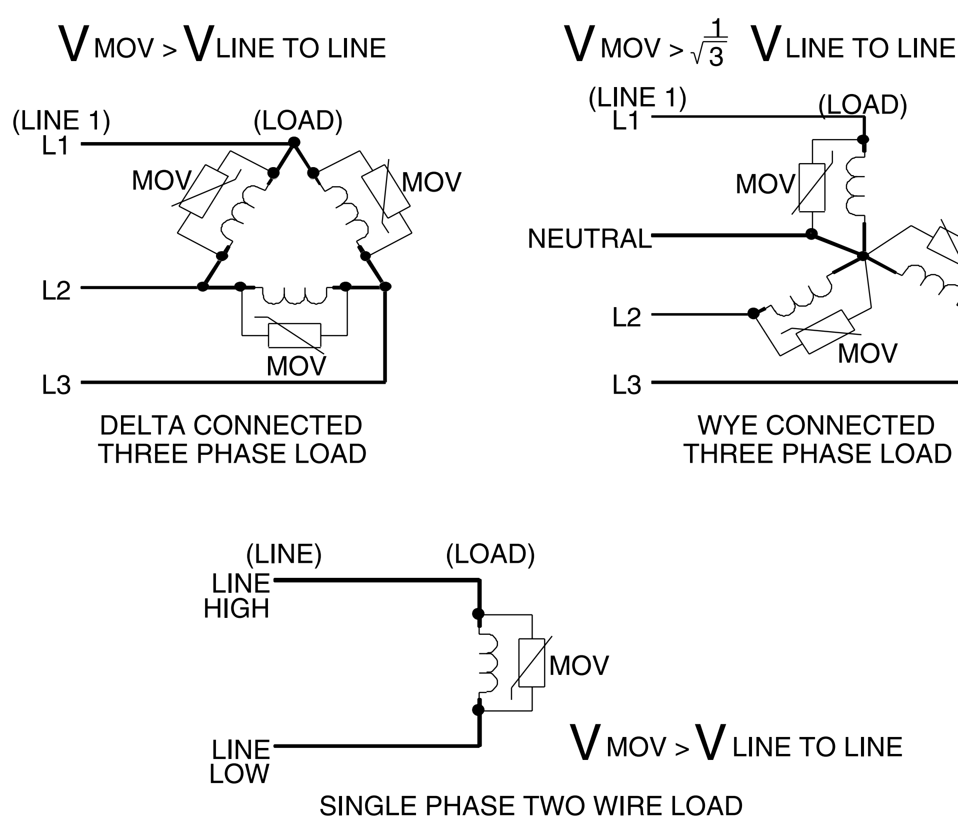
Amps

INPUT - PLUG, RED, FEMALE-(PS100GR)
OUTPUT - PLUG, RED, MALE-(PP100GR)

Volts

HIGH - PLUG, BLACK, FEMALE-(PS25GB)
LOW - PLUG, WHITE, FEMALE-(PS25GWT)
SINGLE PHASE AC or DC CONNECTIONS

Figure 1. Transient Voltage Suppression



SINGLE PHASE AC OR DC CONNECTIONS

See figure 2.

NOTE: Connections are shown grouped in cables.

This diagram shows the phase 1 ($Ø_1$) voltage and current inputs connected for measurement. However, any of the 3-phase inputs can be used. The unused two inputs are jumpered to insure zero inputs.

Power in watts is calculated as follows:

$P = E \times I \times \cos q$

(where q is the phase angle between E and I)

On the 5300, select DISPLAY - $Ø_1$ and MODE -PH. V.

The 5300 displays VOLTS, AMPS and WATTS.

This circuit uses the 5300 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. The voltage sense lines are connected at the line side of CB to help prevent inductive transients from entering the PA as the CB opens. Make sure that connections from CB to the load are heavy conductors and short as possible.

CAUTION

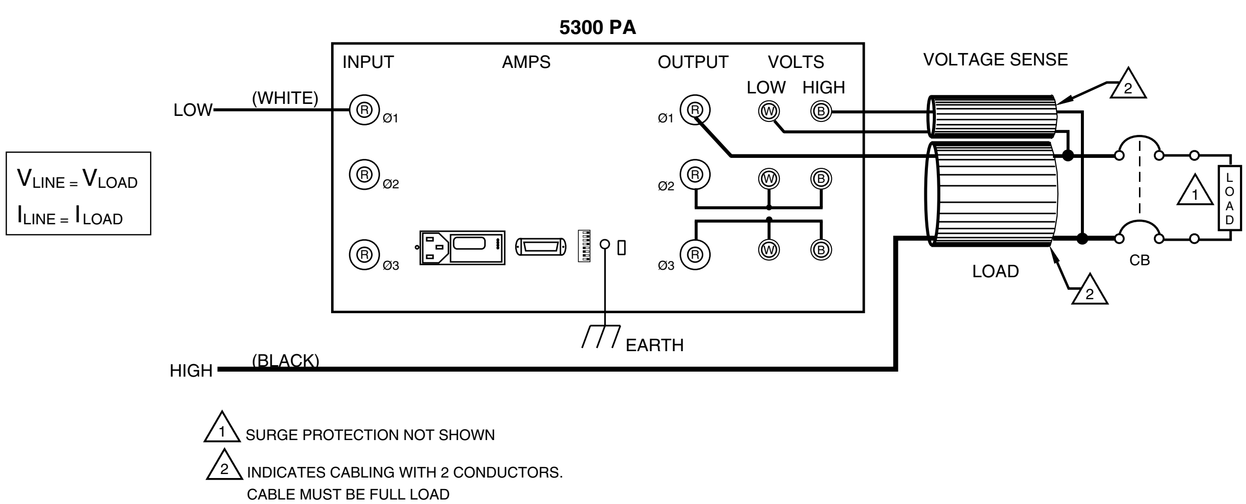
If a circuit breaker is used in the input line to the 5300 PA, a circuit should be used that prevents the breaker from opening until after the load side breaker has opened. Otherwise, potentially damaging inductive transients can be applied to the 5300 PA. Damage caused by these transients are outside 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 5300 PA GND terminal. If the wires connecting the load to the 5300 PA OUTPUT are short and the resulting voltage drop is insignificant, the voltage sense connections can be made at the rear panel of the 5300 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 Connections



3-PHASE 3-WIRE DELTA CONNECTIONS

The power dissipated in each phase ($P_Ø$) is equal to the product of phase voltage (E_{phase}), phase current (I_{phase}) and cosine of the phase angle θ between the phase voltage and phase current:

$$P_Ø = E_{phase} \times I_{phase} \times \cos\theta$$

Each phase power is displayed on the 5300 PA by selecting DISPLAY - $Ø_1$,$Ø_2$ or $Ø_3$ push switch. Total power consumed by the load is the algebraic sum of the 3-phases power measurements:

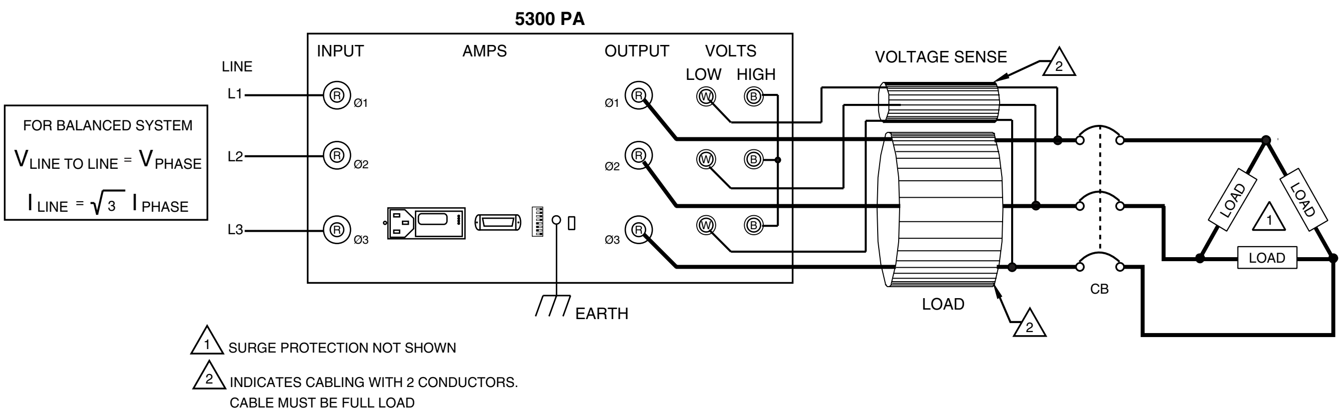
$$P_{TOTAL} = P_{Ø1} + P_{Ø2} + P_{Ø3}$$

The total power is displayed on the 5300 PA by selecting the DISPLAY - ΣK_W push switch.

$$P_{TOTAL} = \Sigma K_W$$

Also, the general discussion for Figure 1 (surge protection) and Figure 2 (single phase AC & DC connection) apply.

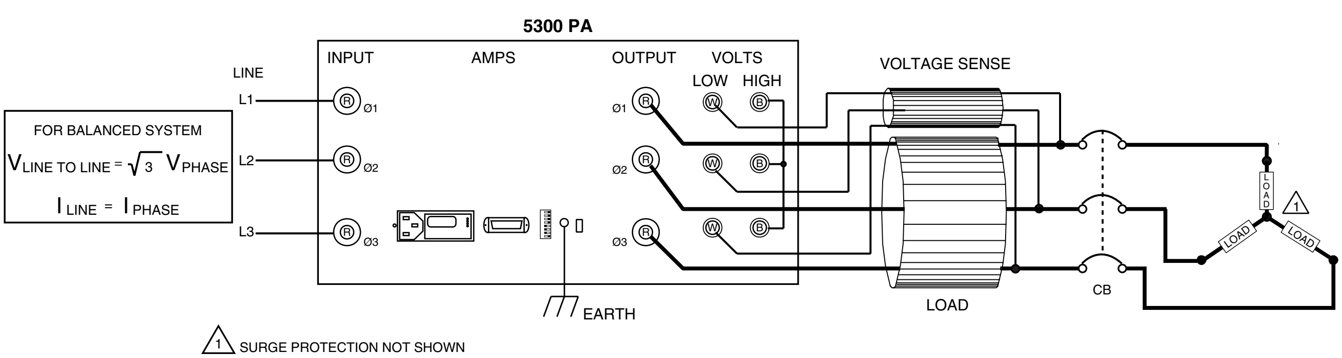
Figure 3. 3-Phase 3-Wire Delta Connections



3-PHASE, 3-WIRE WYE CONNECTIONS

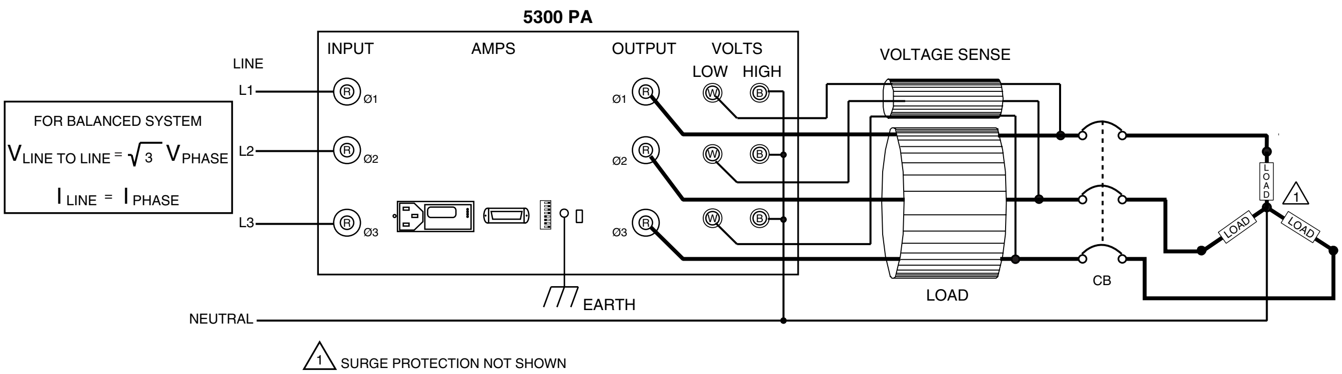
Power conversion formulas for the 3-phase WYE connection are the same as for the DELTA connection as described above. Each phase power is displayed on the 5300 PA by selecting the DISPLAY - $Ø_1$,$Ø_2$ or $Ø_3$ push switch. The total power is displayed on the 5300 PA by selecting DISPLAY - ΣK_W push switch. Also, the general discussion for Figure 1 (surge protection) and Figure 2 (single phase & DC connection) apply.

Figure 4. 3-phase, 3-Wire WYE Connections



3-PHASE, 4-WIRE WYE CONNECTIONS

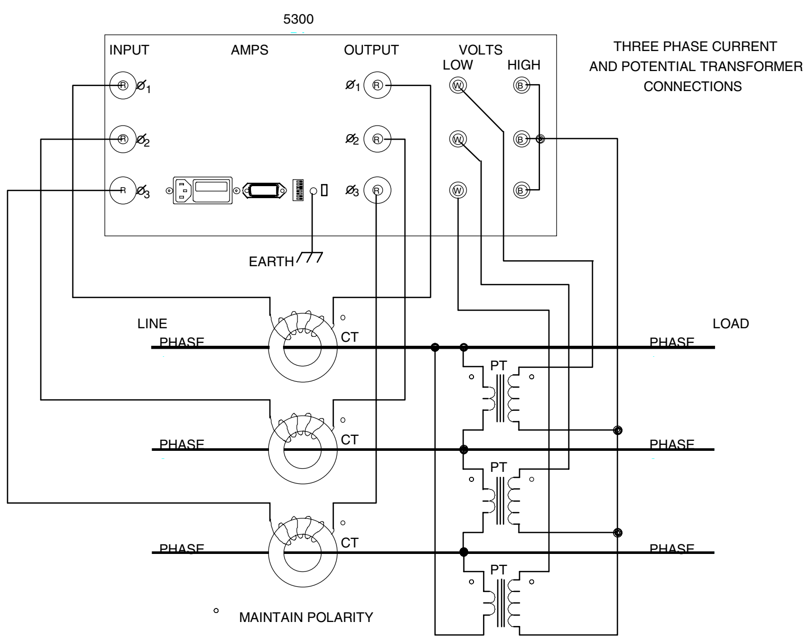
Figure 5. 3-Phase, 4-Wire WYE Connections



Power conversion formulas for the 3-phase 4-wire WYE connection are the same as for the DELTA connection, above. Each phase power is displayed on the 5300 PA by selecting the DISPLAY - $Ø_1$,$Ø_2$ or $Ø_3$ push switch. The total power is displayed on the 5300 PA by selecting DISPLAY - ΣK_W push switch. Also, the general discussion for Figure 1 (surge protection) and Figure 2 (single phase & DC connection) apply.

3-PHASE, CURRENT AND POTENTIAL TRANSFORMER CONNECTIONS

Figure 6. 3-Phase, Current and Potential Transformer Connections



Voltage and current measurement ranges can be extended by using current and potential transformers. Frequency response of the measurements will be determined by the characteristics of the transformers used. The current transformer (CT) and the potential transformer (PT) are shown located near the 5300 PA. The line voltage drop can be eliminated from the power calculations by connecting the PT at the load.

Also, the general discussion from Figure 1 (surge protection) and Figure 2 (single phase & DC connection) apply. See Section 5, CT/PT Installation for more information.

Read Section 1 and make sure unit is connected properly (see Section 3) before proceeding.

GENERAL

1. Using Sections 1 and 3 as a guide, connect the 5300. Before connecting the power mains, double check all connections (an Ohmmeter is helpful).
   Verify that the overcurrent circuit breaker is open and connect the power mains.
2. Observing the 5300 front panel indicators, turn the 5300 power switch ON and confirm proper operation - see "Initial Checkout" in Section 1 - Introduction.
3. 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 5300 has:

- Four MODES - HOLD; AVG (averaging), PF (Power factor) and PH. V. (phase voltage)
- Three AMPS ranges plus AUTO (auto ranging)
- Four DISPLAY selections -Ø1, Ø2, Ø3, (phases 1 through 3) and ΣK_W (sum of kilowatts)
- Three VOLTS ranges plus AUTO.

All have adjacent red LEDs indicating the active mode or measurement range.

AMPERES DISPLAY

The AMPS display is a four digit, unsigned floating point display of true AC rms or DC current flowing into the AMPS INPUT connector (red) on the rear panel. For detailed information see Section 2, Specifications.

The 5300 defaults to AUTO (auto ranging) at DISPLAY power turn on. AUTO up-ranging occurs if the rms current exceeds the top of the range value plus about 5 %. AUTO down ranging occurs when the current is just less than the full range value of the next lower range.

Selection of any amps range push-button activates the selected range by overriding the AUTO- range selection - the 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 105% of the range full scale. If the current falls below the value of the selected range, that range will then reactivate. 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 maximum rating is exceeded.

VOLTAGE DISPLAY

The VOLTS display is a four digit, unsigned floating point display of AC rms or DC voltage difference 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 (PF) as a decimal number. WATTS is the power ON default MODE. Press the MODE - PF button to measure POWER FACTOR.

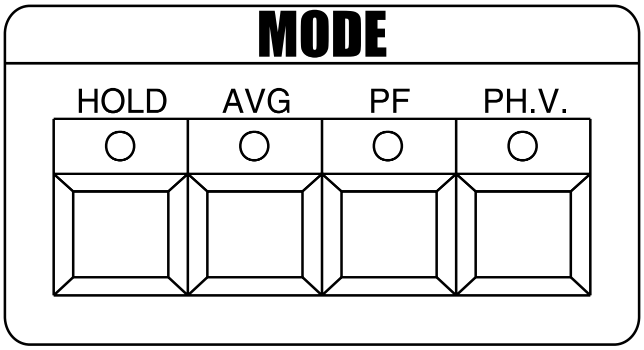
Watts measurements are from about 100 milliwatts (auto zero off) through 60 kilowatts, and Power Factors from 0.0001 through 0.9999. WATTS = V * I * cos * = TRUE POWER The WATTS range is set by the AMPS and VOLTS active ranges.

Power Factor is:

$$PF = \frac{V \times I \times \cos\theta}{V \times I} = \frac{POWER_{TRUE}}{POWER_{APPARENT}}$$

MODE SELECTIONS

Figure 7. Mode Selections



MODE HOLD

The HOLD push-button may be depressed at any time. When depressed, the displayed values are held and data accumulation stops. 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 held. The HOLD and AVG functions can be combined to provide added functions.

MODE AVG

The AVG MODE is an integration or averaging function for the display of VOLTS , AMPS and WATTS. The VOLTS, AMPS and WATTS data are sampled at 10 readings per second and a running average is computed by dividing the summed values of each parameter by the total number of summations. When averaging is turned off, the VOLTS, AMPS and WATTS data, their summations, and the sample count are stored in non-volatile RAM memory. 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 to stabilize the displayed values.

The HOLD and AVG functions can work together. When entering AVG with HOLD off, the averaging registers are cleared and integration starts from a zero value. With the HOLD function active first, pressing AVG starts the integration point from the last RAM stored values of AMPS, VOLTS or WATTS. The HOLD automatically resets off.

When AVG is turned off, non-averaged values are displayed and the averaged values are then stored in non-volatile RAM memory. Upon re-entering the AVG mode, the stored values will be returned as the new averaging starting points. This function allows you to exit the AVG mode, perform some other task, then return and continue averaging where you left off. Also, it can be used simply to retain and recall data.

While in AVG mode and the PA power is turned off, the last averaged values stored will be held in non-volatile RAM and returned to the display when the PA power is turned on and the AVG mode 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: WATT-HOURS can be determined by using the AVG function and a timing clock.

Watt-hours = (watts avg × time in hours).

NOTE: Power Factor (PF) can not be averaged.

MODE POWER FACTOR (PF)

Pressing the PF (power factor) push switch displays the power factor on the WATTS display. Power factor is computed by:

$$PF = \frac{P_{\phi 1} + P_{\phi 2} + P_{\phi 3}}{V_{\phi 1} I_{\phi 1} + V_{\phi 2} I_{\phi 2} + V_{\phi 3} I_{\phi 3}}$$

AVG mode is not active while in PF mode

MODE PH. V.

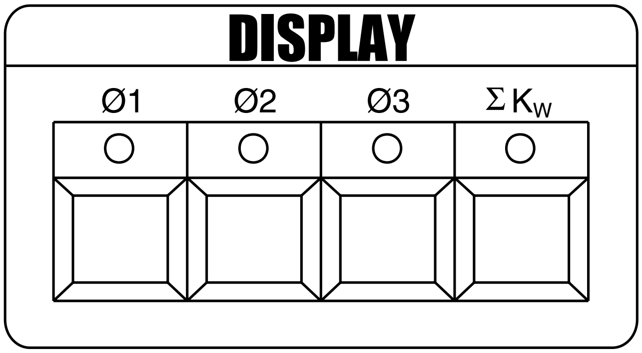
Pressing the PH. V push switch modifies the phase VOLTS measurement to indicate line to line voltage on the display by applying:

$$E_{LINE} = E_{PHASE} \times \sqrt{3}$$

This relation is valid for a balanced system. For an unbalanced system, there can be a difference between the displayed voltage and the true line to line value.

DISPLAY SELECTIONS

Figure 8. Display Selections



DISPLAY Ø1, Ø2, Ø3

Individually selects Phase 1, Phase 2 or Phase 3 WATTS for display.

If all three push-buttons are simultaneously pressed, the four LEDs illuminate, indicating that the AMPS display reads the SUM of the three phase currents, the VOLTS reads the AVERAGE of the three phase voltages and the WATTS reads SUM of the three phase powers, as follows:

$$AMPERES = I_{\phi 1} + I_{\phi 2} + I_{\phi 3} \quad \text{(SUM)}$$

$$VOLTS = \frac{V_{\phi 1} + V_{\phi 2} + V_{\phi 3}}{3} \quad \text{(AVERAGE)}$$

$$KILOWATTS = \frac{W_{\phi 1} + W_{\phi 2} + W_{\phi 3}}{1000} \quad \text{(SUM)}$$

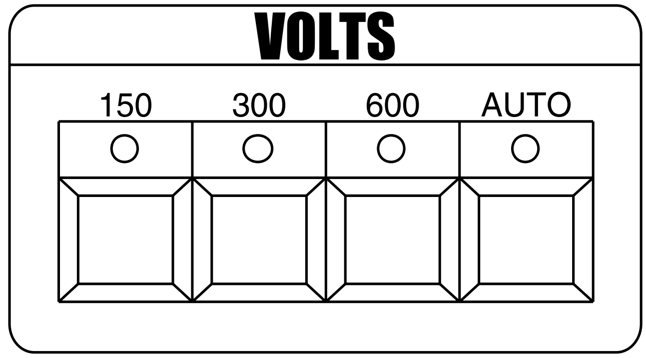
DISPLAY ΣKW

The WATTS display indicated the total 3-phase power in kilowatts.

$$KW = \frac{W_{\phi 1} + W_{\phi 2} + W_{\phi 3}}{1000} \quad \text{(SUM)}$$

VOLTAGE RANGES

Figure 9. Voltage Range Selections



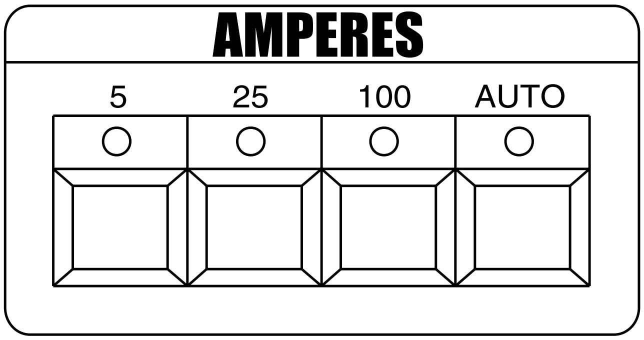
150, 300 and 600 volts rms plus AUTO range. At power turn on, the 150 volt range and AUTO (auto-ranging) are active, by default. Up ranging occurs when the measured voltage on any phase exceeds that range maximum voltage by 5% (>105%). This feature is active in either AUTO (LED on) or manual (LED off). Automatic down ranging occurs only in AUTO when the measured voltage falls to about 1/4% below that range maximum value.

If MODE PH. V. is off, up ranging occurs at 105% of the range times $\sqrt{3}$.

The PA up-ranging feature protects the instrument from overload and ensures accurate measurements. Exceeding the PA maximum voltage of 600 volts causes the instrument to display "HELP." This means that you must reduce your input voltage.

AMPERES RANGE

Figure 10. Current Range Selections



5, 25 and 100 Amperes rms plus AUTO range: At power turn on, the 5 Amps range and AUTO (auto ranging) are active, by default. Up ranging occurs when the measured current on any phase exceeds that range maximum current by 5% (>105%). This feature is active in either AUTO (LED on) or manual (LED off). Automatic down ranging occurs only in AUTO when the measured current falls to about ¼% below that range's maximum value.

The PA up-ranging feature protects the instrument from overload and ensures accurate measurements. Exceeding the PA maximum current of 100 Amps on any phase causes the instrument to display "HELP." This means that you must reduce your input current until the normal display reappears.

ANALOG OUTPUT OPTION

This option provides analog output signals for AMPS, VOLTS and WATTS.

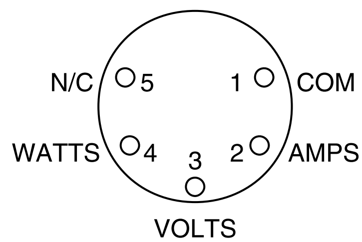
These three analog outputs with their common are isolated from the measured circuits at 750 Volts continuous breakdown.

The outputs are provided through a standard 5 pin DIN style connector located on the rear panel of the 5300 - see figure 11 for connections. The analog output voltage is 5.00 volts at each AMPS, VOLTS or WATTS range maximum value.

See Section 2 - Specifications.

NOTE: Analog output of POWER FACTOR is not provided

Figure 11. Analog Output Connections



5 - CT/PT Installation

External current and potential transformers can be used to extend the measuring ranges of the PA. See Section 4, Figure 6 for a connection diagram.

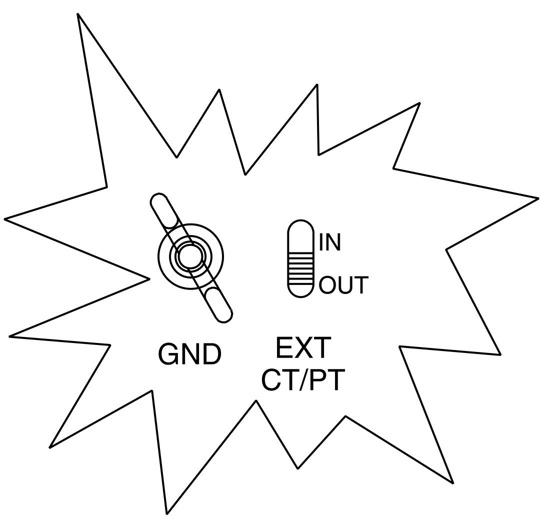
CALIBRATION

The 5300 has special provisions allowing entry of transformer ratios into the non-volatile RAM via the GPIB (IEEE-488) rear panel input. The PA display then includes the transformer ratios and reads actual current, voltage and power directly.

CT/PT DETECTION

At power turn on initialization, the MPU interrogates that portion of memory where the CT and PT compensation values reside. If a value is found, the MPU looks to see if the rear panel CT/PT slide switch (see Figure 12) is set to the "IN" position (to include the transformer ratios). If it is, normal calibration factors are revised by applying the transformer factors. The displays indicate actual load values.

Figure 12. Current & Potential Transformer Selections



Since the above interrogation and scale factor setup occurs only at power turn on, the scale factors are active until power is turned off, the CP/PT switch turned to "OUT" and power turned "ON." The CP/PT factors are now removed and the standard factory calibration factors become active.

CT/PT RATIO RANGE

The 5300 PA compensates all display values for transformer ratios from 0.01 to 255.

DIGITAL RANGE

The digital display holds four digits for AMPS and VOLTS, and five digits for WATTS or KW. When a value exceeds these limits, the decimal point is turned off. This is a warning that the compensated value is above the display capability and is in error. If this should occur during GPIB use, an exclamation mark is substituted immediately to the right of the least significant digit (i.e. !=ASCII033) to signal that there is an unknown magnitude.

GPIB-CT/PT PROGRAMMING

The 5300 PA accepts either upper or lower case characters, and whole numbers in any numerical format.

For CT installation: CTnnncl

For PT installation: PTnnncl

Where: nnn=0.01 to 255.

("cl" denotes a carriage return/line feed termination character.)

For example:

A CT with 250:1 ratio is: CT250.cl

A PT with 10:1 ratio is: PT10.0ct

The PA will ignore any value outside of the range of 0.01 to 255. If an out of range entry is attempted, the display will warn by showing "HELP." Correct and re-enter your factor.

CHANGING OR REMOVING CT/PT VALUES

To modify a value, simply overwrite the existing value(s).

To remove a CT or PT value, output a CT(cl) or PT(cl), only.

To remove both, and save the data, switch the rear panel slide switch to "OUT," and toggle the power OFF then ON.

If you remove both the CT and PT value correction factors by GPIB instructions, the PA will automatically reset, eliminating the need to cycle power OFF/ON.

NOTE: When removing transformer conversion factors and measuring without CT(s) or PT(s), set the rear panel CT/PT switch to the "OUT" position.

6 - GPIB Communication

GPIB (IEEE-488)

The IEEE-488 or GPIB (General Purpose Interface Bus) provides direct connection and control of the 5300 from any appropriately equipped computer for the purpose of data acquisition and display. MAGTROL factory assistance is available if required.

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 PCs.

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 5300 uses the Hewlett Packard - HPIB™ standard ASCII termination characters "Carriage Return (CR) and Line Feed (LF)," in that order. On a read cycle, the 5300 looks for the CR-LF to signal completion of an instruction and transmits these characters upon conclusion of a data write cycle.

PRIMARY ADDRESS

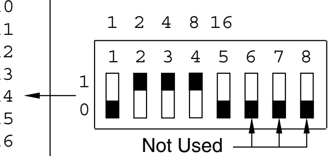
All instruments serviced on the bus have a separate primary address code. The factory setting for the 5300 is fourteen (14). This code can be changed by changing the settings of the DIP switch that are located on the rear panel next to the GPIB connector. Change this address only if there is a bus addressing conflict with other instrumentation. Refer to the table in Figure 13 to set the DIP switch pattern - set to address 14.

Some PC interfaces (National GPIB-PC2A) will access 0 to 15 (4 bit) primary address numbers only. Other interfaces may access up to 31 (5 bit code). The 5300 PA code range uses the 5 bit code format. Before selecting a value greater than 15, check that your particular interface has the 5 bit code capability.

Figure 13. GPIB Address Selection

(Address 14 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



PC TO 5300 PA

A5, A25, A100	AMPERES RANGE selection.
V150, V300, V600	VOLTAGE RANGE selection.
AA	AMPS AUTO range ON.
VA	VOLTS AUTO range ON.
FULL	Sets data FORMAT to AMPS, VOLTS, WATTS for 3 phases. See 5300 PA TO PC.
SGL	Sets data output format = to front panel display. See 5300 PA to PC.
SYNC	GPIB data output rate is synchronized to 0.10 sec. bus output rate. See DATA RATE.
OPEN	Data OUTPUT is transmitted upon request. See OPEN INSTRUCTION.
SP1, SP2, SP3	Selects PHASE 1, 2, or 3.
SPA	Selects ALL PHASES (same as pressing Ø1, Ø2 and Ø3 simultaneously).
LV	Select to read LINE VOLTAGE.
PV	Select to read each PHASE VOLTAGE.
KW	select to read KILOWATTS
W	Select to read PHASE WATTS.
P	Select to read POWER FACTOR.
I, IC	Averaging ON, Averaging OFF.
H, HC	HOLD ON, HOLD OFF.
L, LC	LOCKOUT, and LOCKOUT CLEAR of all front panel push switches.
AZ	Cancel of AUTO ZERO function.
CT, PT	CANCEL, or ENTER data for current or potential transformer calibration.
RES	Soft RESET of PA (same as power on).

In addition to the standard instructions listed in the table on the left, there are special instructions for reading and writing directly to the PA memory elements.

A specific program running in the host computer is necessary. If you have a special situation where you want direct memory access to alter 5300 PA functions or change calibration, please contact Magtrol for software assistance.

5300 PA TO PC

There are two choices for VOLTS, AMPS and WATTS data format. Before you execute a read statement, it is necessary to instruct the PA as to which data format you wish to receive. This selection is retained by the PA and becomes the default mode used for subsequent data transmissions.

"SGL" INSTRUCTION

Sets the data format to a string length of 24 ASCII characters, including carriage return and line feed combination (••).

A=nn.nnV=nnn.nW=nnnn.n••

n (as shown) is any integer number 0 through 9
V (as shown) is volts
W (as shown) is watts
P is power factor
K is kilowatts
•• is carriage return and line feed combination

NOTE: Use leading zeros to maintain a fixed string length.

"FULL" INSTRUCTION

Data for all 3-phases is supplied. The string is 68 contiguous ASCII characters:

A=xx.xxV=xxx.xW=xxxx.xA=yy.yyV=yyy.yW=yyyy.yA=zz.zzV=zzz.zW=zzzz.z••

x is an integer number 0 through 9 for phase 1.
y is an integer number 0 through 9 for phase 2.
z is an integer number 0 through 9 for phase 3.

This string transmits volts, watts and amps. To get line voltage, power factor (PF) or kilowatts (KW), the host computer must make the following calculations:

$$PF = \frac{W_{\varnothing 1} + W_{\varnothing 2} + W_{\varnothing 3}}{E_{\varnothing 1} I_{\varnothing 1} + E_{\varnothing 2} I_{\varnothing 2} + E_{\varnothing 3} I_{\varnothing 3}}$$

$$E_{LINE\,(n)} = E_{PHASE\,(n)} \sqrt{3}$$

(Where “n” is the phase number)

$$KW = \frac{W_{\phi 1} + W_{\phi 2} + W_{\phi 3}}{1000}$$

DATA RATE

The OPEN and SYNC commands affect bus timing. Selection is dependent upon what other instruments are on the bus, their acquisition rate, and how you wish to process the data.

“OPEN” INSTRUCTION

If your data acquisition is random, or you don't want to wait for the full 0.1 second data sampling rate, you can use the OPEN instruction. Data output is nearly immediate, depending upon the MPU status at the time of request. If multiple data

requests are made within the MPU's 0.1 second sample rate, you will receive multiple transmissions of the same data. If your program is accumulating data in an array, you will want to include a routine to ignore the second of any two identical received data words.

INSTRUCTION

The host PC will be held by the 5300 PA until the sampling period is over. In this mode, data will always be the result of the most recent sampling period. However, if you are using a Magtrol controller like the Model 4629B or 5240, the two instruments should be synchronized to avoid a timing conflict. This synchronization is done as follows:

Output any instruction (except "RES") to each of the instruments without including the combination carriage return/line feed (oo) terminating instruction. Now, both instruments are "hung up" at fixed program locations waiting for the carriage return/line feed instruction. Synchronization is accomplished by restarting both programs by outputting only the carriage return/line feed instruction (oo) in successive statements to both instruments.

At restarting, the instrument will be synchronized, but will slowly drift apart and require re-synchronization. If you are acquiring data in batches, execute the above synchronization routine just prior to each data input routine.

PROGRAMMING EXAMPLE

The following program sets the 5300 PA in the "SYNC" mode with "FULL" data format. The CRT monitor displays:

Amperes - summed for total 3-phase line.

Voltage - average 3-phase line.

Power - 3-phase kilowatts.

This example (on the following page) assumes that the National GPI-PC interface hardware and Microsoft Quick Basic are used.

```
'Read 5300 PA full data - Magtrol Inc., 91 rt
'Primary address set to 14
    Bdname$ = "DEV14"
    CALL IBFIND(Bdname$, bd%)      'initialize GPIB
    cl$ = CHR$(13) + CHR$(10)      'assign carriage return and line feed.
    CLS

'Set PA for "FULL" data
    wrt$ = "FULL" + cl$
    CALL ibwrt(bd%, wrt$)

'Set PA for "SYNC" transfer timing.
    wrt$ = "SYNC" + cl$
    CALL ibdwrt(bd%, wrt$)

'Assign input word length.
    rd$ = SPACE$(68)

    LOCATE 20,50: PRINT "Any key ends..."

DO: s$ = UCASE$(INKEY$)      'Loop starts here.
    CALL IBRD(bd%, rd$)

'Amps - convert from string to numeric and sum.
    ap1$ = MID$(rd$, 3, 5)        'Extract Phase 1 amps.
    ap2$ = MID$(rd$, 25, 5)       'phase 2.
    ap3$ = MID$(rd$, 47, 5)       'phase 3.
    amps = VAL(ap1$) + VAL(ap2$) + VAL(ap3$)

'Volts, conv' numeric, average, and conv' from phase to line voltage.
    vp1$ = MID$(rd$, 10, 5)       'extract phase 1 volts.
    vp2$ = MID$(rd$, 32, 5)       'phase 2.
    vp2$ = MID$(rd$, 54, 5)       'phase 3.
    volts = (VAL(vp1$) + VAL(vp2$) + VAL(vp3$) * .57735 ' = |3/3

'Power, convert to numeric, sum and convert to KW.
    wp1$ = MID$(rd$, 17, 6)       'extract phase 1 watts.
    wp2$ = MID$(rd$, 39, 6)       'phase 2 watts.
    wp3$ = MID$(rd$, 61, 6)       'phase 3 watts.
    Kw = (VAL(wp1$) + VAL(wp2$) + VAL(wp3$)) / 1000

    LOCATE 12, 10: PRINT "Line Volts = ";
    PRINT USING "###.#"; volts
    LOCATE 13, 10: PRINT "Amperes = ";
    PRINT USING "###.#"; amps
    LOCATE 14,10: PRINT "3-phase KW = "; Kw
  LOOP WHILE s$ = ""

END
```

8 - Operating Principles

The Magtrol 5300 PA uses the three wattmeter method to measure true RMS power. Voltage and current are sensed and amplified in an isolated analog front end, analog to digital converted with 16 bit precision, processed through an 8 bit microprocessor (MPU) and output in BCD form for display on the front panel meters. The PA provides a digital display for each selected phase of rms volts, amps, and watts; average rms volts, amps and watts; and total load power factor (PF).

AMPERES TRANSDUCING

Current measuring is accomplished using a three section calibrated manganin resistance shunt per phase. The 5, 25 and 100 amp sections are 0.016 Ohm (80 mV), 0.003 Ohm (75 mV) and 0.001 Ohm (100 mV), respectively. See Figure 14.

The current flow through each shunt is determined by measuring the voltage drop across the shunt and the MPU, applying Ohm's Law. Current ranges are set by the MPU and energize the appropriate shunt bypass relays CR1 and CR2. The 5 amp range energizes (opens N/C contacts) of both CR1 and CR2; the 25 Amp. range energizes CR1, and both relays remain de-energized for the 100 Amp range. The CRs are very low resistance, high current mercury wetted relay contacts that bypass unused sections of the metering shunts.

VOLTAGE SENSING

Each VOLTS input terminal connects a 1.5 Megohm resistive voltage divider to provide scaled phase voltage for measurements. The three 1.5 Megohm resistors form a classic "Y Box" neutral. The resulting phase voltage signals are amplified and scaled for processing. See Figure 14.

NOTE: Connecting the Voltage Sense leads incorrectly (e.g. connecting the voltage sense from phase 1 to phase 2 current lines) will cause the Watts display to show an incorrect value. If you are experiencing poor readings, shut down the system and carefully review your connections.

ANALOG PROCESSING

Input signals proportional to AMPS and VOLTS are amplified and calibrated for each range by amplifiers 78B146-U7, U8, U9 and U10. These scaled signals pass through true rms to DC converters 78B147-U1 & U4, voltage to frequency converters 78B147-U2 & U5 and optical isolators 78B147-U3 & U6. The resulting frequency signals represent true rms current and voltage (AF_0 and VF_0,) scaled to 0.0707 volts per 1.0 kilohertz.

Figure 14. 5300 Current Shunt Inputs

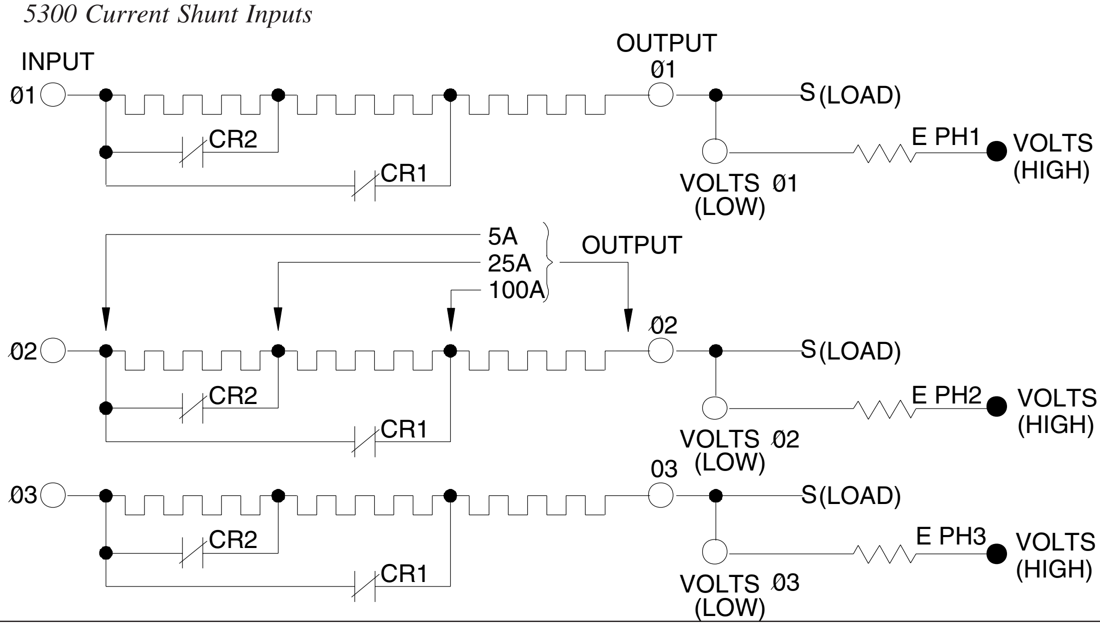
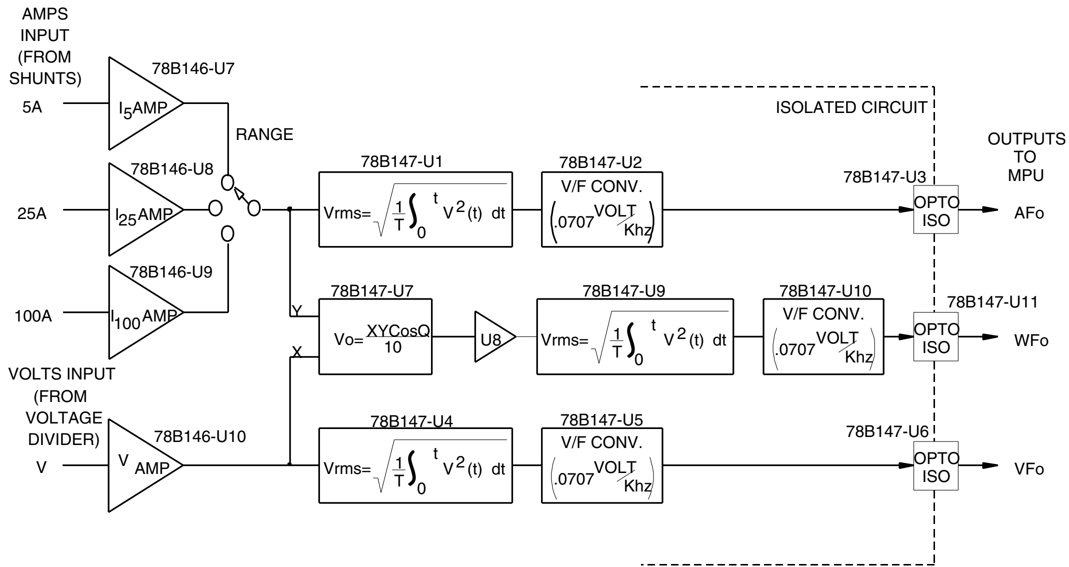


Figure 15. 5300 Block Diagram



Also, the AMPS and VOLTS signals are input to a precision four quadrant X-Y multiplier 78B147-U7, averaged by an active two pole Butterworth filter 78B147-U8, converted to frequency in voltage to frequency converter 78B147-U10 and isolated by optical coupler 78B147-U11. The resulting frequency signal, WF_0 represents true power ($V \times I \times \cos\theta$), at a scale factor of. 0.0707 volts per 1.0 kilohertz. There is 2500 volts isolation between the measured circuit and the AF_0, VF_0 and WF_0 frequency signals.

DIGITAL PROCESSING

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

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 push-button control inputs 25 times per second. When a push-button is pressed, the appropriate program loop is entered and the function is executed on the next program cycle. No damage will result to the 5300 PA from any combination of push-button selections.

In the AVG MODE (averaging), the 5300 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 as the power consumption changes.

DISPLAY "HELP"

If the AMPS or VOLTS displays show the word HELP, the maximum peak range of the 5300 PA has been exceeded. This can occur from a high rms input or the peak of a high crest factor wave form. "HELP" can be a transient condition resulting from high momentary starting current and is of no danger if the "HELP" message disappears after a few seconds. The Auto up-ranging feature of the 5300 will automatically up range the instrument as the current or voltage increases over each ranges maximum, up to the 100 amps range. The 5300 can sustain an overload of up to 200 amps for 5 seconds, maximum. Circuit breaker(s) should be installed for personal safety and protection of the 5300 PA. See "Current Overload." in Section 1 - Introduction.

POLYPHASE LINE BALANCE

Good polyphase line operating efficiency dictates that line voltages and currents be closely balanced. Usually, this requires putting some effort into balancing the loads. Also, power factor (PF) measurements will be inaccurate unless a good line balance is maintained.

GENERAL

Complete calibration of the 5300 PA is beyond the capabilities of most users. Magtrol, Inc. recommends that the 5300 PA be returned to the factory for calibration certifying the instrument to full specifications.

However, this section includes Calibration Accuracy Verification procedures and steps to make minor trim-ups of calibration.

NOTE: To perform these steps, the factory calibration seal will be broken. This voids the factory Calibration Certification that comes with the 5300 PA.

TEST SETUP

The recommended test setup for each phase is shown in Figure 16.

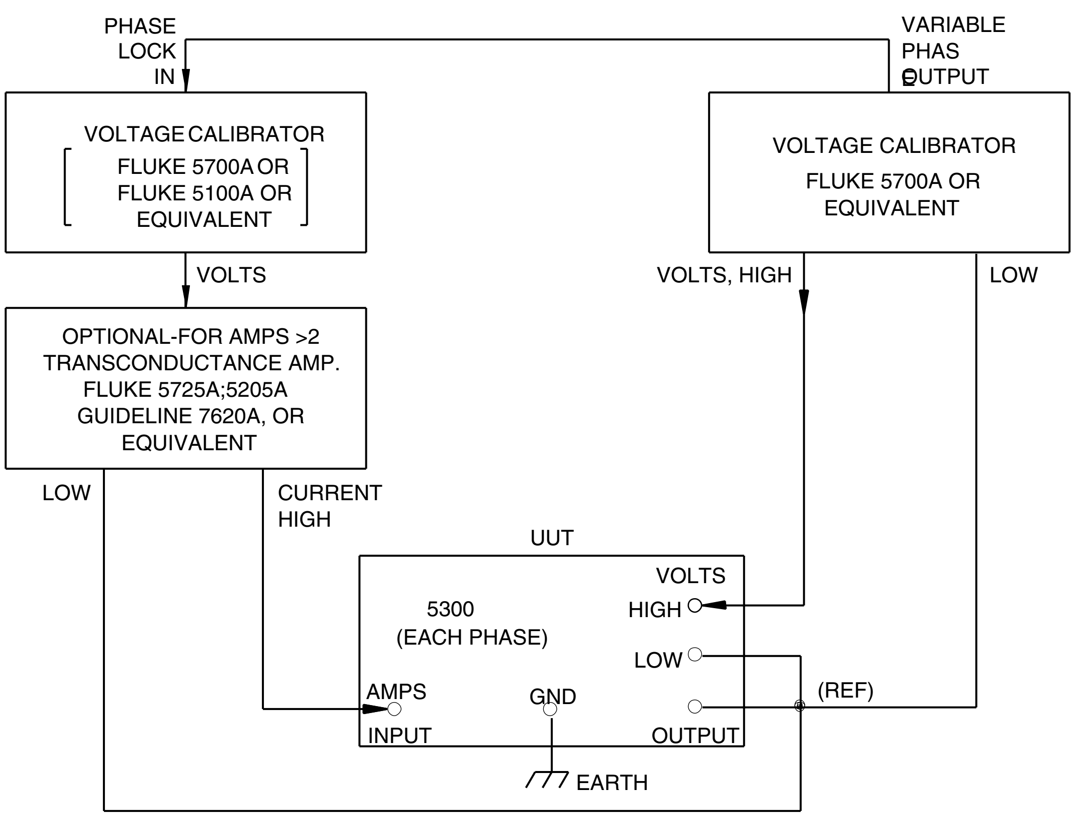
NOTE: The same test setup is repeated for each of the 3-phases.

The accuracy of the voltage and current standards used for calibration should be at least four times the accuracy of the 5300 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 5300, output impedance of the calibrators, impedance of the load and wiring inductance.

Figure 16. Calibration Verification Test Setup

(For Each Phase)



Since the current calibrator output is usually a low impedance with low compliance voltage, the 5300's current measuring shunts are the circuit's 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 $\therefore$ $2 \pi FL \approx 0.004$

θ Arctan ($2 \pi FL / R$) = Arctan (0.004 /0.021)

$\theta \approx 11$ degrees, or about 1.8 % measurement error. This error can be eliminated by adjusting the calibrator's variable phase shift control. This demonstrates the need for care in making power analyzer calibration measurements.

CALIBRATION VERIFICATION

Refer to Figure 16 for the recommended test setup. If other test equipment is used, appropriately modify the test steps for your equipment. Each of the 3-phases ($\phi1$, $\phi2$, $\phi3$) are identical and are individually tested. The same procedure is used for each of the 3-phases.

WARNING

Potentially lethal voltages are used in the following test steps. Take appropriate precautions to avoid electrical shock. Refer to your calibrator operator manual for operating instructions. Because 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 $\phi1$

DC:

1. On the 5300 PA, press the 150 volts range push-button.
2. Set the volts calibrator for zero volts DC and operate mode.
3. The 5300 VOLTS display should read zero + 0.0001% max of volts full scale range.
4. Set volts calibrator for + 150 volts DC.
5. The 5300 VOLTS display should read 150.0 volts. Record the VOLTS readings.
6. Set the calibrator for - 150 volts DC and repeat the above step. Record the VOLTS readings.
7. Repeat the above for the 300 and 600 volts ranges.

WARNING

Lethal voltages are present. Take appropriate safety precautions.

8. Compare the above readings to the values given in Section 2, Specifications.

   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 5300, press the 5 AMPERES range push-button.
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 + 5 Amperes DC. The AMPERES display should read 5.000 Amps.

   Record the current readings.
4. Set the current calibrator for - 5 Amperes. The AMPERES display should read 5.000.
5. Repeat the above for the 25 and 100 Amp ranges.
6. Compare the above readings to the values given in Section 2 - Specifications.

   The (+) and (-) readings should be within ± 2 least significant digit (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 5300 PA.

DC:

1. On the 5300, 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.

   Switch the calibrators to OPERATE mode.
3. The WATTS readout should show a power that is the product of the VOLTS and AMPS indications

   (POWER = $V \times I$).
4. Compare the 5300 PA WATTS readout to the product of VOLTS and AMPS from the calibrator's output.

   This difference is the WATTS error.

AC:

POWER = $V \times I \times \cos\theta$

where = 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 5300 PA. Refer to the calibrator instruction manuals for this adjustment procedure.

The phase shift control should be carefully set to provide a peak 5300 PA WATTS indication, corresponding to zero volts to amps phase angle. Repeat the procedure as used for the DC power verification and record readings.

Compare the recorded reading to the values given in Section 2 - Specifications.

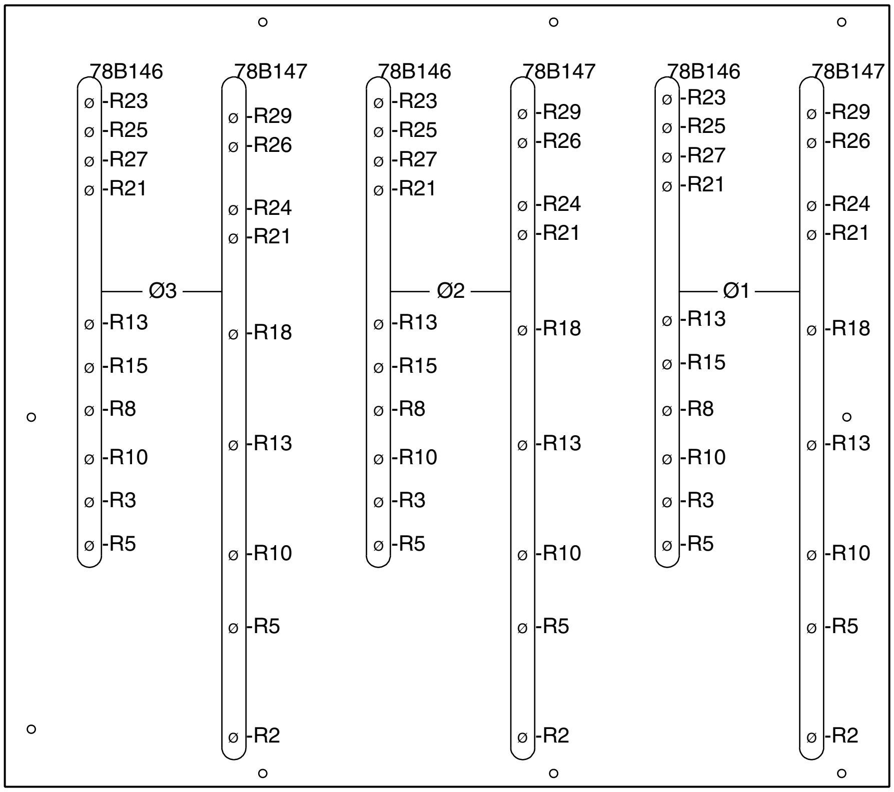
MINOR ADJUSTMENT (IF NEEDED)

NOTE: All trim pot adjustments are located on the 78B146 and 78B147 circuit boards of the 5300. See Figure 17 for trimpot adjustment locations.

WARNING

Lethal voltages are present. Take appropriate safety precautions.

Figure 17. Trimpot Adjustment Locations



Volts Zero

1. Disable the auto zero function, refer to Special Functions in Section 5.
2. Go to the 5300 VOLTS range that needs zero adjustment.
3. Set the volts calibrator for zero volt DC output.
4. Adjust trim pot 78B146-R21 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 auto zero function. See Section 5, CT/PT Installation.
2. Go to the 5300 AMPERES range(s) that need adjustment.
3. Set the current calibrator for zero amp DC output.
4. For the 5 amp range, adjust trim pot 78B146-R5, 25 amp range adjust trimpot 78B146-R10, and the 100 amp range adjust trimpot 78B146-R15 for zero AMPERES display indication.

Volts Scale Factor

1. Go to the 5300 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 150 volt range, adjust 78B146-R27.

   For the 300 volt range, adjust 78B146-R25.

   For the 600 volt range, adjust 78B146-R23.

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 5 Amp. range, adjust 78B146-R3.

   For the 25 Amp. range, adjust 78B146-R8.

   For the 100 amp range, adjust 78B146-R13.

NOTE: Calibration on the 25 and 100 Amps ranges may have to be done at less than full range scale, depending on your calibration equipment.

Volts Balance

1. Go to the 5300 PA 150 VOLTS range.
2. Set the voltage calibrator for + 150 volts DC output. Note the VOLTS display reading.
3. 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 78B147-U4 pin 14 and adjust trim pot 78B147-R10 for zero ± 0.1 millivolt dc.

Current Balance

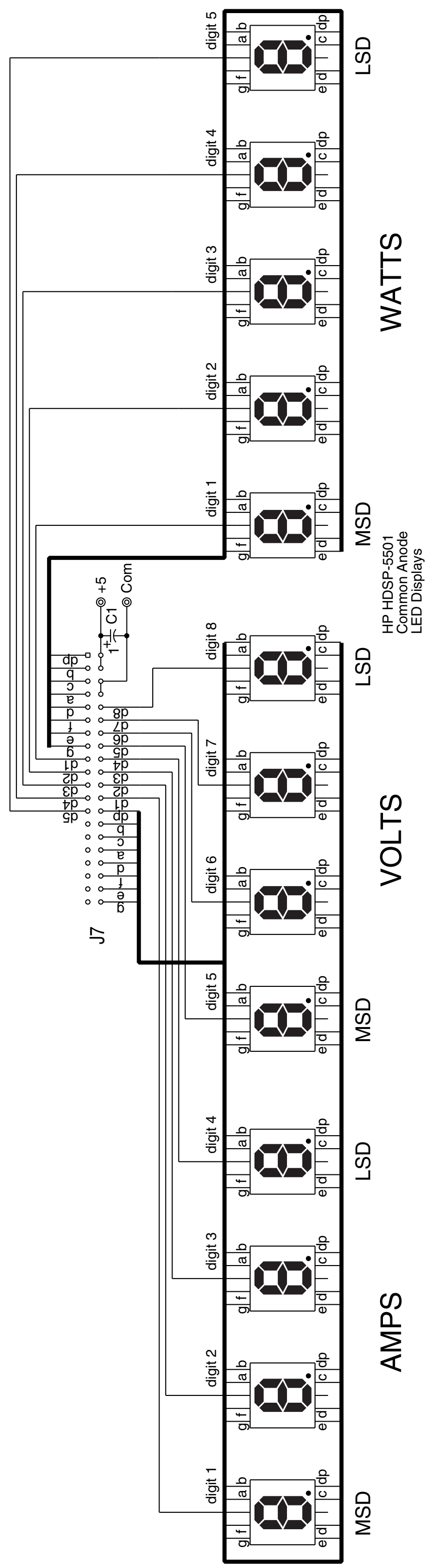
1. Go to the 5300 PA 5 amp. range
2. Set the current calibrator for + 5 Amps DC output.
3. Note the AMPERES display reading. Reverse the calibrator polarity to - 5 Amps DC. If the plus and minus display readings differ by more than ± 2 LSD, connect digital voltmeter at amplifier 78B147-U1 pin 14 and adjust trim-pot 78B147-R2 for zero ± 0.1 millivolt DC.

Watts Scale Factor

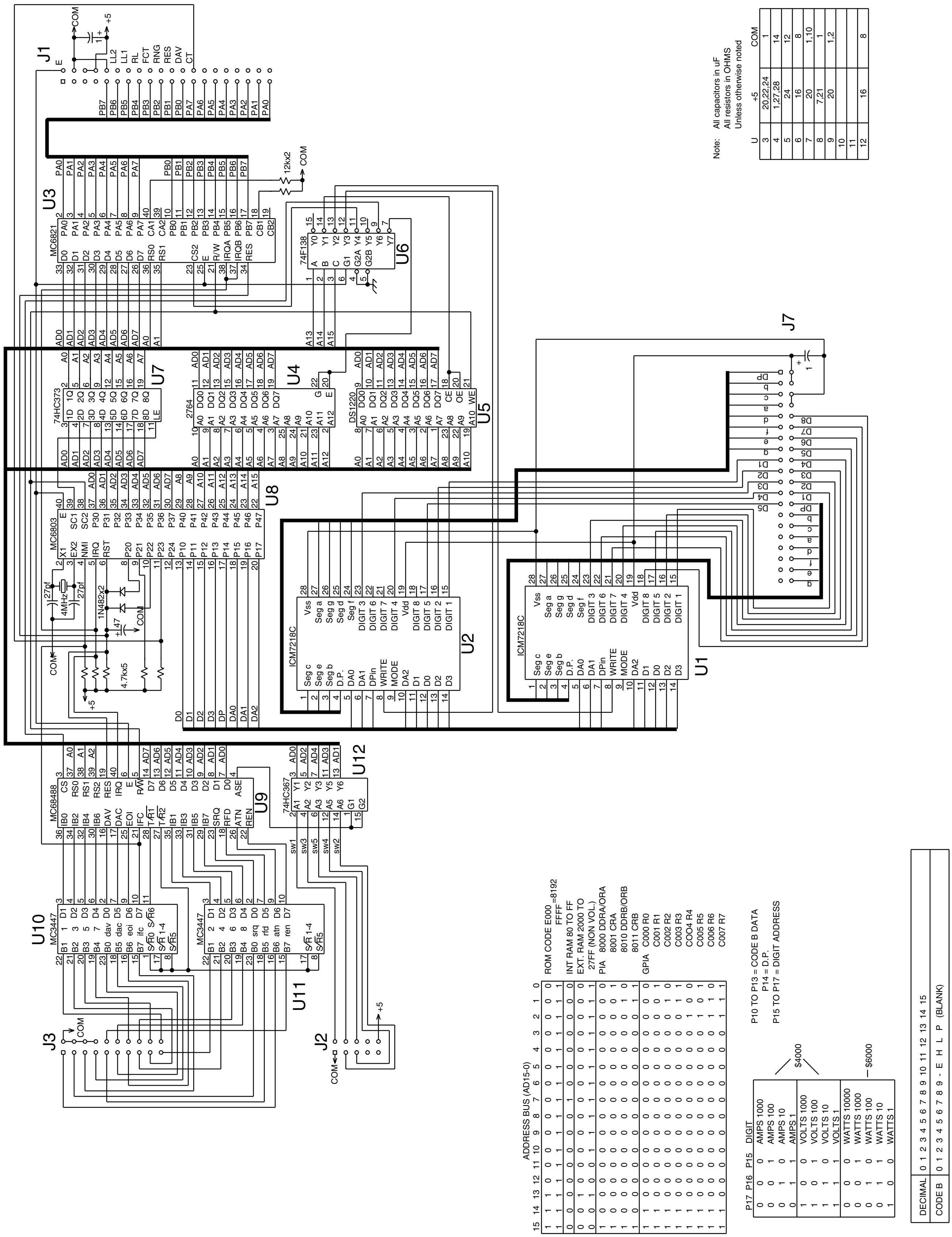
1. Set the volts and current calibrators for 150 VDC and 5 Amp DC output.
2. Adjust trim pot 78B147-R18 for 750.00 WATTS display reading.
3. Confirm AC measurement accuracy by setting the calibrators for 150 VRMS and 5 Amps RMS at 60 Hz. The WATTS display should read close to 750.00 watts and be within the specification accuracy. See Section 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--AC," Step 3.

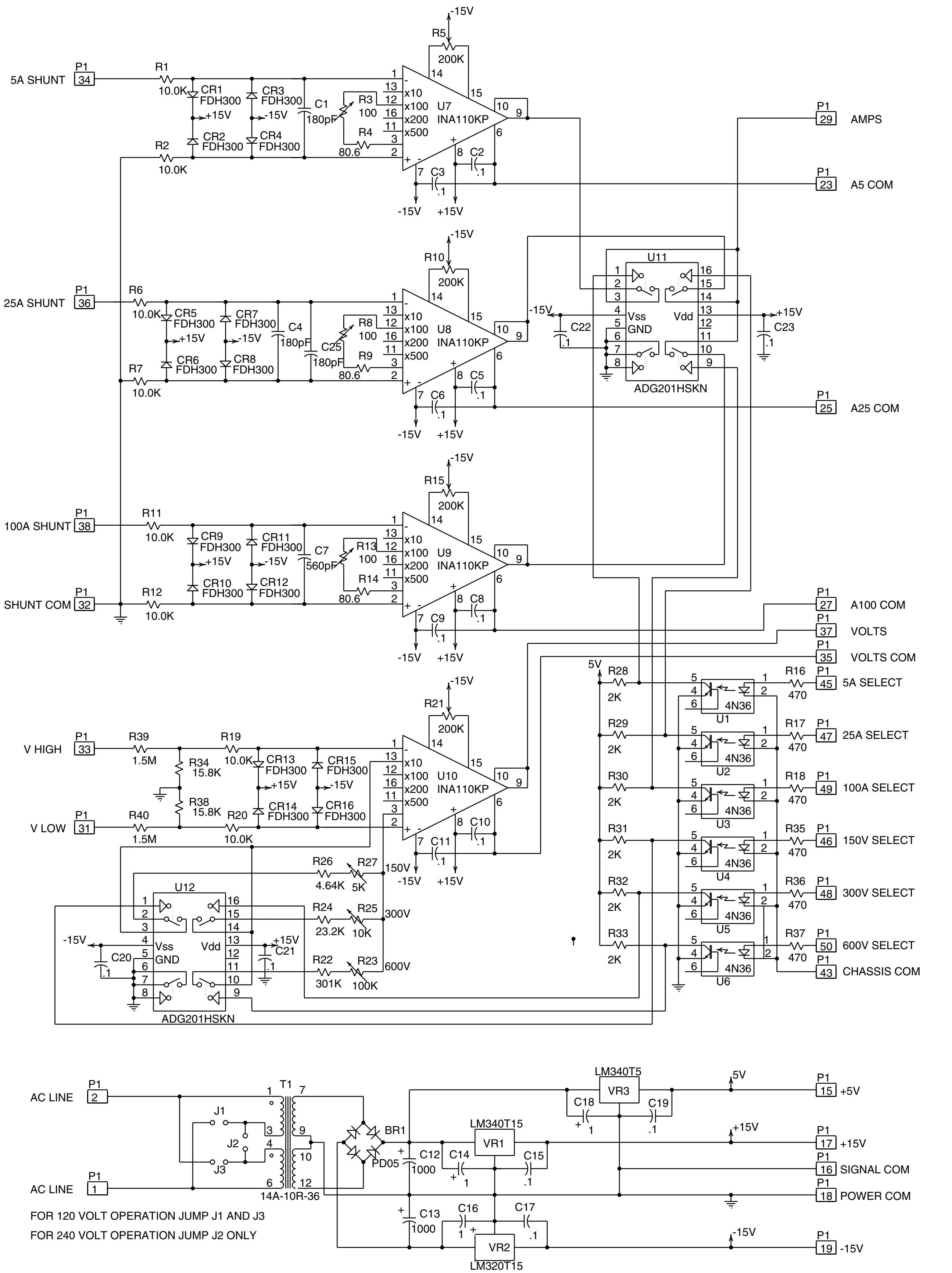
CIRCUIT BOARD 78B128 - LED DISPLAY



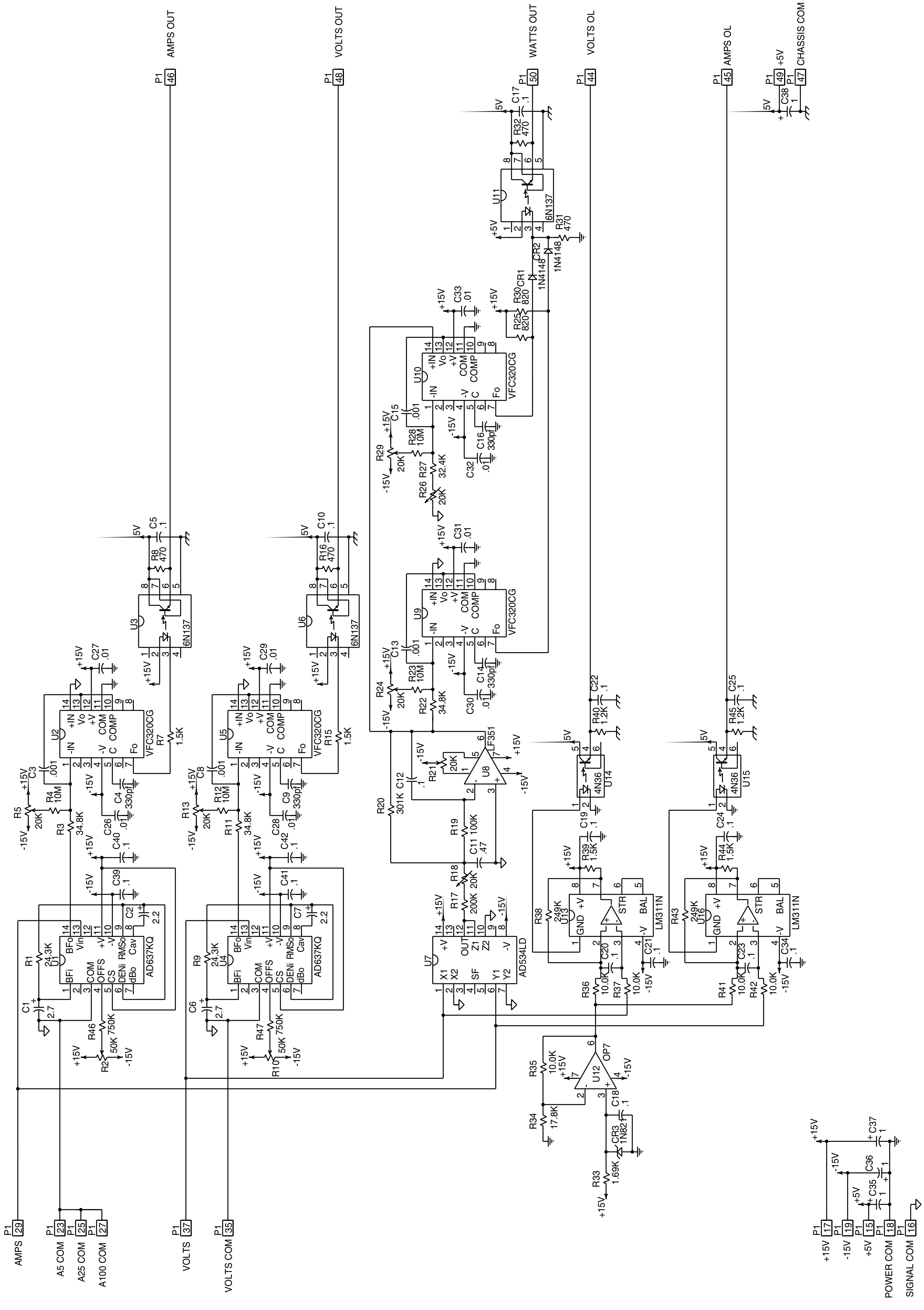
CIRCUIT BOARD 78B145 - DIGITAL READOUT & MPU



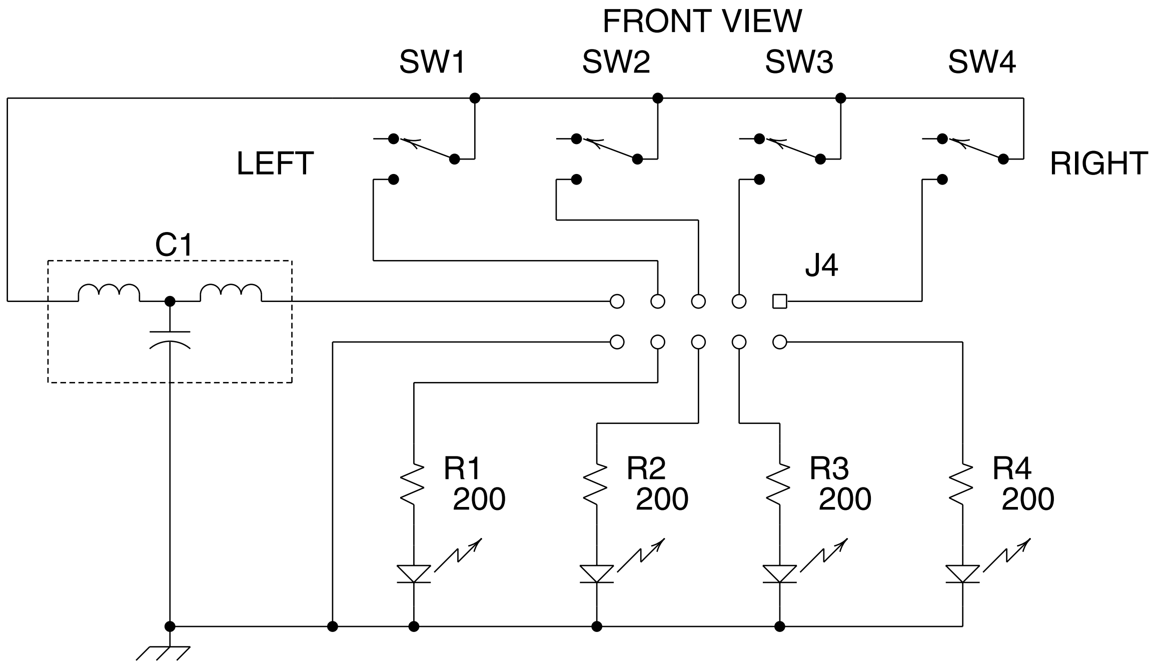
CIRCUIT BOARD 78B146 - ANALOG INPUT BOARD



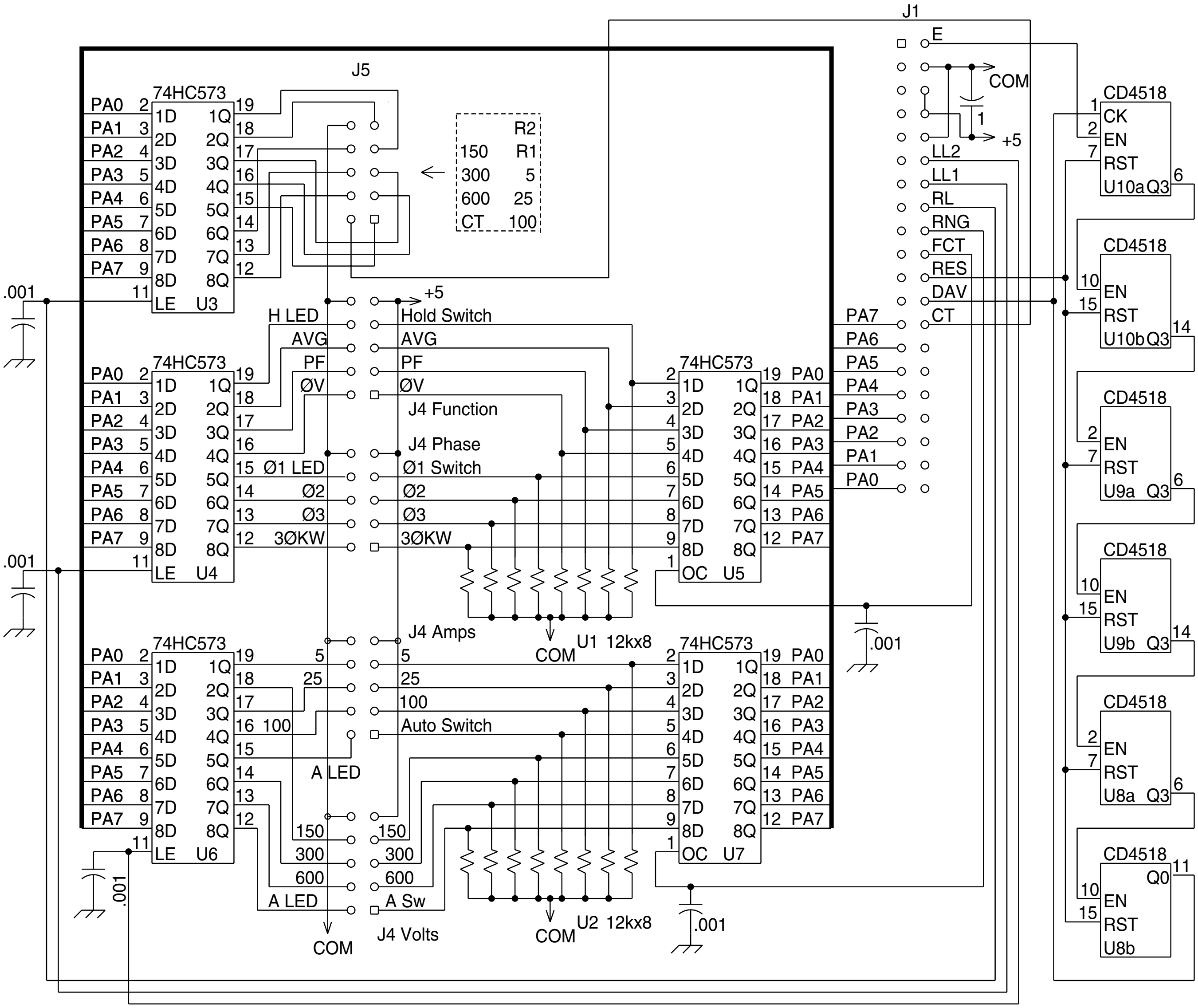
CIRCUIT BOARD 78B147 - CONVERTER BOARD



CIRCUIT BOARD 78B149 - SWITCHBOARD



CIRCUIT BOARD 78B153 - SWITCH INTERFACE

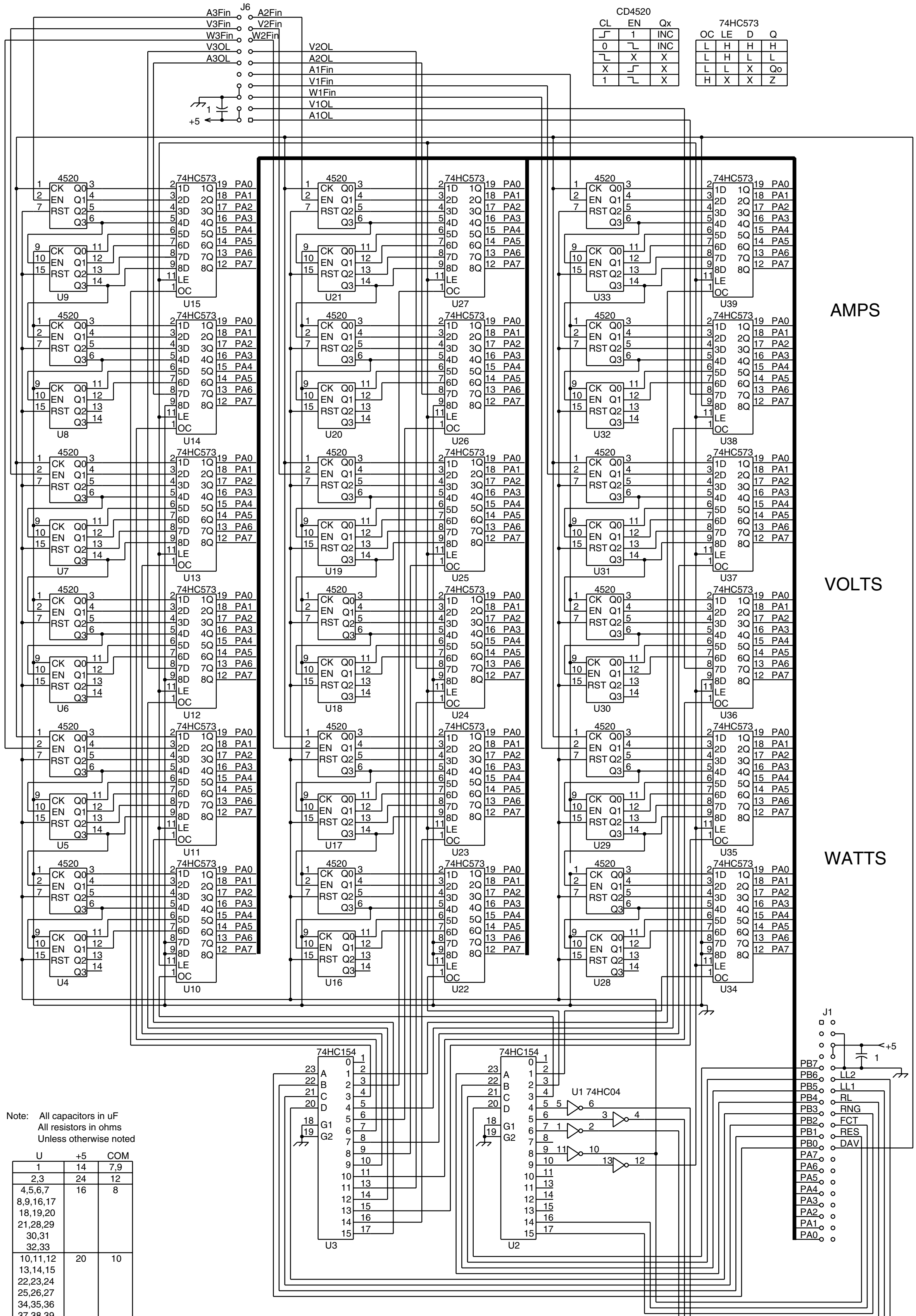


Note: All capacitors in uF
All resistors in OHMS
Unless otherwise noted

U	+5	COM
3,4,6	20	1,10
5,7	11,20	10
8,9	16	1,8,9
10	16	8,9

Range	R1	R2
5	1	1
25	0	1
100	0	0

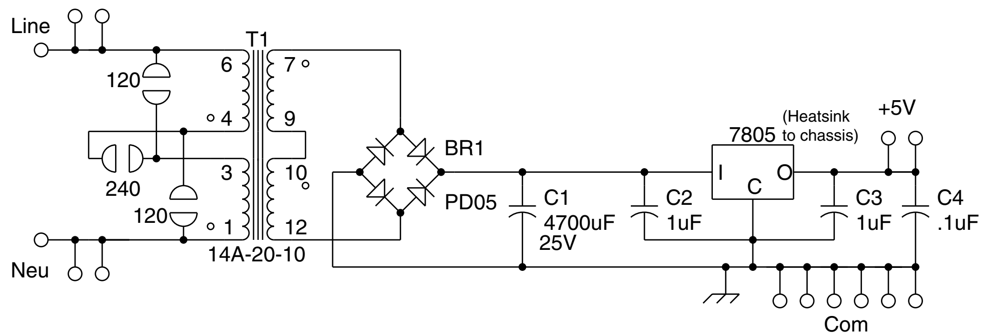
CIRCUIT BOARD 78B154 - COUNTERS BOARD



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

U	+5	COM
1	14	7,9
2,3	24	12
4,5,6,7 8,9,16,17 18,19,20 21,28,29 30,31 32,33	16	8
10,11,12 13,14,15 22,23,24 25,26,27 34,35,36 37,38,39	20	10

CIRCUIT BOARD 78B175



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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.**

THE FOREGOING WARRANTY IS PURCHASER'S SOLE AND EXCLUSIVE REMEDY AND IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESSED OR IMPLIED, INCLUDING BUT NOT LIMITED TO ANY IMPLIED WARRANTY OF MERCHANTABILITY, OR FITNESS FOR ANY PARTICULAR PURPOSE OR USE. MAGTROL SHALL NOT BE LIABLE FOR ANY SPECIAL, INDIRECT, INCIDENTAL, OR CONSEQUENTIAL DAMAGES OR LOSS WHETHER IN CONTRACT, TORT, OR OTHERWISE.

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.