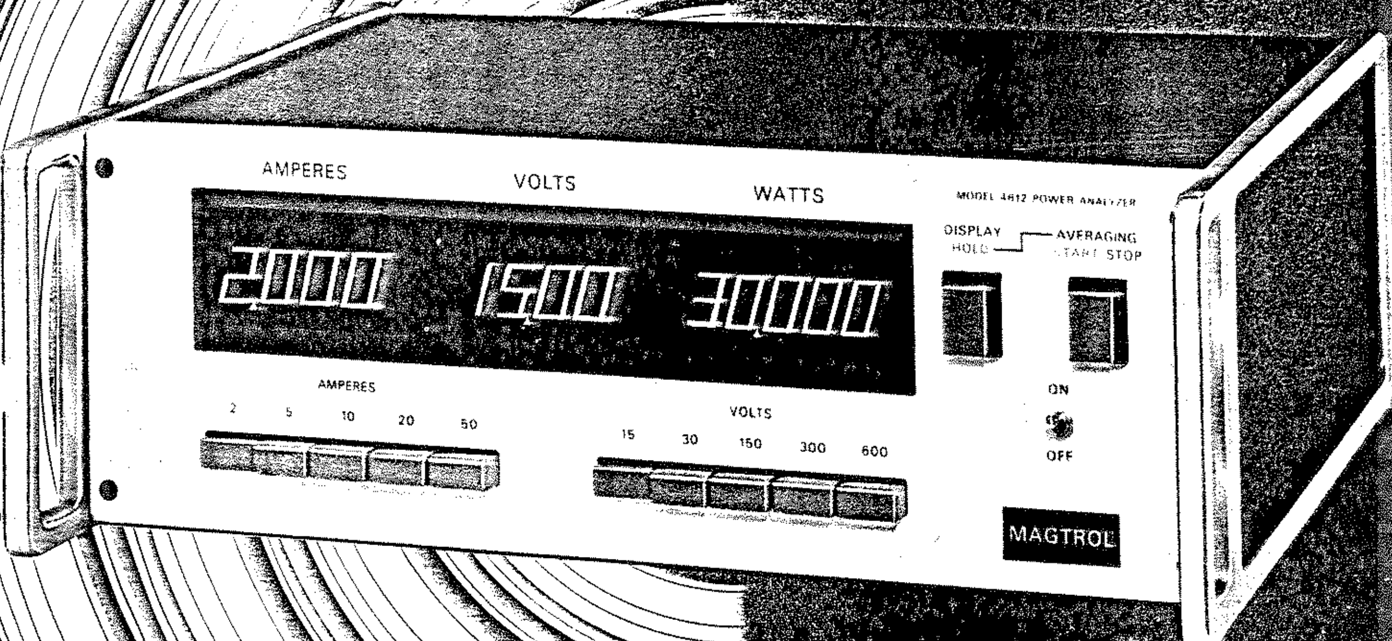
DIGITAL POWER ANALYZER
MODEL 4612

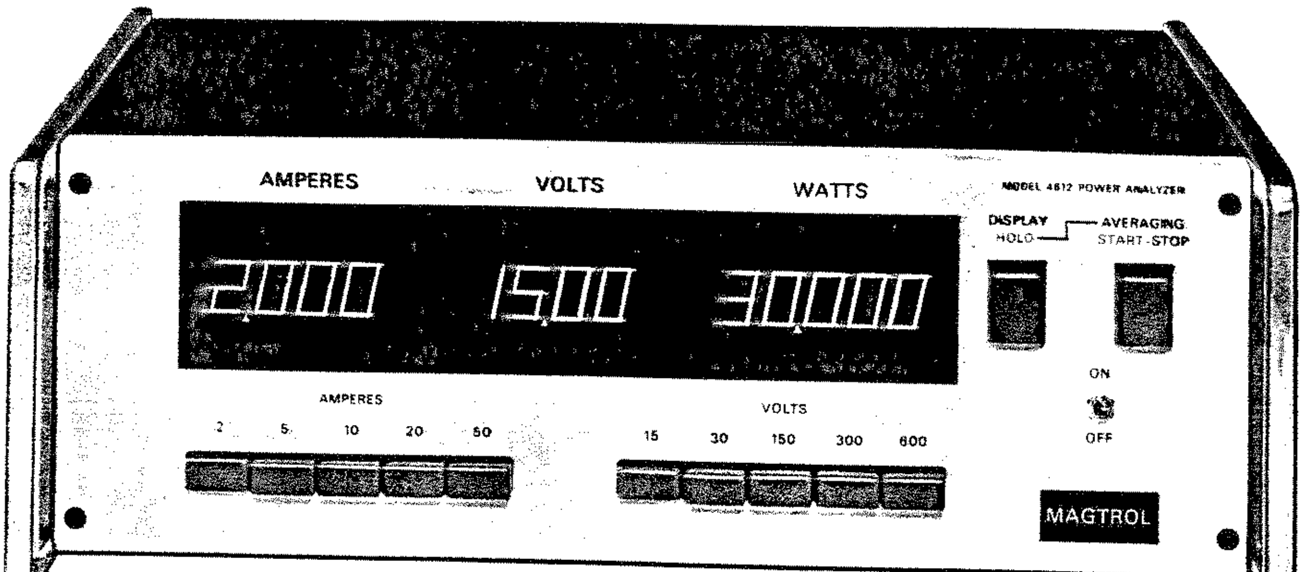
INSTRUCTION AND REFERENCE MANUAL



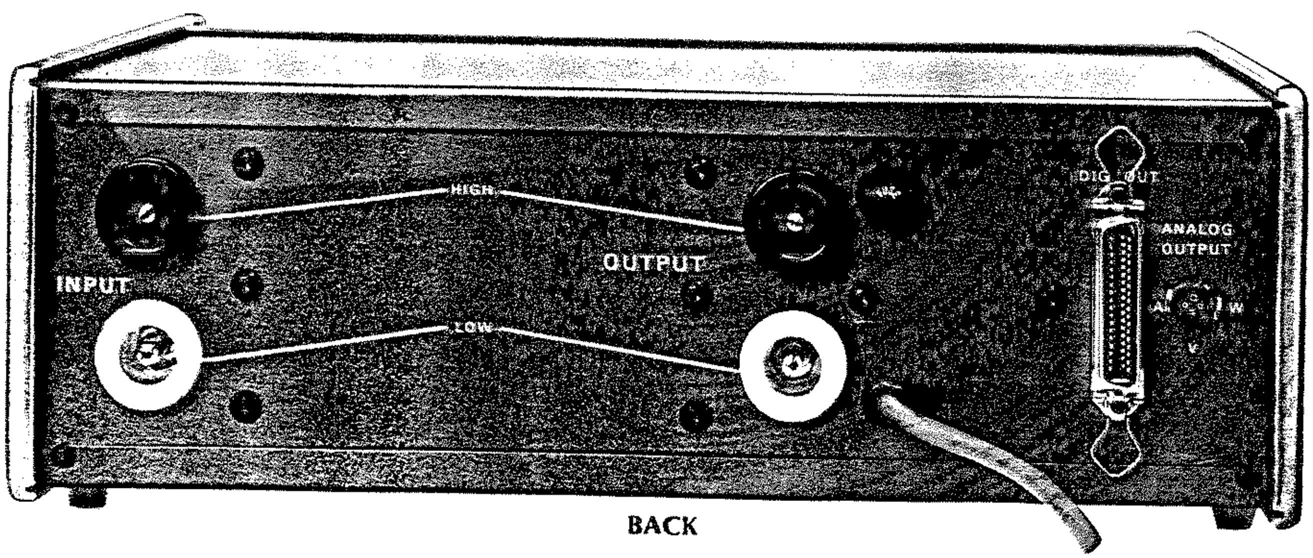
products for controlling and measuring power

MAGTROL

MODEL 4612 DIGITAL POWER ANALYZER



FRONT



BACK

MAGTROL
DIGITAL POWER ANALYZER

MODEL 4612

INSTRUCTION AND REFERENCE MANUAL

CONTENTS

OPERATING INSTRUCTIONS

1.0 INTRODUCTION

1.1 UNPACKING All shipments leaving our plant are adequately packed and packaged. If there are signs of damage to this carton or its contents, please notify the shipper within 24 hours and retain carton and packing material for his examination.

If there is evidence of anything loose inside the unit, remove the two screws retaining the top cover and remove the cover to ascertain damage, if any. This action will not affect the warranty. Replace the top cover before operating the unit.

1.2 ELECTRICAL CHECKS Plug the line cord into a grounded three-wire single-phase outlet. The power drawn by this is approximately 20 watts. Line power is isolated from all other inputs and outputs on the rear panel of the instrument.

CAUTION: THE LINE CORD ON THE POWER ANALYZER IS THE STANDARD (NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION) THREE-WIRE GROUNDED LINE CORD. THE GROUND CORD MUST CONNECT TO AN EARTH-GROUNDED LINE. UNDER SOME CONDITIONS OF VOLTAGE AND FREQUENCY, FAILURE TO MAINTAIN THE CABINET AT GROUND POTENTIAL COULD RESULT IN ELECTRICAL SHOCK HAZARD.

2.0 NO-LOAD READINGS

Turn the ON/OFF switch to ON. After a suitable warmup period the digital indicators should light and settle down to the one or two least significant digits on all readouts. (Some residual value is normal with open inputs.)

3.0 INSTALLATION

Generally, the power line is inadequate as a power source for high-accuracy measurements. This is because voltage regulation is usually poor, especially in manufacturing plants. Additionally, since power varies by the square of the applied voltage, a small change in voltage causes a much larger change in power (watts). Therefore it is advisable to use some form of power-regulating equipment as a source for operating the load to be measured.

4.0 ENVIRONMENT

This unit was factory-calibrated at a room ambience of approximately 22°C. after two hours of warmup. For accurate operation it should be maintained at room temperature, and it must be operated in a horizontal, or nearly horizontal, position.

5.0 CONNECTIONS

Two sets of input/output connectors are supplied with each unit. Their purpose is to provide a means for connecting the line to the load with mechanical ease and minimum line loss.

STANDARD CONNECTION :

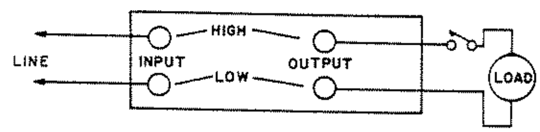


FIGURE 1

5.1 INPUT Apply the power to be measured to the two input lines located on the rear left side of the cabinet. Two sets of mating connectors are supplied for this purpose. When using a 115-volt power line as a source, follow the standard black-and-white line color code. For any other type of power the line colors have little significance except that the effects of stray capacitance are reduced if the lowest potential side (closest to the ground) is maintained on the white input. If the input and output line should be reversed, the instrument will not be damaged, and the connection error will be indicated by an 88888. reading on the WATTS display.

5.2 OUTPUT The output lines are at center right on the rear of the cabinet. Note that the through connections between input and output are high to high and low to low. For voltage, the actual potential measurement is made at the output terminals; for current, it is in series with the low line (white to white).

5.3 SHORT-CIRCUIT PROTECTION This instrument contains no fuses or other current-limiting devices in the power-measurement circuit. Therefore it is advisable to use a thermal circuit breaker or fuse to protect against excessive overloads or short circuits. CAUTION: As indicated in Figure 1, open and close the load with a switch on the load side; this relieves the instrument of having to absorb the severe voltage transients common in highly inductive loads.

6.0 DIGITAL DISPLAYS

Both volts and amps read in true RMS. Wattage is the instantaneous value of EI cos θ.

6.1 UNDERRANGE This unit is not an autoranging instrument. The correct ranges for the power to be measured must be operator selected, using the pushbuttons on the front panel. This is mentioned because all displays operate in a floating-point format, which has the appearance of autoranging. For example, if 2.345 volts are applied to the unit, the voltage display will read that value (± the full-scale accuracy) on every range from 15 to 600V, with the best accuracy naturally on the 15V range; on the 600V range the reading could be anywhere from .845 to 3.845, a substantial variation.

6.2 AMPS UNDERRANGE INDICATOR On the 5, 10, 20, and 50A ranges, an ampere value of less than 40 percent of full scale is detected by the internal processor and the ampere readout is pulsed on all digits, without impairing the reading, to indicate that a lower range can be selected. This characteristic does not apply to the volts readout, since voltage is usually fixed and known.

7.0 OVERRANGE CAPABILITY

The instrument is susceptible to wave-form clipping and subsequent error if the applied potential or current is in excess of the selected range by the following margins:

7.1 AC RMS: range + ($>$10%, $<$ 30%)

7.2 AC peak: range ($\sqrt{2}$) + ($>$10%, $<$30% of range)

7.3 DC: AC peak

If the RMS value exceeds the above, the least significant digit will flash on and off to indicate an overload, or near overload, that could cause a reading error. Under extended overloads both the overrange and underrange indication may appear, in which cases the overrange indication predominates.

7.4 DISTORTION A square wave consists of a large quantity of harmonics in phase with the fundamental. This instrument will recognize these and any other wave forms where the peak value remains within the range value, to the rated accuracy.

7.5 HIGH CREST FACTOR Crest factor is the ratio of E peak/ERMS. It is the condition common to odd harmonic content and can quickly result in clipping by the power analyzer, without any overrange indication if the time duration of the overrange is very short. If the crest factor is known, simply select a higher current range (distortion is most commonly on the current side) or voltage range equal to the true RMS value times the crest factor. Note that this value is peak, and therefore a range can be selected within the limits shown in paragraph 7.2. If the wave shape is distorted and the crest factor is unknown, test the value by selecting a higher range; if a significant change in value is thereby detected, use the higher range — otherwise, switch back.

7.6 The power analyzer is internally protected against overloads to the extent that inadvertent selection of any combination of volts-amps will not result in damage to the instrument provided that the applied power is within the instrument's maximum ratings. High surge currents (motor-starting surges, e.g.) will not adversely affect the unit if they are not unduly prolonged.

8.0 PRECAUTIONS

8.1 To minimize potential shock hazards:

8.1.1 Be sure all wiring is neat and insulated, and connectors are always used.

8.1.2 Always maintain the load-side connectors in place when the input connectors are installed.

8.1.3 **NEVER OPEN THE TOP COVER OF THE INSTRUMENT, OR ATTEMPT SERVICING OR INTERNAL INSTRUMENTATION MEASUREMENTS, WITH THE POWER LINE CONNECTED TO THE INPUT CONNECTORS.**

8.1.4 Refer again to the grounding caution in paragraph 1.2.

8.2 OVERLOADS Do not exceed an applied voltage ≥600V RMS. Do not exceed 100 amps current.

9.0 OPERATING INSTRUCTIONS

9.1 Turn the unit on, and after all electrical connections have been made and the correct ranges selected, allow at least ten minutes for warmup.

9.2 To hold a reading, depress the pushbutton DISPLAY HOLD. This pushbutton indicates a locked display by lighting red. NOTE: This pushbutton holds the digital displays only. Analog outputs (optional) follow the inputs; they are not affected by DISPLAY HOLD.

9.3 AVERAGING START/STOP This is a manually controlled function to produce a reading of watt, volt, and ampere hours.

9.3.1 Initiate this function by depressing the AVERAGING pushbutton with HOLD off.

9.3.2 At the instant the measurement period is to start, press the AVERAGING START/STOP pushbutton. This will light up the button and at the same time cause the instrument to drop the previously held data. Just prior to the first reading the display will indicate all zeros, followed by a reading which is the first averaged value. Subsequent readings are then summed accordingly.

9.3.3 To stop the averaging function at the conclusion of the desired measurement period, depress the HOLD button. The values on the display are the averaged readings of amperes, volts, and watts over the period of time that AVERAGING was on with HOLD off. The final display of averaged values will remain for as long as DISPLAY HOLD is engaged.

9.4 Interaction of the AVERAGING START/STOP and HOLD functions permits the following data possibilities.

9.4.1 If you wish to retain the averaged data for later recall proceed as follows:
   a. With HOLD depressed, release AVERAGING START/STOP.
   NOTE: The display will update to the last reading obtained in the normal operating mode.
   b. Release HOLD, permitting normal operation.

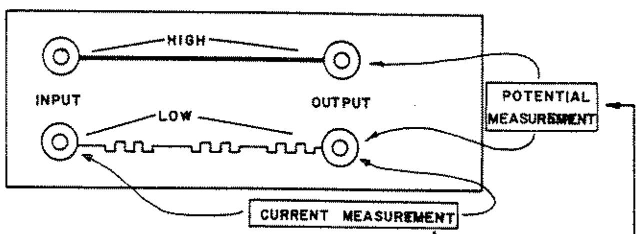
9.4.2 To recall the data obtained above:
   a. Depress HOLD.
   b. Depress AVERAGING START/STOP.

9.4.3 If you wish to average new data into the old data, proceed as follows:
   a. Depress HOLD.
   b. Depress AVERAGING START/STOP.
   c. Release HOLD.

9.4.4 If you wish to clear the old data and start averaging new information, proceed as in paragraph 9.3.1, i.e.; depress AVERAGING START/STOP with HOLD off.

9.5 Limitations: The averaging function will not necessarily correctly average transient or surge information, if that information is of a duration faster than the response time of the instrument. For best accuracy, volts and amperes should be stable for at least 1/2 second. The unit will ignore surges of a few milliseconds.

10.0 OPERATIONAL DESCRIPTIONS



RANGE	VOLTAGE CIRCUIT RESISTANCE ACROSS OUTPUT: (POTENTIAL BURDEN)
15	110 K
30	110 K
150	250 K
300	500 K
600	1.0 MEG.

RANGE	CURRENT CIRCUIT RESISTANCE: (TYPICAL)
2,5,10,20	.012 OHM (ALL)
50	.005 OHM

FIGURE 2

Figure 2 shows the internal connections of the power-measurement circuits of this instrument. Note that the input high is directly connected to the output high. For proper operation the current and potential circuits are inseparable, since they share a common point at output low.

10.1 INSTRUMENT-MEASURING BURDENS The Figure 2 charts show actual burdens for the potential and current circuits with values in load resistances. Inductive and capacitive reactive components are internally compensated and insignificant. The burden in VA can be calculated as follows:

$$\text{potential circuit burden} = \frac{\text{volts}^2}{\text{resistance}}$$

In all cases the burden is ≤.2VA up to 440V.

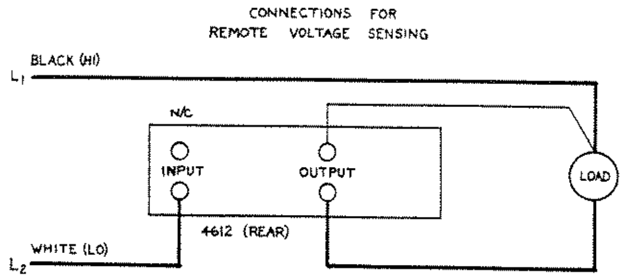


FIGURE 3

10.1.1 REMOTE POTENTIAL SENSE Figure 3 shows an alternate connection method requiring only one line of the load circuit to be interrupted. Since very little current flows through the potential line to output high, light wire is satisfactory for this connection.

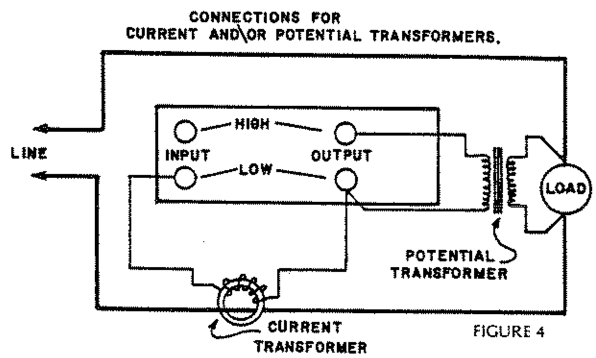


FIGURE 4

10.1.2 CURRENT AND POTENTIAL TRANSFORMERS As shown in Figure 4, the unit can be used with either current or potential transformers. When this is done the correction factor prescribed by the transformer ratio utilized must be applied to the instrument readings. NOTE: A current transformer is available with a split core to make interruption of the line unnecessary. For details contact our customer service department.

10.2 AVERAGING START/STOP—HOLD SWITCH FUNCTIONS The averaging function is accomplished by a means of digital integration. The process is performed identically on all three parameters of amps, volts, and watts. Each parameter is summed into three registers while simultaneously incrementing a fourth register each reading cycle. Additionally, on each machine cycle of approximately 400 milliseconds, the data are reduced and displayed. This readout function is done by separate registers so that the summation registers remain intact. This is the method by which a running average is continuously displayed. There is no practical time limit on the averaging function.

The HOLD switch interrupts the above process and provides an instruction to the CPU to store all of the data. Thereafter the information can be recalled and summed into, or cleared for a fresh start. The use of the switches for this manipulation of data is described in foregoing paragraph 9.4.

11.0 SPECIFICATIONS

11.1 Accuracy, resolution, and response time for the Model 4612 power analyzer:

11.1.1 ACCURACY AC The following long-term (rated) accuracies take into account the effects of noise, distortion, and either capacitive or inductive loads. REF ANSI C39.6 1969.

Ampere Ranges
2A to 20A: rated accuracy ± (.25% of reading +.2% of full scale ±1 LSD) from 40 Hz to 100 Hz.
50A: rated accuracy ± (.25% of reading +.25% of full scale ±1 LSD) from 40 Hz to 100 Hz.

Volt Ranges
15V to 300V: rated accuracy ± (.25% of reading +.2% of full scale ±1 LSD) from 40 Hz to 100 Hz.
600V: rated accuracy ± (.25% of reading +.28% of full scale ±1 LSD) from 40 Hz to 100 Hz.

Watts, all range combinations
P.F. 0-1 lead or lag: rated accuracy ± (.25% of reading +.2% of full scale ±1 LSD) from 40 Hz to 100 Hz.

ACCURACY DC AND 100 TO 500 Hz As stated above, + (±5 LSD).

11.1.2 RESOLUTION Amps, all ranges: 1.0 MA or .0167% of full scale, whichever is greater.
Volts, all ranges: .0167% of full scale.
Watts: .0167% of full scale volt-amps.

11.1.3 RESPONSE In normal mode, each reading is updated every 750 milliseconds. In integrating mode, each data sample is obtained at intervals of approximately 400 ±20 milliseconds.

11.2 Accuracy, resolution, and response time for the analog output, option 01:

11.2.1 ACCURACY, ALL RANGES Rated accuracy ±(.35% of full scale +.1% reading + 300μv/°c) DC and 40 Hz to 400 Hz.

11.2.2 RESOLUTION Infinite.

11.2.3 RESPONSE From 10% to 90% of range with a stepped input of 0 to full scale at 60 Hz, all ranges: volts and amps, 160 milliseconds; watts, 80 milliseconds.

12.0 CALIBRATION

CAUTION: THE ANALOG CIRCUIT BOARD AND MANY OF THE COMPONENTS THEREON ARE COMMON TO THE INPUT AND OUTPUT CONNECTORS. IF THE POWER LINE IS CONNECTED TO THE INPUTS, DO NOT CONNECT ANY TEST INSTRUMENTS TO ANY POINT ON THIS BOARD.

Two levels of calibration are covered in the following descriptions. Section 12.1 is a condensed procedure for full-scale calibration of all ranges of volts, amps, and watts. Section 12.2 is a complete procedure for offset feed-thru adjustments.

12.1 FULL-SCALE CALIBRATION Disconnect all input connectors and the power service lines to the instrument. To remove the top cover, first remove the retaining screws in the upper left and right corners, then slide the cover panel to the rear.

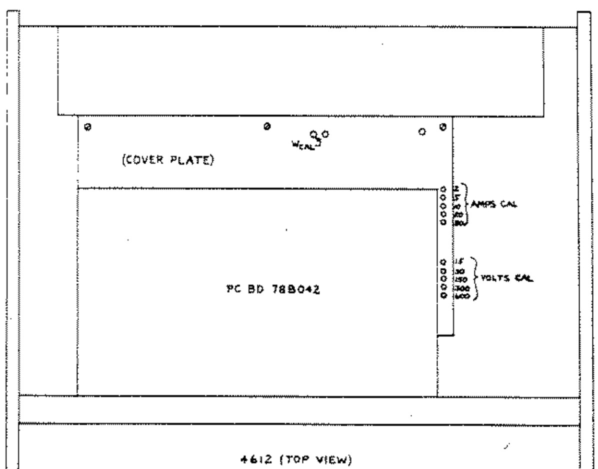


FIGURE 5

12.1. 1 VOLTS CALIBRATION A source of stable AC voltage of known value is required. Turn on the power analyzer and apply the potential to the black and white input terminals. After a suitable warmup time, refer to Figure 5 and adjust the appropriate trim pots, accessible through the holes in the cover plate, until the indicated value agrees with the diagrammed reference.

12.1. 2 AMPS CALIBRATION Follow the instructions for volts calibration, except that a known value of AC amps must be applied through the two lower white terminals.

12.1. 3 WATTS CALIBRATION To calibrate AC watts, it is necessary to set up a high power-factor load with a known voltage and a known current. This needs to be done on only one range of volt-amps. To minimize power-factor errors when calibrating by the volt-amp method, the circuit inductance should be kept as low as possible and the total circuit resistance as high as possible, since

$$\theta = \tan^{-1} \frac{2\pi FL}{R}, \text{ and P.F.} = \cos \theta.$$

For a typical suitable range, use a resistive load of 1½ to 2 amps at 120 to 150 volts and 50 to 60 Hz. By twisting together the output leads and keeping clear of any ferrous metals it should be possible to maintain the power factor above .9995. Calibrate the watts reading at W CAL, as shown on Figure 5, equal to the known values of volts times amps.

12.2 OFFSET FEED-THRU CALIBRATION

12.2. 1 The following equipment is necessary to proceed with the complete balancing procedure (note that it requires DC):
1. DC power supply 0-15V @ 0-2A minimum.
2. Stable resistor of 5 to 10 ohms @ 50 watts.

12.2. 2 Turn on the power analyzer and allow one half hour for stabilization.

12.2. 3 As shown in Figure 1, connect the DC power supply to the input (line), and the power resistor across the output (load). The load switch is for convenience but it need not be used.

12.2. 4 Remove the top cover and the inside plastic cover plate, which will partially expose the analog circuit board. Now refer to the circuit-board sketch provided on the lower left of the instrument, and shown on the next page as Figure 6. (A glossary of the elements and functions shown on the sketch appears later in this manual as section 15.0.)

12.2. 5 Turn on the power supply, adjust the voltage for 12 to 15 VDC, and note the volts reading on the 15V range of the power analyzer. Now reverse the polarity at the power supply without changing the voltage setting. Compare the reading with the previous one and adjust V BAL (drawing location 2A) until the reading repeats within .02 volts when the polarity is repeatedly reversed.

12.2. 6 With 15 VDC applied and the range set on 15V, record the exact reading. Switch the range to 600V and adjust VRMS BAL (location 4G) for the same value obtained on the 15V range, ±.1 volts.

12.2. 7 Reduce the input to zero voltage and short the input. With the range on 600V, carefully adjust V-F BAL (location 9G) for a volts reading of 0.000 to 0.100 but predominantly 0.000.

12.2. 8 Repeat the procedure outlined in paragraph 12.2.6, but with 1.0 VDC applied to the input instead of 15 VDC. Again adjust VRMS BAL for ±.1 volt repeatability.

12.2. 9 The procedure for the amps reading is similar to that for the volts reading outlined in paragraph 12.2.5. Adjust the voltage for a current reading of 1.0 to 1.5 amps. The reading must be stable before proceeding. Using the 2A range, reverse the polarity of the applied voltage and adjust A BAL (location 2G) until with repeated changes of polarity the reading is constant to within ±2.0 milliamps.

12.2.10 Reduce the DC power supply voltage to obtain a value of current of approximately .2 amps on the 2A range. Switch to the 20A range and adjust A RMS BAL (location 3G) until the reading repeats within ±5 milliamps when switching repeatedly back and forth on the 2A and 20A ranges.

12.2.11 Open the load so that there is only an applied voltage to the unit, and set the ranges at 2A and 15V. Rotate trim pot W BAL (location 8G) either clockwise or counterclockwise until a reading of .5 to 1.0 appears on the watts display. Reverse the polarity of the applied voltage. If the watts reading changes by more than .01, adjust X BAL (location 5G) until the reading remains constant to within ±.01 while the polarity is repeatedly reversed.

12.2.12 Still using the 2A and 15V ranges, adjust the W BAL trim pot until the watts reading is zero to 0.005.

12.2.13 Close the circuit to the load resistor and adjust the power supply voltage for a watts reading of between 15 and 30. Be sure neither the amps nor volts reading is over range. Reverse input polarity repeatedly while adjusting Y BAL (location 6G) to maintain a consistent reading within ±.01 watts during the reversals.

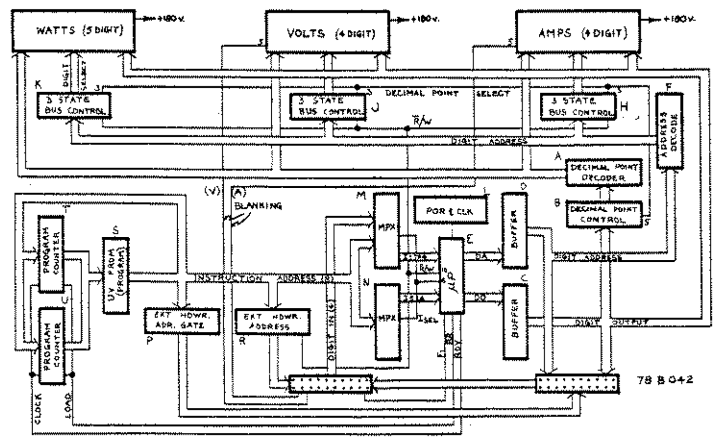
This completes the offset and feed-thru balancing procedures. The calibration outlined in paragraph 12.1 will not affect these adjustments. However, some of the offset adjustments can influence the full-scale calibration values; therefore AC calibration should be performed following the offset balancing. (For a more technical description of the offset and calibration adjustments, see section 13.1)

12.3 ANALOG OUTPUT (OPTION 01) BALANCE AND CALIBRATION The calibration and balance controls are located on the analog circuit board. See paragraphs 12.2.2 to 12.2.4 for locations.

DIGITAL READOUT PC BD 78 B 042

PC BD IDENT.	MAGTROL P.N.	TYPE NUMBER
A	76 D 051	CD 4028
B	76 D 025	CD 4042
C, D	76 D 035	74 C 902
E	76 D 039	57109
F	76 D 024	74C42
H, J, K	76 D 052	80C96
L	76 D 034	74C04
M, N	76 D 033	74C157
P	76 D 026	74C00
R	76 D 027	74C08
S	76 D 040	1702A
T, U	76 D 032	74C161
READOUT DRIVERS(4)	76 D 043	TI 75584
READOUTS	75 D005	SP 752
	75 D 006	SP 753

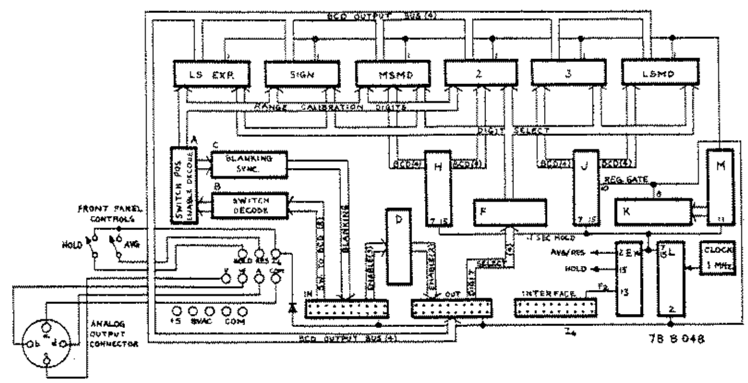
DIGITAL READOUT SECTION



DIGITAL CONTROL PC BD. 78 B 048

PC BD IDENT.	MAGTROL P.N.	TYPE NUMBER
A	76 D 040	1702 A
B	76 D 028	74C32
C	76 D 026	74C00
D	76 D 049	CD 4044
E	76 D 051	CD 4028
F	76 D 024	74C42
H, J, L	76 D 050	CD 4518
K	76 D 029	74 C 30
M	76 D 038	CD 4040
LS EXP, SIGN, MSMD,	76 D 047	CD 40257
2, 3, LSMD	"	"
CLOCK	76 M 008	TP 830

DIGITAL CONTROL SECTION

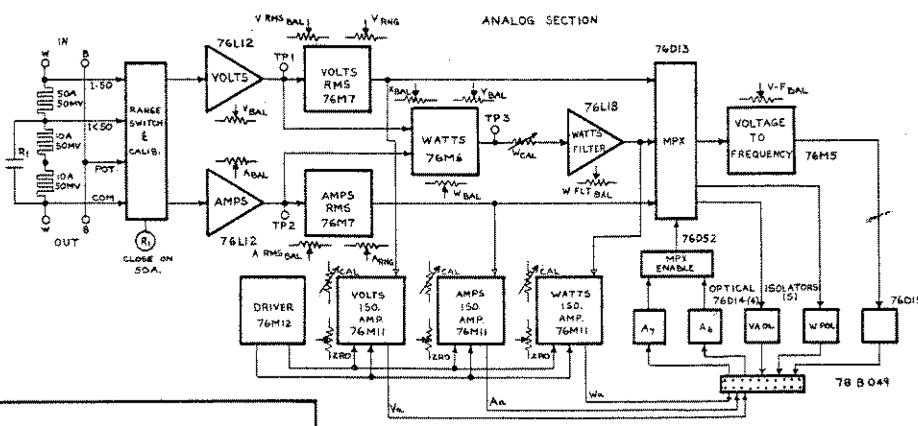


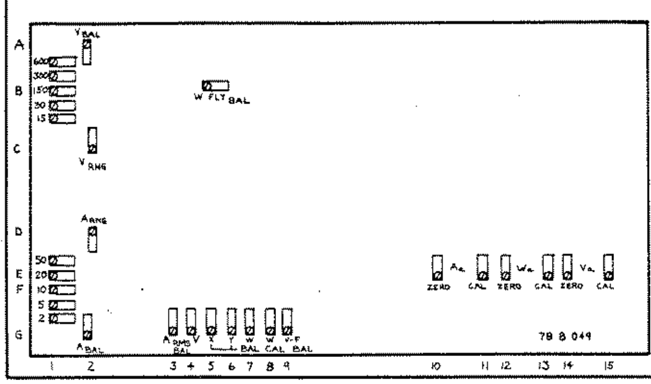
ANALOG PC BD 78 B 049

REFER TO INSTRUCTION MANUAL FOR BALANCE & CALIBRATION PROCEDURE.

NOTE: ISOLATION AMPS & DRIVERS INSTALLED ON OPTION -01 ONLY.

ANALOG SECTION





MODEL 4612

MAGTROL, INC.

FIGURE 6

12.3. 1 The three calibration controls are located as follows: amps at 11E, watts at 13E, volts at 15E. Change in calibration, if over .25 percent, may slightly alter the zero balance (output at zero input). Therefore any calibration change over .01 volts (at full scale) should be followed by the zero balance procedure given below in paragraph 12.3.3, and the calibration repeated.

12.3. 2 Calibration consists simply of reading the output voltage on the analog output connector and adjusting the corresponding potentiometer for a full-scale value equal to 5.0 VDC. If an exact full-scale value is not convenient, use a partial value and ratio the output voltage as follows:

$$\text{analog output (V)} = \frac{\text{actual value (V, A, or W)}}{\text{selected range}} \times 5.0$$

Do not calibrate any value above 5.0 VDC output and use an accurate high-input impedance meter. The output resistance of the analog output is approximately 1K ohms.

12.3. 3 ZERO BALANCE Balance potentiometers are located at 10E, 12E, and 14E. Zero balance is accomplished simply by adjusting the analog output to zero ±.005 volts, with zero input voltage (shorted input connectors) applied to the unit.

13.0 TECHNICAL DESCRIPTIONS

13.1 ANALOG Two PC boards contain all of the isolated electronics that transduce the input line measurements.

13.1.1 The range-control PC board is accessible from the bottom of the unit by removing the bottom cover, the two lower mounting screws on the front plate, and the internal plastic shield. This section is a passive component containing the mounting means for the range switches, and the divider resistors. It is serviced by two connectors, and directly wires to the rear-panel elements.

13.1.2 The analog PC board consists of the elements identified in Figure 6. In addition to the calibration and offset adjustments described in section 12, there are some additional range-control elements, most of which are accessible only by removing the front panel and upper shield. Two controls, V RNG at drawing location 2C and A RNG at location 2D, provide the same function as the ten calibration controls shown in line at location 1. V RNG adjusts the output of the digital and analog voltage level without affecting watts output, and A RNG does the same on the amps section. If one or more individual range calibration controls reach the end of their adjustment range so that watts and volts (or amps) cannot be simultaneously calibrated, then A RNG or V RNG will allow independent gain adjustment. However, adjustment from factory setting should not be required unless enough elements are changed to produce a massive alteration in the original signal voltage levels. Another trim pot, W FLT BAL (location 5B), functions identically to W BAL outlined in paragraph 12.2.12, except that its offset is applied to the watts filter.

13.2 DIGITAL Since the power analyzer is microprocessor-controlled, all digital readouts and operational functions are under software control. Therefore many operating characteristics can be readily altered simply by changing the programmable read-only memory element. Following is a partial list of the characteristics that can be altered:

1. overrange indication
2. underrange characteristic
3. all display rates, functions, and parameters
4. hold function
5. averaging function
6. auxiliary watts readouts (i.e., time, etc.)

In addition, a complete scientific math capability is readily accessible, making possible any trig function or other mathematical data reduction. Any alteration in equipment performance, however, is likely to affect the averaging function, since virtually all of the memory and internal processor registers are utilized for this function. (To investigate possible readout alterations, contact our customer service department.)

14.0 OPTIONAL OUTPUTS

14.1 DIGITAL OUTPUT A connector on the rear panel provides a digital output. Since the format is in a code not readily interfaceable, a separate interface — our optional model number IF03 — is required. If technical information is needed only for the electrical and connector details of this output, refer to our data sheet IF03L, available on request.

14.2 ANALOG OUTPUT This option provides three lines and a common, identified on the rear panel at the output connectors as to pin connections. The lines provide an analog voltage proportional to the readouts for amps, volts, and watts. The level is 0 to 5.0 VDC for zero to full scale on each digital readout. The output impedance is ≃1K ohms. For signal characteristics, refer to preceding paragraph 12.3.2.

15.0 GLOSSARY OF ELEMENTS AND FUNCTIONS

V BAL	voltage balance, first amplifier
A BAL	amperage balance, first amplifier
C (HI)	common, isolated from ground, common to input
VRMS BAL	volts RMS operator balance, input
ARMS BAL	amps RMS operator balance, input
Aa	amps analog DC output
Va	volts analog DC output
Wa	watts analog DC output
W BAL	wattmeter output balance
W FLT BAL	wattmeter filter balance
X BAL	multiplier X input zero balance
Y BAL	multiplier Y input zero balance
V-F BAL	voltage-to-frequency converter balance
W CAL	wattmeter calibration
A RNG	ammeter range control, RMS element
V RNG	voltmeter range control, RMS element
VAOL	volts-amps overload protection
W POL	watts polarity detection

16.0 COMMONLY USED FORMULAS

D.C. CIRCUITS

E = potential in volts
R = resistance in ohms
I = current in amps

OHMS LAW: $E = IR$, $I = \frac{E}{R}$, $R = \frac{E}{I}$

POWER LAWS

P = power in watts
(watts = joules per second)

$P = \frac{E^2}{R}$, $P = I^2R$, $P = EI$

or

$E = \sqrt{PR}$, $E = \frac{P}{I}$

$R = \frac{P}{I^2}$, $R = \frac{E^2}{P}$

$I = \frac{P}{E}$, $I = \sqrt{\frac{P}{R}}$

A.C. CIRCUITS

r.m.s. (*effective* or root mean square) = $\frac{\sqrt{2}}{2}$ x peak (sine wave)
θ = phase angle
p.f. (power factor) = $\cos \theta$
L = induction in henrys
C = capacity in farads
f = frequency (hz)
X_L = inductive reactance
X_C = capacitive reactance
Z = impedance in ohms
t = time in seconds

$X_L = 2\pi fL$

$X_C = \frac{1}{2\pi fC}$

$Z = \sqrt{X_L{}^2 + R^2}$

$Z = \sqrt{X_C{}^2 + R^2}$

$P = I^2Z \cos \theta$

$P = \frac{E^2 \cos \theta}{Z}$

$P = EI \cos \theta$

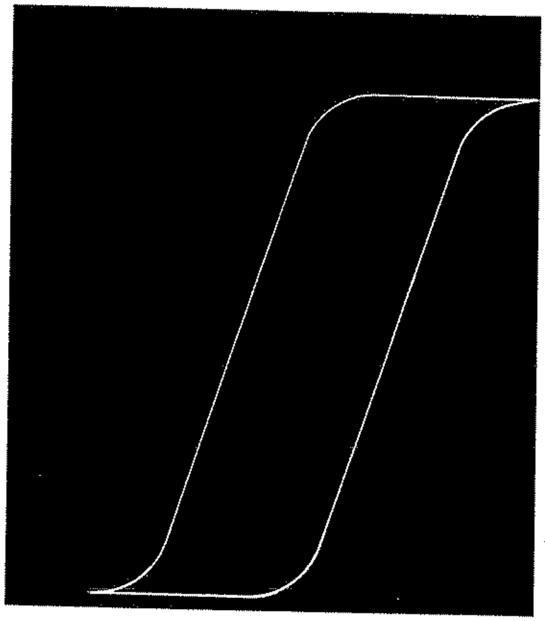
instantaneous value = peak x [sine(π tft)]

MAGTROL LIMITED WARRANTY

This Magtrol product is warranted against defects in materials and workmanship for ninety (90) days from the date of delivery. We will repair or replace products which prove to be defective during the warranty period provided they are returned to Magtrol. Additionally, any repairs which may become necessary beyond the ninety (90) day warranty period will be made subject to review by our quality control department. No other warranty is expressed or implied. We are not liable for consequential damages.

Customer assistance agreements are available for Magtrol products that require maintenance and repair on site.

MAGTROL, INC. **BUFFALO, NEW YORK 14224**



MAGTROL PRECISION DEVICES, EQUIPMENT, AND INSTRUMENTS

FOR TORQUE CONTROL

Hysteresis Brakes and Clutches Hysteresis advantages for the OEM include extra-long life, precise repeatability, environmental stability, temperature insensitivity, broad speed range, operational smoothness, and low power consumption. Use hysteresis brakes and clutches in your product for speed control, tensioning control, load simulation, disc-pack stopping, mechanical damping, limited-rotation slip clutching, antibacklash, and similar torque-control applications.

Friction Brakes and Clutches Miniature, high-precision, available for special needs particularly in aerospace, missile, and computer applications.

FOR MOTOR ANALYSIS

Absorption Dynamometers and Accessory Equipment Magtrol absorption dynamometers incorporate hysteresis brakes, thus providing the hysteresis advantages outlined above. Precise torque control permits testing of motors from no-load to locked rotor or armature. Other dynamometer features include variable load capacity through single-knob control on power supply, and calibration in English or metric. Several models. X-Y programming and plotting available.

Dynamometer accessory equipment includes power supplies, tachometer, torque/speed readout, and controller.

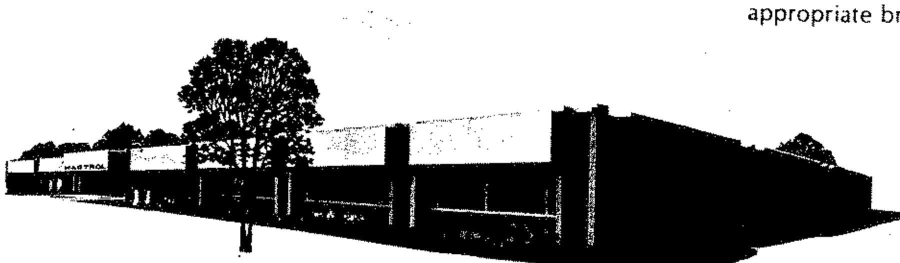
FOR POWER MEASUREMENT

Multi-Range Digital Analyzer A versatile instrument for testing and certifying electric motors and equipment. Simultaneously displays 2-50 amps, 15-600 volts, and 30-30,000 watts. Error-proof and highly accurate, the Magtrol analyzer offers many features including all electronic circuitry and simple plug-in and pushbutton operation.

* * * * * *

Two informative booklets free on request: *Torque Control with Hysteresis Devices*, and *Hysteresis Brakes for the OEM.*

Literature is available on all Magtrol products. Tell us your interests and we'll be happy to send you appropriate brochures.



MAGTROL, INC.

70 GARDENVILLE PARKWAY WEST/BUFFALO, N. Y. 14224

716-668-5555