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# Instruction Manual
for
# Model 636
## Multifunction Power Analyzer

RFL Industries, Inc.
A Dowty Group Company

# Instruction Manual
for
# Model 636
Multifunction Power Analyzer

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Book MA-95200

## Warranty

The Model 636 Multifunction Power Analyzer is warranted for 12 months from date of delivery for replacement of any part which fails during normal operation or service. A deficient part should be returned to the factory, shipping charges prepaid, for replacement f.o.b. Boonton, N.J.

***RFL Industries, Inc.***
*A Dowty Group Company*
***Boonton, New Jersey, U.S.A.***




## WARNING:

The Equipment Herein Described Contains High Voltage

Exercise due care during operation and servicing.
Read safety summary on reverse of this page.

## *SAFETY SUMMARY*

***The following safety precautions must be observed at all times during operation, service, and repair of this product. Failure to comply with these precautions, or with specific warnings elsewhere in this manual violates safety standards of design, manufacture, and intended use of the product. RFL assumes no liability for failure to comply with these requirements.***

### GROUND THE CHASSIS

To minimize shock hazard and to allow the equipment to perform optimally, the chassis and cabinet must be connected to an electrical ground. All equipment is provided with a ground terminal on the rear, or with a three-connector ac power cable. The ground terminal must be connected to an electrical ground by suitable cabling. For its location refer to the wiring diagram for the chassis or cabinet. The power cable must be plugged into an approved three-contact electrical outlet.

### DO NOT OPERATE IN AN EXPLOSIVE ATMOSPHERE

Do not operate the product in the presence of flammable gases or fumes. Operation of any electrical equipment in such an environment constitutes a definite safety hazard.

### DO NOT OPERATE IN WET OR DAMP AREAS

Do not operate the product in wet or damp areas. Operation of any electrical equipment in such an environment constitutes a definite safety hazard.

### KEEP AWAY FROM LIVE CIRCUITS

Operating personnel must not remove covers. Replacement of components and internal adjustments must be made by qualified maintenance persons. Disconnect power cable when replacing components. Under certain conditions, dangerous voltages may exist even with the power cable removed. To avoid injuries always disconnect power and discharge circuits by grounding before touching them.

### DO NOT SERVICE OR ADJUST ALONE

Do not attempt internal service or adjustment unless another person capable of rendering first aid and resuscitation is present.

### DO NOT SUBSTITUTE PARTS OR MODIFY EQUIPMENT

Because of the danger of introducing additional hazards, do not install substitute parts or perform an unauthorized modification to the equipment. The product may be returned to RFL for service and repair to ensure that safety features are maintained.

### DANGEROUS-PROCEDURE WARNINGS

Throughout this manual, warnings identify potentially dangerous procedures. Instructions contained therein must be followed.



## CONTENTS

RFL Model 636 Multifunction Power Analyzer.



# OPERATING INSTRUCTIONS

## DESCRIPTION

The Model 636 Multifunction Power Analyzer is a highly accurate instrument which senses ac voltage, current, phase angle, time interval, and period. From these measurements, it can calculate and display watts, amperes, volts, watthours, VARs, VAR-hours, voltamperes, phase angle, power factor, and frequency.

Voltage ranges are scaled in a 3, 6, 15 format with five significant digits at full scale. This enables potential measurements to be made from one volt to 660 volts with high accuracy. The decimal point for the VOLTS display is automatically switched as the range is changed. Input resistance is 1000 ohms per volt for each range.

Current measurements from 25 mA to 55 amperes are made in nine full-scale ranges. Currents up to 25 amperes are carried through front-panel-mounted binding posts, and currents up to 55 amperes are carried through heavy, low-resistance plug-type connectors on the rear panel. The five-digit AMPERES display provides high resolution over complete current range.

The power analyzer displays watts as true power, that is, EI cos∅. Accuracy at unity power factor is approximately 0.05% of full scale. A correction for lower power factors leads to a derating of accuracy as detailed in the Specifications. The display uses a five-digit readout augmented with a two-digit exponent, in order to cover the extensive dynamic range of the instrument.

## SPECIFICATIONS

**Voltage Ranges:** 15, 30, 60, 150, 300, and 600 volts

**Current Ranges:** 0.1, 0.25, 0.5, 1.0, 2.5, 5, 10, 25, and 50 amperes

**Power Ranges:** Voltage x Amperes

**Watthour/Varhour Ranges:** From 0 to 999.99 x $10^{99}$ maximum

**Accuracy:** At 50-60 Hz, with sinewave full-scale inputs at 23° ±5°C. See notes 1 through 6 for exceptions.

| Function ± | (% Reading | + % Range | + Digit) | See Note |
|---|---|---|---|---|
| VOLTS | 0.03 | 0.02 | 1 | 1a |
| AMPERES | 0.03 | 0.02 | 1 | 1b |
| WATTS (Positive Power) | 0.025 | 0.025 | 1 | 2, 3 |
| WATT HOURS | ).025 | 0.025 | 1 | 3 |
| VAR | 0.07 | 0.02 | 1 | 1b, 4 |
| VAR HOURS | 0.07 | 0.02 | 1 | 1b, 4 |
| P.F. | 0.07 | 0.025 | 1 | 1b, 3 |
| VA | 0.07 | 0.02 | 1 | 1b |
| DEG (phase angle) | ±0.2° (for angles between -170° and +170°) | | | |
| FREQ | ±0.02 Hz(35 to 450 Hz) | | | |

**Notes 1(a) and 1(b):** To determine accuracies at less than full scale, divide percent of range, given in the foregoing table, by the following factors:

(a) $F_a$ or $F_v$ or,

(b) $\sqrt{F_a \times F_v}$ where:

$F_v$ = the fractional reading of the full-scale voltage range, and

$F_a$ = the fractional reading of the full-scale current range.

For example, if one reads 4.0 amperes on the 5-ampere range, then $F_a = 4/5 = 0.8$. Then, by dividing the full-scale accuracy of the chosen range by $F_a$, we obtain 0.02/0.08 = 0.025% of range at the 4-ampere point. Thus, the accuracy of the 4-ampere reading, as read on the 5 ampere range is ±(0.03% of reading + 0.025% of Range + 1 digit).

**Note 2:** Accuracy applies for all positive-sign power readings. For reversed power reading (negative-sign), accuracy is ±(0.05% Reading + 0.05% Range +0.05% Range +1 Digit).

**Note 3:** Add (0.01 tan ∅) percent to watts, watthour, or power-factor accuracies when the power factor is less than unity.

**Note 4:** Add (0.03 ctn ∅) to var and varhour accuracy when the power factor is greater than zero.

**Note 5:** Accuracies hold for 25 to 110% of full-scale range for measurements of volts, amperes, degrees, voltamperes, and frequency. Accuracies hold for 10 to 120% of full-scale range for measurements of watts, watthours, vars, varhours, and power factor.

**Note 6: Temperature Derating:** TC ± 20 ppm/°C except for volts and watts i.e., on 15V range, add +20 ppm/°C; on 30V range, add +10 ppm/°C.

**Operating-Temperature Range:** 0 to 40°C.

**Humidity Range:** 20 to 80% relative humidity.

**Voltage Burden:** 1000 ohms per volt.

**Current Burden:** At 60 Hz, current burdens are somewhat less than the maximum voltages shown in the following table:

| RANGE AMP | BURDEN VOLTS | RANGE AMP | BURDEN VOLTS | RANGE AMP | BURDEN VOLTS |
|---|---|---|---|---|---|
| 0.10 | 0.025 | 1.0 | 0.25 | 10 | 0.15 |
| 0.25 | 0.015 | 2.5 | 0.15 | 25 | 0.075 |
| 0.50 | 0.015 | 5.0 | 0.15 | 50 | 0.10 |

**Size:** 19" (48.3 cm) W x 7" (17.8 cm) H x 16" (40.6 cm) D

**Weight:** 30 pounds (13.6 kg)

**Power:** 115/230 Vac (switch selectable); 50/60 Hz

**Options:** IEEE-488 Bus Interface, DC Calibration Module

## INSTALLATION

Prior to connecting the instrument to a source of power, one should check the line-voltage adjustment, marked on the rear panel, to be certain that it is set for the line voltage to be used. On the rear panel, one of the two rectangles will be marked to designate the line-voltage setting when the instrument left the factory. If the marking does not agree with the line voltage to be used, check that the power cord is disconnected and then remove the top cover. The input-voltage selector will be found on the main circuit board, at the bottom of the cabinet, and it may be moved to indicate the desired powerline voltage. After making any necessary changes, the top cover should be replaced and the rear-panel marking should be changed to show the current status of the power-input circuit.

**CAUTION**

To avoid exposure to hazardous voltages, observe procedure given on Pages iii and iv.

If the power analyzer is to be used in a system with other equipment, the proper connections to the accessory jack, and to the IEEE-488 Bus connector, if used, should be made at this time.

## OPERATION

The Model 636 Multifunction Power Analyzer is provided with two input circuits, one for voltage and one for current. They can be used independently for measurement of rms-volts or rms-amperes, but most of the functions for which the power analyzer is especially useful require signals simultaneously at both inputs.

**CAUTION**

Input leads to the Model 636 Multifunction Power Analyzer can have potentials as high as 1500 volts peak-to-peak.

Because high voltages are hazardous, operators are cautioned to make connections only when the circuit under test is de-energized, at which time connections should be made correctly, firmly, and tightly to preclude any subsequent need for touching them.

Front and rear views of the power analyzer are shown in Figure 1.

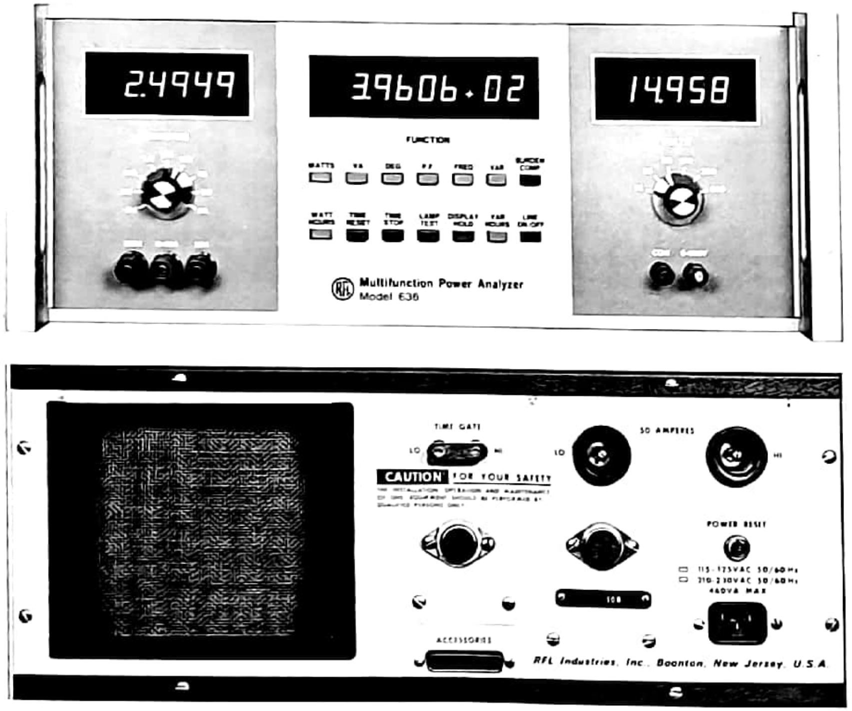



Figure 1. Front and rear panels of Model 636.



## CURRENT INPUTS

The current inputs will accept currents between 25 mA and 55 amperes, and the instrument will display them to the specified accuracies. Currents between 10 and 25 amperes should be connected through the 25-ampere terminal on the front panel. Currents between 25 and 55 amperes must be connected through the jacks provided on the rear panel. The AMPERES range switch does not switch the 25- and 50-ampere inputs, but it is essential that the range corresponding to the input terminals used be selected on this switch. If a crest factor of 3 is exceeded, the most-significant digit of the AMPERES display will flash to indicate that a higher range should be selected. If the input current exceeds 110% of range, the AMPERES display will extinguish until the appropriate range is selected.

## VOLTAGE INPUTS

Voltage inputs are connected to the voltage-common terminal and the 0-600 terminal. The instrument operates within specifications for voltage inputs between 3.75 and 660 volts. If an input range is overdriven, a protective circuit will open the voltage-input circuit. This indicates that a higher range should be selected. After about two seconds, the protective relay will close and sample the input, and if it is now within range, the relay will remain closed. If a crest factor of 2 is exceeded, the most significant digit of the VOLTS display will flash to indicate that a higher range should be selected. If the input exceeds 110% of the range selected, the display will blank until the appropriately higher range is chosen.

## FUNCTION DISPLAY AND CONTROLS

The FUNCTION display has 14 pushbuttons associated with it. The lower right-handed red button is the Power ON-OFF switch. At the upper left is the WATTS switch. Selecting this function will display power consumed by the load, on the FUNCTION display, in scientific notation. Be certain that the WATTHOURS button is released. The operator is cautioned, as follows, when interpreting the WATT, VOLT-AMPERE, WATTHOUR, VAR, and VARHOUR display. If a full-scale reading is greater than 1.0000 EXX, and a down-range reading is made below 1.0000 EXX, the five-digit readout will shift left by one digit, and the exponent will be reduced by 1. The operator should disregard the least-significant digit of the five-digit display since it is no longer significant. If a negative mantissa is obtained, this indicates that either the current or the voltage input is reversed; and it is recommended that the phasing between inputs be corrected to obtain positive power displays. When the VA button is depressed, the product of volts and amperes will be displayed. When the DEG switch is depressed, the display will indicate the phase difference between the current and voltage inputs, using the voltage channel as the reference phase. A negative display indicates a lagging current. A positive display shows a leading current. The phase angle is derived by using zero-crossing detectors, so that if significant distortion exists on the input signals then the possibility of an erratic or erroneous reading should be considered when interpreting the display.

Depressing the PF (power factor) button will display the power factor, which is derived by dividing the watts reading by the voltampere product.

Pressing the FREQ button will display the frequency of the signal connected to the VOLTS input. A current input is still required to display frequency.

Pressing the VAR button will display reactive volt-amperes on the FUNCTION display; but one must be certain that the VARHOURS button is released. The VAR indication is derived by taking the product of EI sin Ø. If the input signals are significantly distorted, then the possibility of an erratic or erroneous reading should be considered when interpreting the display.

Figure 2 shows the generally accepted arrangement of connections when both current and voltage inputs are energized. Observe that the current drawn by the voltage input, the so-called burden of the voltage-input circuit, is drawn through the current-input terminals. This means that when functions such as watts, watthours, vars, varhours, and voltamperes are displayed the indications are in error by an amount determined by the current burden of the voltage-input circuit. Because one knows the input sensitivity of the voltage channel is 100 ohms per volt, the error can be calculated so that the displayed information can be corrected. In the Model 636, however, a feedback circuit from the voltage to the current channel is provided so that when the BURDEN COMP button is depressed this correction is made automatically. When this is done, the correct power is indicated for all current ranges.

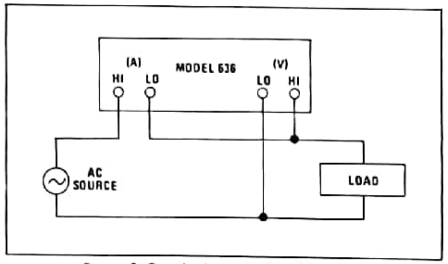



Figure 2. Standard connections for measuring power.

Note that if the voltage channel is connected not as in Figure 2, but to the supply side of the power source, the burden-compensation circuit is not only ineffective but its use will give erroneous results.

The watthour computation is made by pressing both the WATTS and the WATTHOURS buttons. The period over which watthours are computed starts when the TIME RESET button is released, and it continues until the TIME STOP button is pressed. Watthour periods can also be controlled with logic signals connected through TIME GATE terminals provided on the back panel for this purpose. Logic levels are +2.7 volts (HI) and 0 volts, or ground, (LO). Th measuring interval is started with a logic LO, stopped with a logic HI. The display is cleared, at any time, by pressing the TIME RESET button. Note that the TIME RESET button must be pressed before each measurement when using the external TIME GATE input in order to reset the internal counters.

The minimum time interval for measuring watthours and varhours is two seconds. This minimum period is established so that the accuracy specification of the power analyzer is met for these measurements.

Pressing LAMP TEST should cause all segments to be displayed in all positions on all three displays. The DISPLAY HOLD button is a push-push type switch which freezes the display to enable an operator to record data for a particular point in time. During the DISPLAY HOLD period, the decimal points will flash.

To measure varhours, the VARHOURS button must be depressed along with the VAR button. Varhours are measured similarly to watthours; that is, using either the front-panel buttons or an external gate (at the back panel).

## REAR PANEL

A power receptacle is provided for connecting an ac line cord to the instrument. Two jacks are provided for current inputs in the range between 25 and 55 amperes. A black (LO) and red (HI) jack accommodate external-gate inputs. The shorting plug provided should be used whenever the front-panel time-control buttons are used.

A two-ampere circuit breaker, with reset button on the rear panel, is provided to protect against circuit failures that could cause internal damage to the instrument.

An EIA connector is located at the bottom of the rear panel for connecting accessories. Two pins in that connector provide signals from the active transformers, and an oscilloscope may be used to monitor a facsimile of the waveshapes of incoming signals at these points. The output-signal level is 4 Vrms for full-scale input, and the signals are provided through 10K isolation resistors. Output-signal level accuracy is as follows:

$$\text{Volts} = \pm(0.04\%\ \text{Reading} + (\frac{0.01}{F_V})\%\ \text{Range} + 1\ \text{Digit})$$

$$\text{Amps} = \pm(0.04\%\ \text{Reading} + (\frac{0.01}{F_I})\%\ \text{RAnge} + 1\ \text{Digit})$$

where $F_V$ = fractional reading of the full-scale voltage range.

and, $F_I$ = fractional reading of the full-scale current range.

When the optional IEEE-488 Bus Adapter is used, the standard connector for this function is provided on the rear panel.

The air filter should be cleaned periodically.

## DISPLAY-INTENSITY CONTROLS

The display intensity can be adjusted as follows: Removing two screws and sliding the top cover back will provide access to four potentiometers located on the switch board. The VOLTS and AMPERES display intensities are each affected by one pot. The FUNCTION display intensity is affected by two pots; one for the five-digit display and one for the exponent. The figure below shows the location of each potentiometer used to adjust display intensity.

## APPLICATION DATA

RFL has published application data for power-measuring equipment in a 29-page booklet titled *Power Measurement Handbook*. This text reviews the classical approaches to the measurement of power and discusses the application of instruments such as the Model 636, and others, to measuring both single-phase and polyphase power. Single copies are available on request.

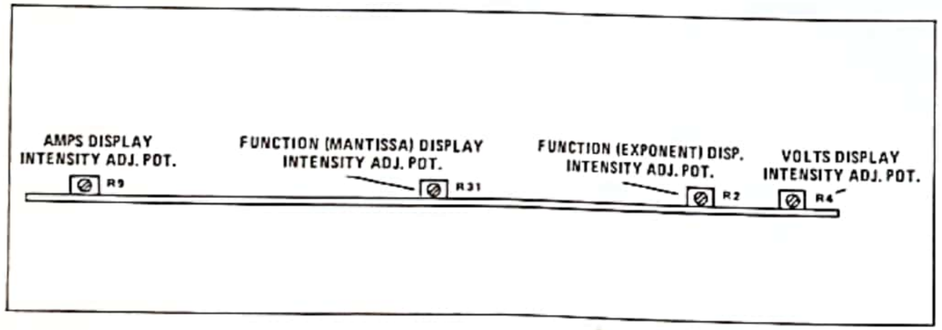



Figure 3. Switch Card, (located behind front panel).



# CALIBRATION

**CAUTION**
To avoid exposure to hazardous voltages, observe procedures given on Pages iii and iv.

## INTRODUCTION

The Model 636 is constructed with a main frame which carries the power supply, front and back panels, the main circuit board, and a card cage holding several circuit cards which carry most of the circuits of the power analyzer. Circuit-symbol numbers are based upon the assignment of a different number series for each card so that the card on which any circuit component is located can be determined from its number. The following table identifies circuit cards, their number series, and associated mating connector.

Circuit cards are mounted in their card-cage in numerical sequence with the lowest number series at the back and the highest at the front. The options card slot is intended to carry the optional IEEE-488 Interface card when that card is used. In some instruments this card slot may be vacant.

The Model 636 calibration procedure in its entirety includes three main parts, namely:

(a) Functional Tests - to be sure that the instrument is operational and that its calibration can be validated.

(b) Calibration Procedures - to set up voltage-levels within specification.

(c) Validation Procedure - to validate accuracy of all measured parameters.

These operations can be done by the user, or the instrument may be returned to RFL for calibration, if desired.

| Assembly Number | Description | Number Series | Connector J-number |
|---|---|---|---|
| --------- | Slot for options card | 100 | J1 |
| 95230 | Real-Time card | 200 | J2 |
| 95225 | Processor card | 300 | J3 |
| 95220 | Clock-Generator card | 400 | J4 |
| 95095 | Phase card | 500 | J5 |
| 95090 | Analog-to-Digital (A/D) card | 600 | J6 |
| 95075 | Watts Multiplier card | 700 | J7 |
| 95080 | Volts and Amps Multiplier card | 800 | J8 |
| 95085 | Transformer Electronics card | 900 | J9 |
| 95060 | Power Supply/Mother Board | 1000 | J10 |
| 95070 | Switch card | 1100 | J11 |
| 95065 | Display card | 1200 | J12 |
| --------- | IEEE-488 Interface card option | 100 | J1 |
| HB-95260 | DC Calibration card (option replaces V/A Electronics card) | 900 | J9 |

Calibration of nearly all circuit cards requires two voltage sources capable of delivering both positive and negative 4 Vdc with an accuracy of at least 0.01%, to simulate the current- and voltage-input signals. These sources may either be a standard, commercial precision calibrator, or they may be provided by RFL Model HB-95260 DC Calibration Card. This is a special tool designed for calibrating the Model 636, and it may be purchased from RFL. This card carries a stable voltage reference and stable buffer amplifiers for the two outputs. It is calibrated with the DC differential voltmeter used for most calibration procedures, and it is used by plugging it into the 900-Series card slot in the Model 636. Refer to Appendix A of this manual.

## FUNCTIONAL TESTS

This group of tests is provided to ensure that all functions of the unit under test are operating. Upon completion of the functional tests the instrument should be completely functional and is ready for calibration.

### Test Equipment Required

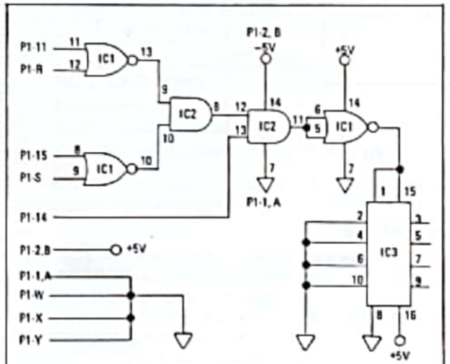
(1) RFL Model HB-95260 DC Calibration module.

(2) Simpson Model 260 Multimeter, or equal.

(3) A 0.1$\mu$F, 50-volt capacitor.

(4) A nominal 150-ohm, 5-watt resistor, measured to $\pm$0.5%.

(5) Fluke Model 883 AB, Differential AC/DC Voltmeter, or equal. When using the Fluke Model 883AB to calibrate the Series 700 Watts Multiplier Board and the Series 800 Volts and Amps Multiplier Board, a 5K-ohm isolation resistor should be used in series with th high lead of the voltmeter.




| IC # | TYPE OF IC |
|---|---|
| 1 | SN7402N |
| 2 | SN7408N |
| 3 | DM8097N |

NOTE: This card is used in place of the Series 600 A/D Card. Keying slot is between pins 15 & 16.

Figure 4. Schematic of crest-factor test card.

(6) If it is desired to test for crest factor of the voltage and current channels, a test card may be built following the schematic shown in Figure 4. This circuit should be assembled on a card which will fit Socket J6, where it is installed in leiu of the Series 600 Analog-to-Digital (A/D) Card when making these tests.

(7) The following signal-generation and -control equipment:

(a) An ac supply for the voltage and current inputs capable of supplying 600 volts, and 0 to 0.5 ampere, over a frequency range of 40 to 400 Hz, and with its phase variable from 0 to 45 degrees, minimum. Refer to Figure 5.

(b) Two RFL Model 828 AC/DC V-A Sources, or two RFL Model 829G Calibration Standards, or one of each, or equivalent signal sources. The two sources are connected with their external inputs controlled by the Model 809 (see below), and they are used to excite the current and voltage circuits of the Model 636 under test.

(c) An RFL Model 809 Phase Generator/Meter to control and indicate the relative output phase of the voltage and current sources listed as Item (7b).

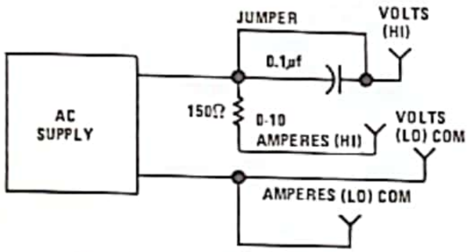



Figure 5. AC-supply connections for functional tests

## Procedure

(1) Remove the Series 900 Transformer Electronics Card and install the Model HB-95260 DC Calibration Module in the slot thereby vacated. Set both channels of the calibration module to ON and to -4Vdc. See Figure 6 for location of all adjustments.

(2) Connect the differential voltmeter to the calibration module with the LO lead to TP1, HI lead to TP2. Adjust R1 for -4.000, ±0.05 mVdc.

(3) Select 4 volts for both signal inputs and adjust R2 for 4.000 ±0.05 mVdc.

(4) Repeat Steps (2) and (3) until the required accuracy of ±0.05 mV is obtained with positive and negative inputs.

(5) Using calibration module, apply 4 Vdc to both inputs, select the WATTS function. Then, in sequence select the current and voltage ranges in the first two columns of Table 1, below, and confirm that the respective current, voltage, and power indications are obtained. Be certain that WATTHOURS and BURDEN COMP are released.

Table 1

| Selection | | DISPLAYS | | | |
|---|---|---|---|---|---|
| | | | | WATTS | |
| AMPS | VOLTS | AMPERES | VOLTS | Mantissa | Exp |
| 0.1 | 15 | 10000 ± .00002 | 15.000 ± .003 | 1.5000 ± 0.0003 | E00 |
| 0.25 | 15 | 25000 ± .00004 | 15.000 ± .003 | 3.7500 ± 0.0005 | E00 |
| 0.5 | 30 | 50000 ± .00006 | 30.000 ± .004 | 1.5000 ± 0.0003 | E01 |
| 1.0 | 60 | 1.0000 ± .0002 | 60.000 ± .007 | 6.0000 ± 0.0007 | E01 |
| 2.5 | 60 | 2.5000 ± .0004 | 60.000 ± .007 | 1.5000 ± 0.0003 | E02 |
| 5.0 | 150 | 5.0000 ± .0006 | 150.00 ± .03 | 7.5000 ± 0.0009 | E02 |
| 10 | 300 | 10.000 ± .002 | 300.00 ± .04 | 3.0000 ± 0.0004 | E03 |
| 25 | 300 | 25.000 ± .004 | 300.00 ± .04 | 7.5000 ± 0.0009 | E03 |
| 50 | 600 | 50.000 ± .0008 | 600.00 ± .07 | 3.0000 ± 0.0004 | E04 |

(6) Select the 600V and the 50A ranges, and the VA function. The FUNCTION display should read 3.0000 ±0.0004 E04.

(7) Change the VOLTS inputs to -4 volts. The FUNCTION display should again read 3.0000 ±0.0004 E04.

(8) Continuing with the same input voltages, select the WATTS function. The display should read -3.0000 ±0.0004 E04.

(9) Press the WATTHOURS switch.

(10 Press TIME RESET and start measuring for one minute starting at the moment of release. After precisely one minute, press the TIME STOP switch. The FUNCTION display should read -5.0000 ±0.0004 E02.

(11) Press DISPLAY HOLD. Switch both inputs on the calibration module to ground. Release WATTHOURS. The display should remain unchanged, but all three decimal points should be flashing.

(12) Release DISPLAY HOLD. All displays should read zero.

(13) Press LAMP TEST. All display numerals should read 8, and the negative and positive signs and two decimal points should appear in the FUNCTION display.

(14) Remove the calibrator module and reinstall the Series 900 Transformer Electronics Card.

(15) Connect the ac supply shown in Figure 5 to the voltage and current inputs of the device under test.

(16) Select the 15-volt and the 0.1-ampere ranges.

(17) Adjust the ac supply so that 15 volts and 0.1 ampere are displayed.

(18) Select the WATTS function. The display should read approximately 1.5000 E00.



(19) Select the FREQ function and vary the supply frequency. The FUNCTION display should track the supply frequency.

(20) Select the DEG function. The FUNCTION display should read approximately 000.00.

(21) Select the P.F. function. The display should read 1.0000.

(22) Select the VAR function. The FUNCTION display should read 000.00.

(23) Remove the jumper from across the 1.0μF capacitor shown in Figure 5, and adjust the ac source to about 60 Hz.

(24) Select the DEG function. The FUNCTION display should read approximately 60.00.

(25) Select the P.F. function. The display should read about 0.5000.

(26) Using the two calibrators described in Item (7b) of the list of test equipment required, and an RFL Model 809 Phase Generator/Meter, set the frequency of the assembly at 60 Hz and adjust the current input to the device under test so that it lags the voltage by 45 degrees, as indicated by the Model 809.

(27) Note and record the reading of the FUNCTION display.

(28) Select the VAR function. The FUNCTION display should read approximately the same as in the foregoing.

(29) Observe the AMPERES display. Depress the BURDEN COMP button. The indication of the AMPERES display should decrease by approximately 68 counts with full-scale voltage input applied.

(30) Release BURDEN COMP.

(31) Select VARHOURS.

(32) Press and release TIME RESET.

(33) After precisely one minute, press TIME STOP.

(34) Note and record the reading of the FUNCION display.

(35) Select WATTS and depress WATTHOURS.

(36) Press TIME RESET.

(37) After precisely one minute, press TIME STOP.

(38) The FUNCTION display should read approximately the value recorded in Step (34).

(39) If a Crest-Factor card is availablo, install it in place of the A/D Converter in Connector J6, used for the Series 600 Card, and replace the jumper across the 0.1μF capacitor shown in Figure 5. If a Crest-Factor card is not available, continue to Step (43).

(40) Monitor the ac supply voltage to the inputs with a multimeter.

(41) Increase the supply voltage until the most-signifiant digit on the VOLTS display starts to flash. The reading on the multimeter should be 21.1 ±2.1 volts.

(42) Increase the ac supply voltage until the most-significant digit of the AMPERES display starts to flash. The reading on the multimeter should be the product of 0.2112 times the actual measured value of the 150-ohm resistor, ±10%. This is approximately 31.68 volts.

(43) Connect an oscilloscope between TP1 (LO) and TP3 (HI) of the Series 900 Transformer Electronics Card. Reduce the signal from the ac supply, Figure 5, until a signal of approximately 20 Vp-p is shown on the oscilloscope.

(44) Increase the input voltage until the signal just disappears, although occassional spikes caused by the overvoltage relay may be seen every one to three seconds. The multimeter should read 31.8 ±6.4 volts.

(45) Remove all test cards and replace with the original cards.

(46) Close up the equipment.

## CALIBRATION PROCEDURE

The Model 636 Power Analyzer is designed to perform a wide range of precision measurements. To accomplish this, calibration tests are required to set up various internal AC and DC output levels to within the specifications contained herein.

## TEST EQUIPMENT REQUIRED

(1) Fluke Model 883 Differential Voltmeter or equivalent.

(2) DC Calibration Card, RFL Model HB-95260. See Appendix A.

(3) Frequency counter capable of measuring 3.2MHz ±100 Hz.

**NOTE:**
When performing calibration, all pc boards should be plugged down in unit and not on extender cards.

## PROCEDURE

(1) Disconnect all external inputs to the Model 636. Turn off power and remove top cover. Remove Series 900 Xfmr. electronics card and replace with DC calibration card. Turn on power and allow minute warm-up. Set AMPERES range switch to 5A and the VOLTS range switch to 150V. Calibrate the cards as follows:

(2) DC Calibrator Module:
(a) See Figure 6 for component locations.
(b) Set switchs S1 and S3 to ON and switches S2 and S4 to -4V.

(c) Connect the voltmeter to TP1 (LO) and TP2 (HI).
(d) Adjust R5 for -4 Vdc ±0.2 mV.
(e) Switch S2 to +4V.
(f) Adjust R6 for +4 Vdc ±0.2 mV. The calibration of the card is then complete.

(3) Watts Multiplier Card (Series 700):
(a) See Figure 7 for component loctions.
(b) Set switches S1 (Amps input) and S3 (Volts input) on DC card to ground. Connect the voltmeter to TP1 (LO) and TP2 (HI) of the Series 700 card. Adjust R42 for 0 to ±0.05 mV. Move the HI lead of the voltmeter to TP3 and adjust R43 for 0 to ±0.05 mV.
(c) Set VOLTS input to -4 Vdc. Adjust R41 for 0 to ±0.05 mV at TP3.
(d) Set VOLTS input to -4 Vdc. Note the output voltage and adjust R41 for ½ the difference of the noted voltage. Switch the VOLTS input to +4 Vdc and adjust R41 until the same reading is obtained for either polarity input.
(e) Perform the following measurements and complete the table:

| AMPS Input | VOLTS Input | *Nominal 2.500V* |
|---|---|---|
| +4 Vdc | +4 Vdc | +2. ______ |
| +4 Vdc | -4 Vdc | -2. ______ |
| -4 Vdc | +4 Vdc | +2. ______ |
| -4 Vdc | -4 Vdc | -2. ______ |

Average Magnitude = ____________

Measure the output voltage at TP3 for all the above combinations of input polarities. Adjust R41 to obtain a magnitude balance among the four measurements which should be within ±0.5 mV. When computing the average magnitude disregard the sign of the voltage.

(4) Volts/Amps Multiplier card (Series 800):
(a) See Figure 8 for component locations.
(b) Set S1 (Amps input) on DC card to ground. Connect the voltmeter to TP1 (LO) and TP2 (HI) on Series 800 card. Adjust R30 for 0V ±0.05 mV. Move the HI of the voltmeter to TP3 (Amps output). Adjust R37 for 0V ±0.05 mV.

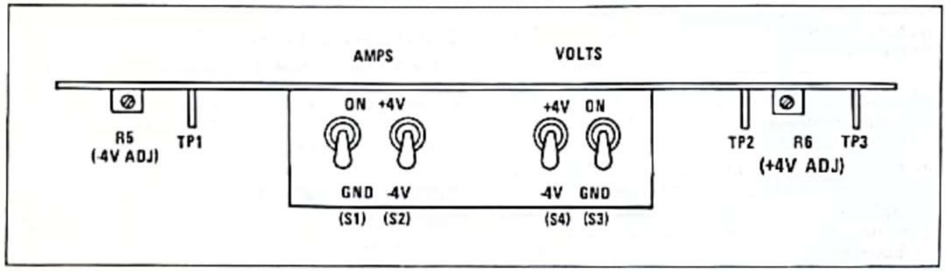



Figure 6. DC calibrator module, location of adjustments

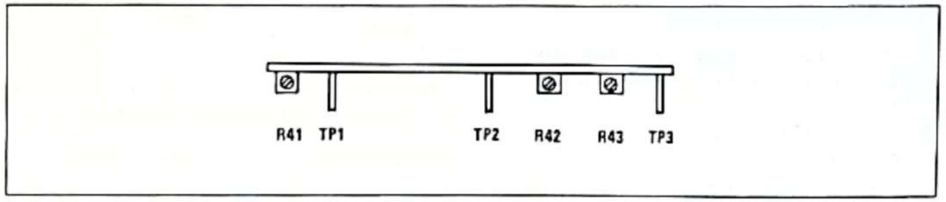



Figure 7. Watts multiplier card, (Series 700), location of adjustments

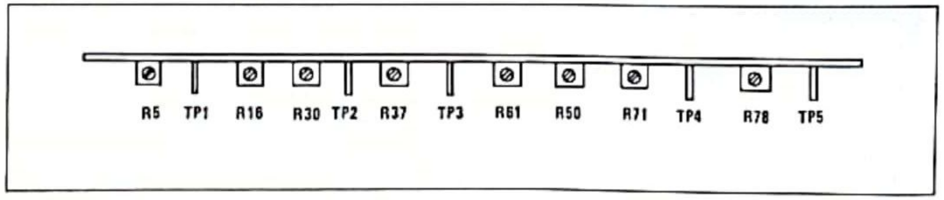



Figure 8. Volts/Amps multiplier card, (Series 800), location of adjustments



(c) Set Amps input to 4 Vdc. Note the output voltage which is nominally 2.5 Vdc.
(d) Set Amps input to -4 Vdc. Note the output voltage. Adjust R16 to ½ the difference between the voltages obtained in Steps (c) and (d).
(e) Repeat Steps (c) and (d) until the same voltage is obtained for both positive and negative 4 volts. Note the final value of the output voltage. On the Series 800 card, adjust R5 (gain) to match the computed output voltage of the Watts Multiplier. Repeat Steps (c), (d), and (e).
(f) Set VOLTS input (S3) on the DC Calibrator Module to GND. On the Series 800 card, connect the voltmeter to TP1 (LO) and TP4 (HI). Adjust R71 for 0 to ±0.05 mV.
(g) Set the VOLTS input from the DC Calibrator Module to 4 Vdc. At TP5, note the output voltage, which is nominally 2.5 Vdc.
(h) Set the VOLTS input to -4 Vdc. Note the output voltage, and adjust R61 to ½ the difference between the voltage observed in Steps (g) and (h).
(i) Repeat Steps (g) and (h) until the same voltage is obtained for either polarity of input. Note the final value of the output, and adjust R50 for the same output voltage as that obtained for the Watts Multiplier at Step (e). Repeat Steps (f), (g), and (h).

(5) A/D Card (Series 600):
(a) See Figure 9 for component locations.
(b) Set both Amps input and Volts input on DC Calibrator module to +4 Vdc.

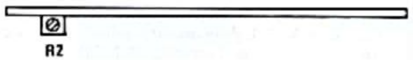



Figure 9. Analog-to-digital (A/D) card, (Series 600), location of adjustments

(c) Select the WATTS function on the Model 636. Then set AMPERES range to 5A, and VOLTS range to 150V.
(d) Adjust R2 on A/D card until a reading of 7.50000 E02 ±.0004 is obtained on the FUNCTION display. The AMPERES display should read 5.0000 ±.0005 and the VOLTS display should read 150.00+.02.
(e) Switch both Amps and Volts on the DC card to -4 Vdc.
(f) The FUNCTION display should read 7.5000 ±.008. The AMPERES display should read 5.000 ±.0005. The VOLTS display should read 150.00+.02. The A/D calibration is then complete.

(6) Clock Generator card (Series 400):
(a) See Figure 10 for component locations.
(b) Connect a frequency counter to TP1 (LO) on the Series 700 Watts Multiplier and to TP1 (HI) on the Series 400 Clock Generator.
(c) Adjust C1 to obtain a reading of 3.2000 ±.001 MHz.

(7) Remove DC calibration card from Series 900 slot and insert Series 900 Transformer Electronics Card in its place.

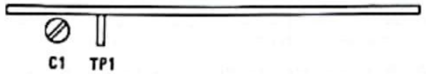



Figure 10. Clock-generator card, (Series 400), location of adjustments

(8) Transformer Electronics Card (Series 900):
(a) Figure 11 shows the locations of adjustments and connections.
(b) Connect the voltmeter to the transformer card between TP1 (LO) and TP2 (HI) and adjust R1 for 0 ±0.1 mVdc after following 5 minutes for warmup.
(c) Move the HI lead of the voltmeter to TP3 and adjust R9 for 0 +0.1 mVdc. This adjustment has a slow response, and one may overshoot the desired point if the control is turned too quickly. When this step is finished, the calibration of the Model 636 is completed.

(9) Disconnect all meters and replace top covers. Check the performance of the Model 636 by using the validation procedure.

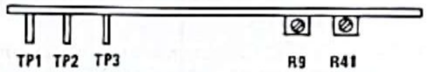



Figure 11. Transformer electronics card, location of adjustments

## VALIDATION PROCEDURE

The Model 636 Multifunction Power Analyzer directly measures rms amperes, rms volts, true power, phase angle, signal period, and time interval. From these direct measurements it derives power factor, voltamperes, vars, varhours, and frequency. This validation procedure is performed to validate the accuracy of all directly and indirectly measured parameters. The procedure assumes that the functional and calibration tests, described in the foregoing, have been properly executed.

Prior to validation, the unit must have been closed and energized for at least one hour.

### Test Equipment Required

In general, accurate sources or means for measuring voltage, current, power, and frequency are required. The following list is only exemplary, and other means for making the requisite measurements may be used, providing the needed accuracy, generally 0.01%, is obtained:

(1) Two RFL Model 828 AC/DC V-A Sources, or two RFL Model 829G Calibration Standards, or one of each, or equivalent signal sources.
(2) RFL Model 809 Phase Generator/Meter.
(3) Fluke Model 887AB Differential AC/DC Voltmeter.

(4) Scientific Columbus Type SC-60 Computing Watt/Watthour Standard, Model 6253A, with calibration traceable to the National Bureau of Standards (NBS).

(5) A precision 100-ohm resistor with an accuracy of at least 0.01%.

(6) A frequency counter such as the Hewlett-Packard Model 5300, or equal.

## Procedure

(1) Perform the measurements indicated in Table 2, using a 60-Hz input signal synchronized to the powerline, if in a 60 Hz area. All readings should fall within the limits shown.

(2) Disconnect all input signals and connect the watthour standard to the inputs. This standard should have been energized for at least one hour prior to use.

(3) Install the 1000-ohm precision resistor on the analog-output terminals of the watthour standard. The resistor should be installed and then the shorting strip removed carefully so that at no time is the circuit opened Connect the differential voltmeter across the precision resistor.

(4) Adjust the unit under test to its 150-volt and 5-ampere ranges.

(5) Select the WATTS function and adjust the input voltage and current, nominally at 120 volts and five amperes, 60 Hz, and 0 degrees, until the FUNCTION display reads 6.0000 E02 ±6 counts.

(6) The differential voltmeter should read 1.200 ±0.00054 Vdc after correction for the NBS calibration of the watthour standard.

(7) Set up the test equipment to provide input signals of 120 volts, 5 amperes, and a current-lagging power factor of 0.5.

(8) The differential voltmeter should read 0.600 ±0.00024 Vdc after correction for the NBS calibration of the watthour standard. Press the DEG function switch and check for a reading of 60 ±0.15 degrees.

(9) Perform a watthour measurement at 120 Vac, 5 amperes, 60 Hz, 0° phase angle. The full-scale ranges of the unit under test should be 5 amperes and 150 volts.

Set up the watthour standard with $N_S = 10{,}000$, $K_h = 0.6$, $M = 0.0006$. Connect the gate terminals of the standard to the TIME GATE terminals of the Model 636. When the internal-gate button (IG) of the watthour standard is pushed, a timed period will be initiated, at the end of which the Model 636 should indicate 6.0000 E01 ±0.0018 watthours. The watthour standard should be corrected for its NBS calibration.

(10) Set the input signals for 120 volts, 5 amperes, with current lagging 60 degrees, power factor at 0.5.

(11) On the Model 636, press TIME RESET. Select WATTS and WATTHOUR functions, and then press the internal-gate button (IG) on the watthour standard. At the end of the period, the Model 636 should read 6.0000 E01 ±0.01 watthours, after correction for the NBS calibration of the watthour standard.

(12) If the watthour standard is calibrated at a leading phase angle, check also at that point.

(13) Repeat each watthour test twice by pressing TIME RESET on the Model 636 and the internal-gate button on the watthour standard. At the end of each period, the FUNCTION display of the Model 636, in watthours, must be within the limits stated in Step (11).

(14) Change the phase angle to the input signal to -45 degrees, current lagging, power factor equal to 0.7070 ±0.0005 counts.

(15) Select VAR and VARHOUR functions on the Model 636, and press TIME RESET. Then press the internal-gate button (IG) on the watthour standard. At the end of the period, the FUNCTION display should read -6.0000 E00 ±0.02 counts.

(16) Release VARHOURS button. Select P.F. function. Check and, if necessary, adjust input signals for a power factor of 0.7070 ±0.0005 counts.

(17) Select the WATTS function. The FUNCTION display should read 4.2420 E02 ±0.0200 counts. Then select the VARS function. The reading should be 4.2420 E02 ±0.2000 counts.

(18) Disconnect the watthour standard.

(19) Set up the input signals for 120 volts, 5 amperes, 50 Hz, and monitor the frequency with the frequency counter. Select FREQ on the Model 636. The indications must agree within 0.01 Hz.

(20) Select 400 Hz for the input-signal frequency and make a measurement similar to that outlined in Step 19. Frequency must agree within 0.01 Hz. This completes the validation procedure.

## TABLE 2

| INPUT SIGNALS | | | | | | ACCEPTANCE LIMITS – UNIT UNDER TEST | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AMPS | | VOLTS | | WATTS (NOMINAL) | PHASE SHIFT DEG | AMPS | | VOLTS | | WATTS | VA | DEG | VAR | P.F. |
| RANGE | INPUT | RANGE | INPUT | | | RANGE | READING | RANGE | READING | | | | | |
| 0.1 | 0.02500 | 15V | 3.750 | 9.3750E-02 | 0 | 0.1 | .02506 / .02494 | 15 | 03.759 / 03.741 | 9.4200E-02 / 9.3300E-02 | 9.4200E-02 / 9.3300E-02 | 0.10 / -0.10 | 0.0000E-XX / 1.6441E-04 | 1.0000 / 0.9987 |
| 0.1 | 0.05000 | 15V | 3.750 | 1.8750E-01 | 0 | 0.1 | .05004 / .04996 | 15 | 03.579 / 03.741 | 1.8780E-01 / 1.8720E-01 | 1.8810E-01 / 1.8690E-01 | 0.10 / -0.10 | | 1.0000 / 0.9989 |
| 0.1 | 0.02500 | 15V | 7.500 | 1.8750E-01 | 0 | 0.1 | .02506 / .02494 | 15 | 07.506 / 07.494 | 1.8780E-01 / 1.8720E-01 | 1.8810E-01 / 1.8690E-01 | 0.10 / -0.10 | | 1.0000 / 0.9989 |
| 0.1 | 0.05000 | 15V | 7.500 | 3.7500E-01 | 0 | 0.1 | .05004 / .04996 | 15 | 07.506 / 07.494 | 3.7530E-01 / 3.7470E-01 | 3.7560E-01 / 3.7440E-01 | 0.10 / -0.10 | | 1.0000 / 0.9991 |
| 0.1 | 0.10000 | 15V | 15.000 | 1.5000E+00 | 0 | 0.1 | .10004 / .09996 | 30 | 15.013 / 14.987 | 1.5006E00 / 1.4994E00 | 1.5019E00 / 1.4981E00 | 0.10 / -0.10 | | 1.0000 / 0.9913 |
| .25 | 0.25000 | 30 | 30.000 | 7.5000E+00 | 0 | 0.25 | .25009 / .24991 | 60 | 30.010 / 29.990 | 7.5024E00 / 7.4976E00 | | 0.10 / -0.10 | | |
| .50 | 0.50000 | 60 | 60.000 | 3.0000E+01 | 0 | 0.5 | .50016 / .49984 | 150 | 60.019 / 59.981 | 3.0012E01 / 2.9988E01 | | 0.10 / -0.10 | | |
| 1.0 | 1.0000 | 150 | 120.00 | 1.2000E+02 | 0 | 1.0 | 1.0004 / 0.9996 | 150 | 120.05 / 119.95 | 1.2006E02 / 1.1994E02 | | 0.10 / -0.10 | | |
| 1.0 | 1.0000 | 150 | 120.00 | 6.0000E+01 | 60 | 1.0 | 1.0004 / 0.9996 | 150 | 120.05 / 119.95 | 1.2192E02 / 1.1808E02 | | 060.10 / 059.90 | 1.0418E-02 / 1.0374E-02 | 0.5005 / 0.4995 |
| 2.5 | 2.5000 | 300 | 300.00 | 3.7500E+02 | 60 | 2.5 | 2.5009 / 2.4991 | 300 | 300.10 / 299.90 | 3.7620E02 / 3.7380E02 | | 060.10 / 059.90 | | 0.5005 / 0.4995 |
| 5.0 | 5.0000 | 300 | 300.00 | 7.5000E+02 | -60 | 5 | 5.0016 / 4.9984 | 600 | 600.19 / 299.81 | -7.5240E02 / -7.4760E02 | | -060.10 / -059.90 | | -0.5005 / -0.4995 |
| 10 | 10.000 | 600 | 600.00 | 1.5000E+03 | -60 | 10 | 5.0016 / 4.9984 | 600 | 600.19 / 600.19 | -1.5048E03 / -1.4952E03 | | -060.10 / -059.90 | | -0.5005 / -0.4995 |
| 25 | 25.000 | 300 | 300.00 | 7.5000E+03 | 0 | 25 | 25.009 / 24.991 | 300 | 300.10 / 299.90 | 7.5023E03 / 7.4977E03 | | 0.10 / -0.10 | | 1.0000 / 0.9993 |
| 50 | 25.000 | 150 | 150.00 | 1.8750E+03 | 60 | 50 | 25.011 / 24.989 | 150 | 150.06 / 149.94 | 1.8810E03 / 1.8690E03 | | 60.10 / 59.90 | | 0.5005 / 0.4995 |
| 50 | 25.000 | 600 | 666.00 | 8.2500E+03 | 0 | 50 | 25.011 / 24.989 | 600 | 600.21 / 599.79 | 8.2525E03 / 8.2475E03 | | 0.10 / -0.10 | | 1.0000 / 0.9993 |
| 2.5 | 2.5000 | 150 | 150.00 | 3.7500E+02 | 0 | 5.0 | 2.5011 / 2.4989 | 300 | 150.12 / 149.88 | 3.7530E03 / 3.7470E03 | | 0.10 / -0.10 | | 1.0000 / 0.9993 |
| 2.5 | 2.5000 | 150 | 150.00 | 1.8750E+02 | 60 | 5.0 | 2.5011 / 2.4989 | 300 | 150.12 / 149.88 | 1.9080E02 / 1.8420E02 | | 60.10 / 59.90 | | 0.5007 / 0.4993 |
| 2.5 | 2.5000 | 150 | 150.00 | 1.8750E+02 | -60 | 5.0 | 2.5011 / 2.4989 | 300 | 150.12 / 149.88 | -1.9080E02 / -1.8420E02 | | -60.10 / -59.10 | | -0.5007 / -0.4993 |
| 2.5 | 2.5000 | 150 | 150.00 | 2.6517E+02 | 45 | 5.0 | 2.5011 / 2.4989 | 300 | 150.12 / 149.88 | 2.6660E02 / 2.6374E02 | | 45.10 / 44.90 | 2.6920E+02 / 2.6110E+02 | 0.7078 / 0.7062 |
| 2.5 | 2.5000 | 150 | 150.00 | 2.6517E+02 | -45 | 5.0 | 2.5011 / 2.4989 | 300 | 150.12 / 149.88 | -2.6660E02 / -2.6374E02 | | -45.10 / -44.90 | 2.6920E+02 / 2.6110E+02 | -0.7078 / 0.7062 |
| 2.5 | 2.750 | 150 | 165V | 4.5375E+02 | 0 | 2.5 | 2.7509 / 2.7491 | 150 | 165.07 / 164.93 | 4.5388E02 / 4.5362E02 | 4.5410E+02 / 4.5340E+02 | 0.10 / -0.10 | | 1.0000 / 0.9993 |

# MAINTENANCE

Maintenance of the Model 636 Multifunction Power Analyzer should require no more than periodic recalibration to assure its continued accuracy. Three-month intervals are suggested.

Failure to perform properly can be caused not only by failure of the equipment but also because of some defect in procedure. Before beginning repair of the equipment, one should be certain there are no defects in the procedure used.

**CAUTION**

To avoid exposure to hazardous voltages, observe procedures given on Pages iii and iv.

When the equipment is at fault, the nature of the failure is a most valuable symptom. An understanding of the organization of the circuits, as shown in the functional block diagram, Figure 12 and discussed in the first part of the chapter titled Circuit Description, will help to suggest the general area of the fault. Moreover, one should not overlook the obvious possibilities of no primary-power input, an open circuit breaker in the instrument, as well as a routine check of power-supply output voltages.

Circuit faults usually can be localized with the aid of the circuit schematic and voltage measurements. Signal tracing with an oscilloscope is also a powerful approach. For access to the sides of certain boards while they are connected in the instrument, a Model 95250 Card Extender is necessary.

Operating the power analyzer while judiciously using the front-panel controls, with input signals applied, will help identify the fault in either the voltage or current channel if the analog section of the instrument is at fault. In this case, the analog signals, which are 4 volts for full-scale input, at the outputs of the voltage and current channels, may be examined. Similarly, the 2.5-volt, full-scale output signals from the voltage, power, and current multipliers, should be checked.

An oscilloscope may be used for checking presence and frequency of all clock signals, and for signal tracing in the digital section of the instrument.

Equipment may be returned to RFL for recalibration and for repair, if needed. Spare circuit cards may be inventoried, if desired, to assist in field repairs.

# CIRCUIT DESCRIPTION

## INTRODUCTION

The Model 636 Multifunction Power Analyzer is constructed as a main frame which consists of necessary structural members, a power supply, front-panel and rear-panel components, and a card cage supporting the major elements of the circuit. Following this pattern, the following discussion describes first the organization of the entire design, and then describes each circuit card in detail.

## ORGANIZATION OF THE CIRCUITS

Figure 12 is a block diagram showing the arrangement of all major circuit elements in the power analyzer.

The instrument has two inputs, a voltage input and a current input. When measuring power, the voltage input is normally the voltage which appears across the load. The load-current input is connected in series with the source that is providing power to the load. This is the desired configuration because it will allow the Model 636 to provide compensation for the loading introduced by its voltage-input circuit.

The voltage input is immediately scaled with series resistors and is routed to an active transformer. The voltage-range switch also provides addressing information to a volts-scale-factor PROM, which will provide scale-factor information to the processor in a later computation of the voltage. The active-transformer circuit has an output of 4 volts for full-scale input, and this is routed to several circuits. First, it feeds the phase and period circuits, next the volts multiplier, third the watts multiplier, fourth the burden-compensation circuit, and finally it is connected to terminals in the rear-panel ACCESSORIES connector, J16.

The current-input signal is passed through a range switch and then to an active transformer, the output of which is 4 volts for a full-scale current input. The current-range switch provides addressing information for the amperes-scale-factor PROM, which will be used by the processor to determine the absolute value of the current measured. The output of the current transformer is routed to several places. First, it feeds the phase and period circuits, next the watts multiplier, the amperes multiplier, and finally it is connected to terminals in the rear-panel ACCESSORIES connector, J16.

If the burden-compensation switch is closed, a current proportional to the voltage input is fed into the active current transformer in a direction which compensates for the loading of the voltage-input circuit. The burden-compensation will be correct only if the power meter is connected as previously described.

The Model 636 is provided with three precision analog multipliers. One receives the output of the voltage circuit, and its output is proportinal to mean-square volts. The watts multiplier has inputs from both voltage and current circuits, and it output is proportional to watts. A third multiplier receives the current signal as its input and its output is proportional to mean-square amperes.

Outputs of the three multipliers are multiplexed into an analog-to-digital (A/D) converter. This is a 4½-digit precision dual-slope converter performing five conversions per second.

The digital output data are temporarily stored in a RAM. When the processor requires output information from the A/D converter, it addresses the RAM. Multiplexer and control logic are designed to provide non-interfering use of the RAM by the converter and processor. This is done by placing the processor in a hold-mode whenever the converter is addressing the RAM. Conversely, whenever the processor is addressing the RAM the converter's output information is ignored.

The phase-and-period section of the power analyzer measures both the period of the input signal and the phase difference between the input signals. The outputs of this circuit are multiplexed onto the processor bus and read during the appropriate modes.

The real-time section of the power analyzer determines precise time increments which are utilized by the processor for computing watthours and varhours. To do this, the output of the crystal-controlled clock is counted down to provide increments proportional to hours. The real-time interval is controlled from the front panel by means of the TIME RESET and TIME STOP buttons or, if desired, an external gating signal can be connected through the TIME GATE input terminals on the rear panel. The output of the clock generator is multiplexed onto the processor bus and is used, when required, for computing watthours or varhours.

The processor is a number-oriented device which requires an external program counter and program PROM s. It communicates with the other circuits through two buses. One is the input bus, already described, which communicates with the RAM associated with the A/D converter, volts PROM, amps PROM, the real-time card, and the phase card. The second bus is an output bus. This communicates with the display circuits and with an optional IEEE-488 Bus coupler, when used.

The program PROM for the processor is addressed by a program counter (PC). At the completion of each computer cycle, the PC is initialized by the jump PROM, which is addressed by a function PROM which is essentially a decoder of the front-panel function-selector switches.

Finally, a power-supply section provides +5 volts, -15 volts and +15 volts as primary power for all analog and digital sections.

Detailed discussion of individual sections follows.

## SERIES 100 ACCESSORY CARD

This card slot (J1) is used as the receptacle for either of two cards. First, it will accept a blank card on which can be assembled a variety of circuits, according to the needs of the user, and it is accessible through an accessory connector mounted on the rear panel. Secondly, the card slot will accept the optional IEEE-488 Bus Interface card, used for external control of the power analyzer and for transmission of its measurements elsewhere.

A 44-pin edge connector provides power, internal data-bus signals, and connections to J16, the accessory connector on the rear panel.

## SERIES 200 REAL-TIME CARD

A block diagram for the real-ime card is shown in Figure 13 and its schematic appears in Figure 22.

The function of this card is to keep track of real-time intervals with a 5-decade counter. The counter's clock is derived from a precise 2.777 kHz source received from the clock generator; the counter can be gated by either an external gate or the control logic on the card.

The processor samples the counter during every computer cycle, and at the completion of a cycle the 5-decade counter will be reset to zero and counting will start again. These time increments are accumulated in the processor's memory, and the real-time count is put on the processor's data bus when it recognizes the address 26 Hex.

The interval during which the 5-decade counter is operating is determined by the time-reset and time-stop signals. The time reset not only resets the counter but it also starts the counter. The signal is latched until the processor acknowledges it by setting the flag F1.

After depressing and releasing the TIME RESET button, a two-second timer blanks the front-panel display. This interval is required to permit the counter to accumulate at least 5000 counts, the minimum required to meet the varhour and watthour accuracy specifications. This requirement also must be observed by an operator using the external TIME GATE input. When using an external time gate, a logic low (0 volts) will start the counting interval, and a logic high (2.7 volts) will stop the counter.

## SERIES 300 PROCESSOR CARD

The block diagram for the processor card appears in Figure 14, and its schematic is shown in Figure 23.

This card contains three sections. First, is the processor with its external program counter and associated PROMs. The second section is the data-input port, which services and A/D converter, the phase card, the period counters, the real-time card, and the amps and volts scale-factor PROMs. The third section is the output port, which services the front-panel displays and the optional IEEE-488 Bus interface card.

Upon application of power to the instrument, the processor is reset and starts through an initialization routine, after which it will respond to the function display switches on the front panel, through the jump PROM.

The jump PROM is addressed by the function switch encoder. Depending upon the function selected, the jump PROM will provide an appropriate address and perform the instructions contained within the program PROM. For example, if WATTS is selected, logic signals are sent to an encoding circuit, the four-bit output of which is wired directly to the address lines of the jump PROM. The jump PROM is now programmed to provide the correct jump address for the processor's PROM. When the processor completes its computation cycle, it will perform a jump instruction. The jump address is obtained from the jump PROM, which presets the processor's program counter with the jump PROM's outputs.

The processor's program counter will now sequence through the instructions, beginning with the new address. The new sequence of instructions will provide the proper computation to display WATTS, as selected. Operation of the watts, and other, routines are given in the description of firmware, at the end of this section.

Input data are routed, through a four-bit bus and a multiplexer, to the processor. The multiplexer time-shares the PROM data with the input I/O data. Time sharing is under the control of the processor through the ISEL line. To determine which input device is providing data, the program PROMs place the appropriate address information on lines I1 through I6. For example, if the processor is in a watts subroutine, a hex address of 20 will be put on the I lines. Hex address 20 is decoded by the RAM on the A/D converter, and this will put the appropriate data on the data lines. In the case of watts, five digits of data are transferred from the RAM to the processor. To keep track of which digit is on a data line at any particular time, the digit-address lines, DA1 through DA4, are decoded.

The output port of the processor contains lines DO1 through DO4, which are the display-output data lines, the READ/WRITE (R/W) signal line, and I1, I2, and I3 lines. When the processor is programmed to send display information out, the proper display is determined by the latter three lines. The correct digital data are sent on DO1 through DO4 in BCD format. Valid data are latched into the display latches when the R/W signal is low. The correct display digit is determined by the coding on digital-address lines DA1 through DA4.



## SERIES 400 CLOCK GENERATOR CARD

A block diagram of the clock generator is shown in Figure 15, and its schematic is Figure 24.

The clock generator card provides the basic timing circuits for all elements of the power analyzer, and it also carries control circuits for the phase and period functions carried out on the Series 500 Card. On the block diagram, the basic timing circuits are above the horizontal, dashed line. The phase-control and period-control functions appear below that line.

The clock chain begins with a 3.2 mHz crystal oscillator. This is divided by 2, by 8, again by 8, and then by 9. Ultimately, this produces a 2.77 kHz clock signal for the real-time card. From this chain, two other signals are taken: (a) the 400 kHz clock for the processor and, (b) the 200 kHz clock to the A/D converter. The 200 kHz clock is also used for the phase- and period-control circuits.

The input to the phase- and period-control section consists of the voltage and current signals derived from the active transformers. These are processed by comparators and clocked into D-type flip-flops. The output of these flip-flops are ANDed together to provide a signal which is related to their phase difference. The phase-difference signals are then ANDed with a 200 kHz clock and sent to the phase counters. A third D-type flip-flop determines whether the current is leading or lagging the voltage, and its output determines the direction of the phase counter, whether it be up or down.

The voltage signal goes through a divide-by-31 circuit which, in effect, produces a 31-period count as a phase difference. This 31-period interval is combined with a 100 kHz clock and sent to the period counter. This control circuit operates the latch and reset lines of the period and phase counters on the phase card, and it insures that only 31 periods are counted, or that only 31 phase comparisons are made corresponding to these periods.

## SERIES 500 PHASE CARD

The Series 500 phase card consists basically of two counters, a phase counter and a period counter. The functional block diagram is Figure 16 and the schematic is Figure 25.

The phase counter, controlled from circuits on the clock-generator card, is a 5-decade, up/down counter. The direction of the count is determined by the phase difference between the voltage and current signals at the input of the power analyzer. The counter is operating at its 200 kHz rate, and it is gated by the phase difference. At the end of 31 periods of counting, the data are shifted into latches. The data and latches are updated every 32 periods of the incoming signal.

When the processor is operating in a routine that requires phase data, the processor will call up address Hex 24. This will activate the tri-state buffers that will put the output of the data latches on the data bus. Each of the five digits will be put on the bus as requested by the processor through digit-address lines DA1-DA4.

The period counter is a 5-decade unidirectional counter. At the end of 31 periods, the data are transferred into latches. When the processor performs a routine that requires period, it will call up address Hex 25 and the tri-state buffers will pass the data from the latches to the data bus. The particular digital data on the data bus will be determined by the configuration of the digit-address lines, DA1-DA4.

The sign of the phase counter is routed to the real-time card where it is multiplexed with data from other devices requiring sign information, such as watts data, to be sent to the processor.

## SERIES 600 ANALOG-TO-DIGITAL CONVERTER CARD

The block diagram for the A/D converter is shown in Figure 17 and its schematic is shown as Figure 26.

The A/D converter accepts any one of three inputs: mean-square amperes, mean-square volts, or watts, and it converts its input signal into a 4½ digit, BCD format. Each conversion is then stored in a RAM. When the processor is operating in a routing that requires any one of the three foregoing quantities, it will set up the address necessary to read the contents of the RAM.

The converter operates at a rate of five conversions per second. The rate is quasi-randomized because the multiplexer is driven by a seven-state counter which is occassionally interrupted by the processor. This procedure prevents a sampling rate that is asynchronous with the input signals.

To avoid conflict as to what controls the RAM, protection circuits allow the RAM to be used on a first-come, first-serve basis. If A/D converter has control of the RAM, the processor is put in the halt mode. Conversely, if the processor has control of the RAM, the information available at that time is lost, and the next conversion is used to update the RAM.

During the watts conversion, sign information will be required. This is ANDed with the watts-select signal and sent to the real-time card where it is multiplexed with the phase sign.

If, during a conversion, the A/D converter is overranged, the overrange signal is used to blank the corresponding display. Underrange signals are obtained from any one of the three multipliers, and these signals logically zero the data stored in the RAM. Ultimately, they produce a zero on the corresponding display.

## SERIES 700 WATTS MULTIPLIER, AND SERIES 800 VOLTS/AMPS MULTIPLIER CARDS

The block diagram for these two circuit cards is shown in Figure 18. The schematic for the watts multiplier is Figure 27, and that for the volts/amps multiplier is in Figure 28.

These two cards are treated simultaneously because their functional circuits are identical. The watts multiplier card has one multiplier; the volts/amps multiplier card carries two such circuits. Their only difference is the manner in which they are connected. Input and output connections for each multiplier are shown in the table included on the block diagram.

The output pulse-width of the multiplier card is controlled by an integrator and a comparator. For a given polarity of the reference input the integrator will ramp to a voltage level which causes the comparator to change state. The comparator drives a switch which reverses the polarity of the reference input to the integrator. Hence the output of the integrator is a triangle wave, and the output of the comparator is a square wave. If a signal is summed with the reference voltage, the slope of the integrator output is increased or decreased depending on whether the input signal adds or subtracts from the reference voltage. With a given input voltage, the integrator integrates at two different rates which causes the comparator output to be asymmetrical i.e., pulse-width modulated.

The pulse height is directly proportional to a second signal and is switched into a filter. The polarity of the second signal is determined by the polarity of the pulse-width modulated signal. The filtered output signal is directly proportional to the product of the two input signals.

Low-level detector circuits are associated with the output of each multiplier. Whenever a level is detected below a predetermined threshold, a logic signal sent to the A/D converter, zeros the corresponding data stored in the RAM during the conversion period.

## SERIES 900 TRANSFORMER ELECTRONICS CARD

The block diagram for the transformer electronics card is shown in Figure 19, and the schematic appears in Figure 29.

On the block diagram, the circuits for the card are outlined to the right of the vertical dashed line. Circuits to the left are shown for reference only.

The voltage input to the power analyzer passes through range-scaling resistors, a voltage-protection circuit, and the input side of an active transformer. This device closely approaches the ideal current transformer. This is done by monitoring the flux in the core with a sense of winding which zeros the flux in the core. A second amplifier is used to convert the reset current to a voltage output directly proportional to the input signal. The voltage-output signal is standardized at 4 volts for full-scale input to the primary of the input transformer. A lowpass filter is required to provide dc feedback to the active-transformer loop.

A crest-factor detector is provided to flash the most-significant digit of the VOLTS display whenever the crest factor of the input signal exceeds two. To prevent damage from overvoltage to the voltage-range resistors, a voltage-level detector is included. This drives a relay which opens the voltage input when an overvoltage condition is sensed.

The output of the voltage active transformer is also routed to a burden-compensation circuit in the current channel. This circuit provides an output current proportional to the voltage sensed. The output current is phased to buck the current drawn by the voltage channel through the current transformer when measuring power in the standard, power-measurement connection.

The current channel is similar to the voltage channel but, rather than switching scaling resistors, the current input uses taps on the primary of the input transformer. The current active transformer operates at a much higher current level, so that current buffers are required in the outputs of the signal amplifiers. These are shown as triangles containing the letter I. A crest-factor detector for the current channel will flash the most significant digit of the AMPERES display whenever a crest factor of three is exceeded.

The active current transformer operates at magnetization levels of either 5 or 50 ampere-turns., depending on the input range selected. The 5-ampere-turn level is used for the 100 mA, 250 mA, and 500 mA ranges. All higher current ranges use the 50 ampere turn level. The change from one level of magnetization to another is made by changing the value of the feedback resistor in the current-to-voltage converter. In all cases, the output is standardized at 4 volts for full-scale input.

## SERIES 1100 SWITCH CARD, AND SERIES 1200 DISPLAY CARD

A block diagram for the switch card and the display card is shown in Figure 20, and schematics for these boards appear as Figure 30.

The display card is mounted on the switch card, and the assembly is conviently treated as a single unit. The separation between the two boards is indicated by the horizontal, dashed line on the block diagram. Operating circuits of the assembly are conviently divided into AMPERES, FUNCTION, and VOLTS displays, and the vertical, dashed lines on the block diagram show these divisions.

The purpose of each display is to accept its data from the processor and store them in its latched decoders. The decoders, in turn, provide the seven-segment data required to drive the seven-segment displays. The cathodes of each LED display are all tied together and returned through a current sink.

Each display is identified with an unique address. The AMPERES display is identified by the I2 line, FUNCTION display by its I1 line, and VOLTS by the I3 line. Data enter the latches when the appropriate address is true and the R/W signal is low. Appropriate blanking circuits are provided, and a lamp-test circuit is associated with each display. Although not shown, the decimal-point lamps for the AMPERES and VOLTS display are each driven through their range switches.

Positions of the front-panel FUNCTION switches are encoded into a BCD format which ultimately goes to the jump PROM on the processor board. TIME RESET and TIME STOP signals are sent to the real-time card.

Brightness of the AMPERES display, the VOLTS display, and the two FUNCTION displays can be individually adjusted with potentiometers associated with their current sinks.

## FIRMWARE

The firmware for the power analyzer is contained in one 32x8-bit PROM and in four 256x4-bit PROMs.

The 32x8-bit PROM is addressed by the front-panel FUNCTION switches through an encoder. The outputs of the PROM are the jump addresses required by the program PROM. Each jump address is unique and is dependent on the function selected.

A 256x4-bit PROM is addressed by the AMPERES range switch through an encoder. The output of the PROM contains the scale factor determined by the range selected. The output data will be put on the data bus whenever the processor requires range-scaling information as, for example, when calculating amperes or watts.

A second 256x4-bit PROM operates similarly, except that it contains voltage-scale-factor information.

The third and fourth 256x4-bit PROMs are operated together as an 8-bit program memory for all subroutines of the functions. Thus, two PROMs contain all the functional programs of which the power analyzer is capable.

The routines are:

(a) no selection
(b) time reset
(c) frequency
(d) phase angle
(e) power factor
(f) watthours
(g) watts
(h) volt-amperes
(j) vars
(k) varhours
(l) rms volts
(m) rms amperes

The particular routine processed at any time is determined by the jump PROM.

To execute these routines, the following inputs are required: watts, mean-square volts, mean-square current, phase angle, signal period, and time interval. A time-reset signal is also required to initialize the varhour and watthour routines. The outputs are those listed in the foregoing. The no-selection routine will cause the FUNCTION display to show all zeros. RMS voltage and current are computed on every computation cycle.

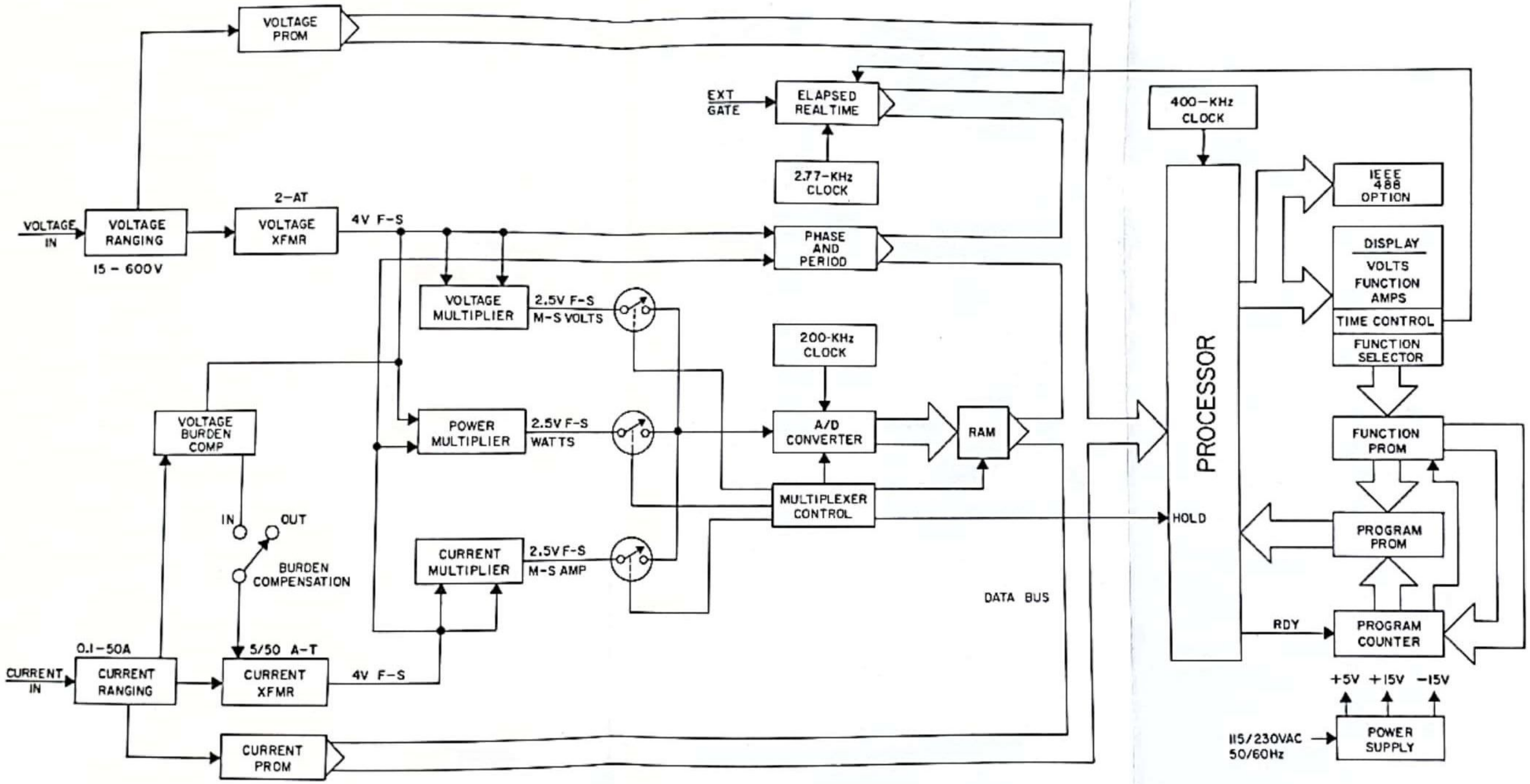



Figure 12. Functional block diagram of complete instrument.

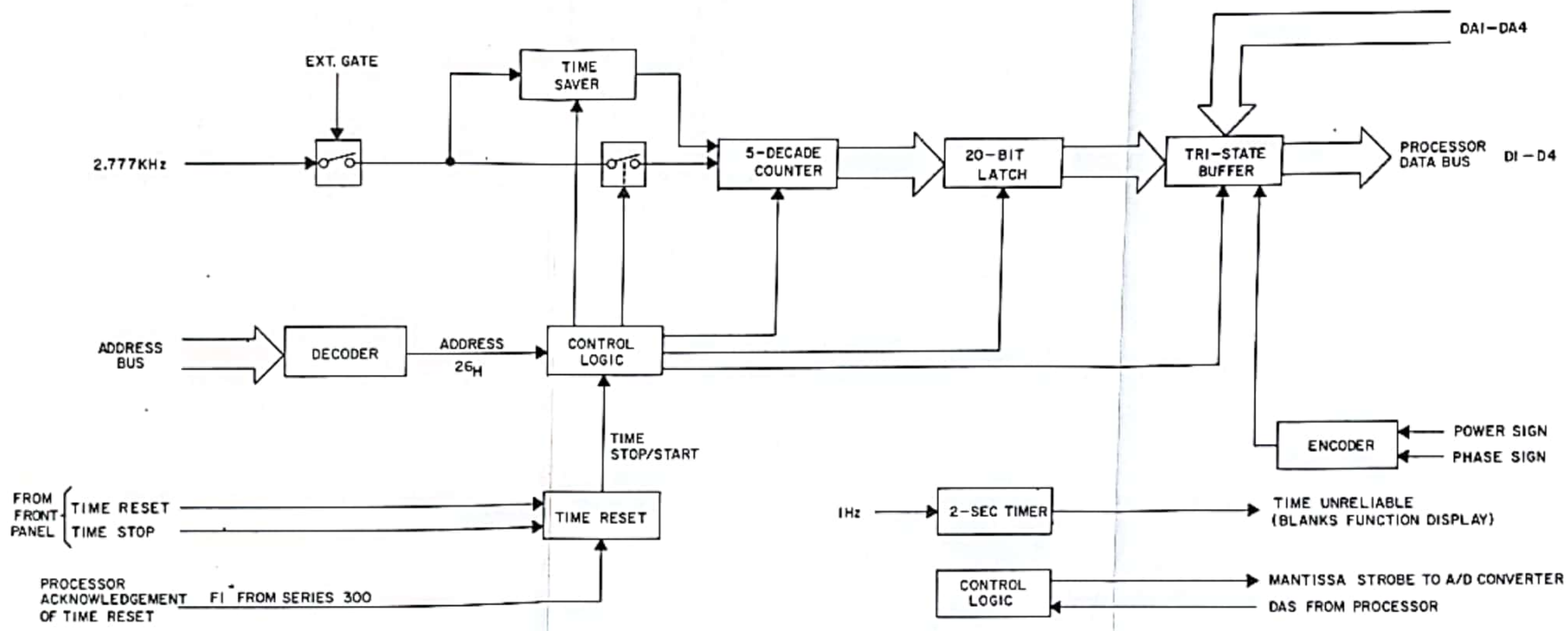



Figure 13. Functional block diagram of real-time card, 200 Series.

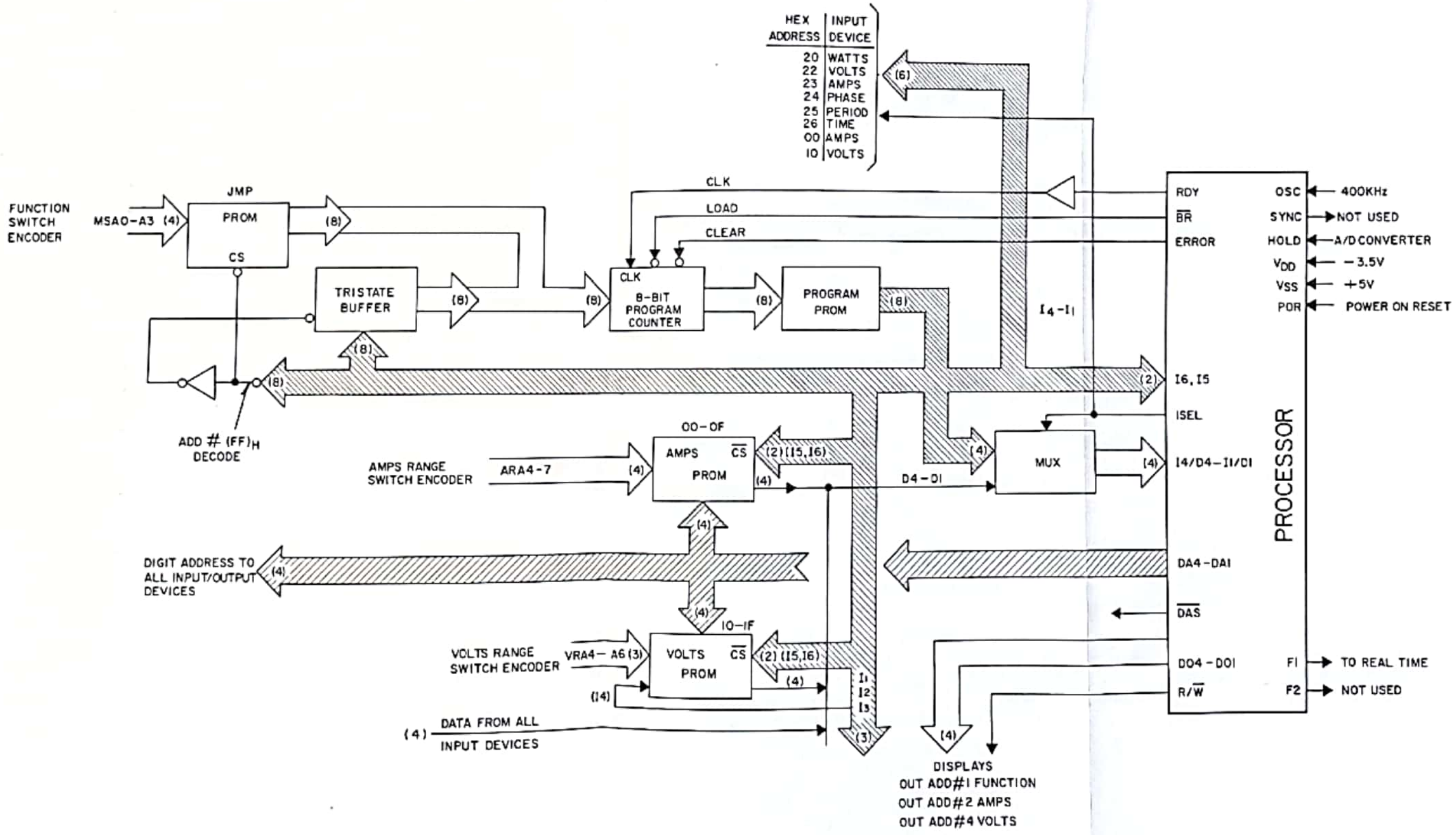



Figure 14. Functional block diagram of processor card, 300 Series.

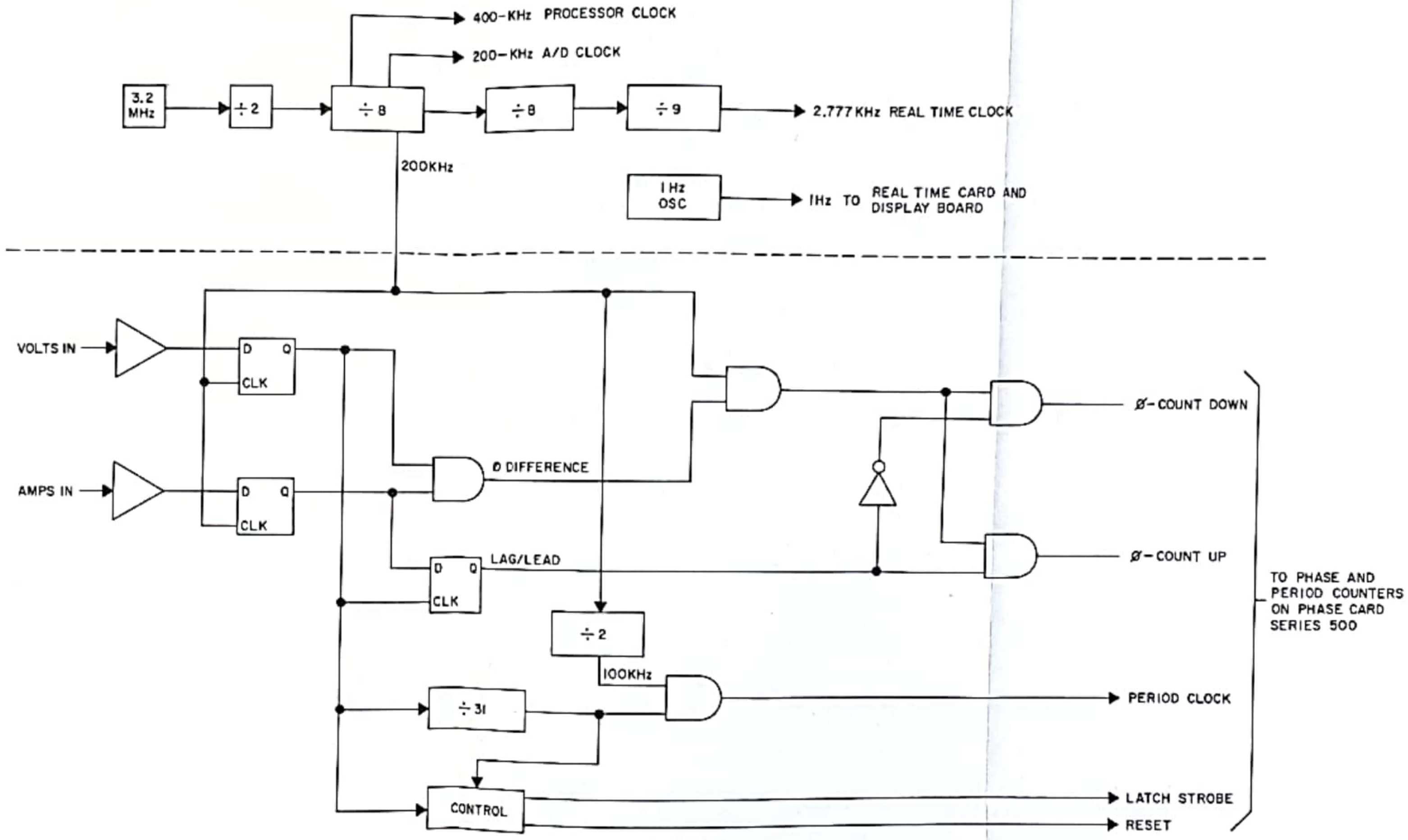



Figure 15. Functional block diagram of clock-generator card, 400 Series.

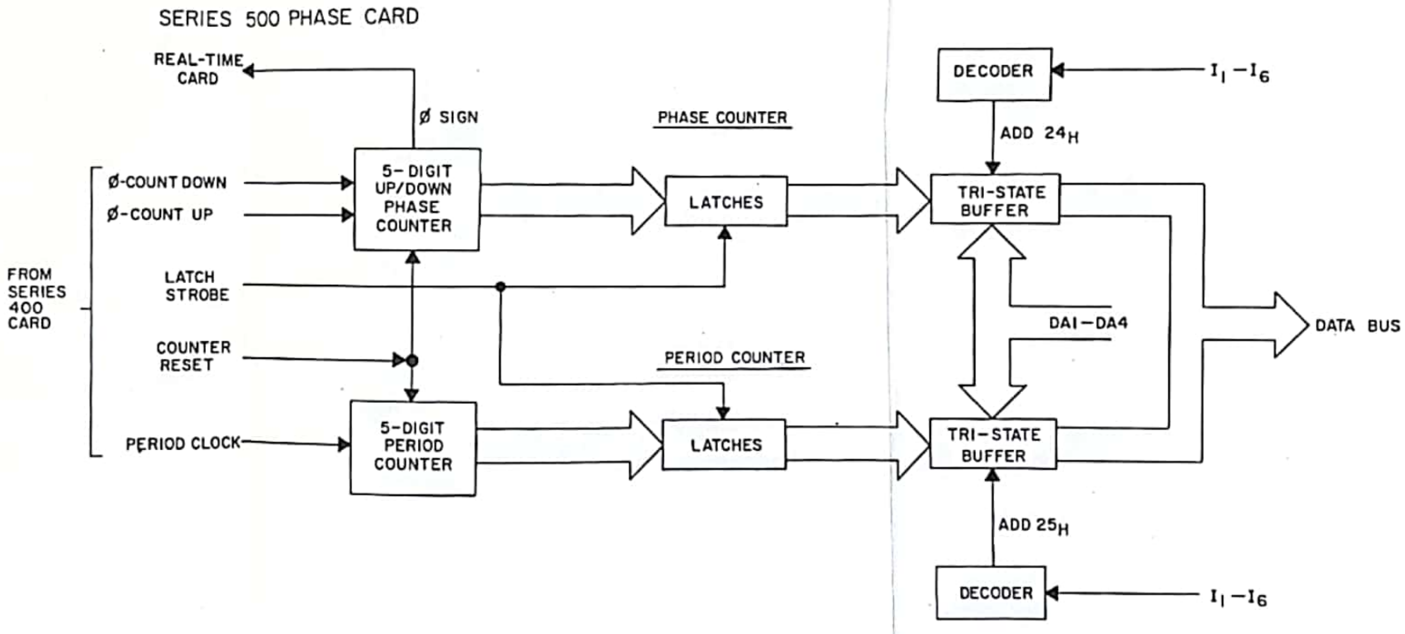



Figure 16. Functional block diagram of phase card, 500 Series

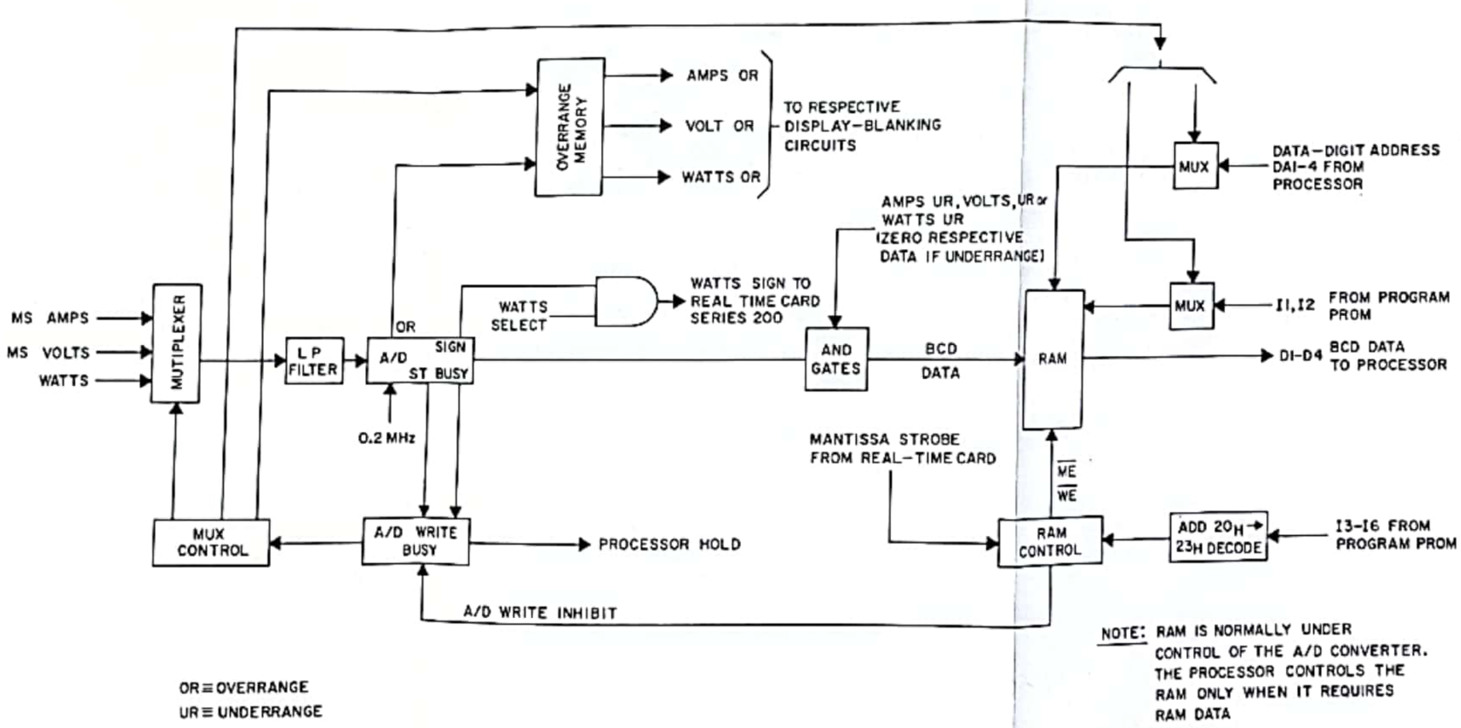
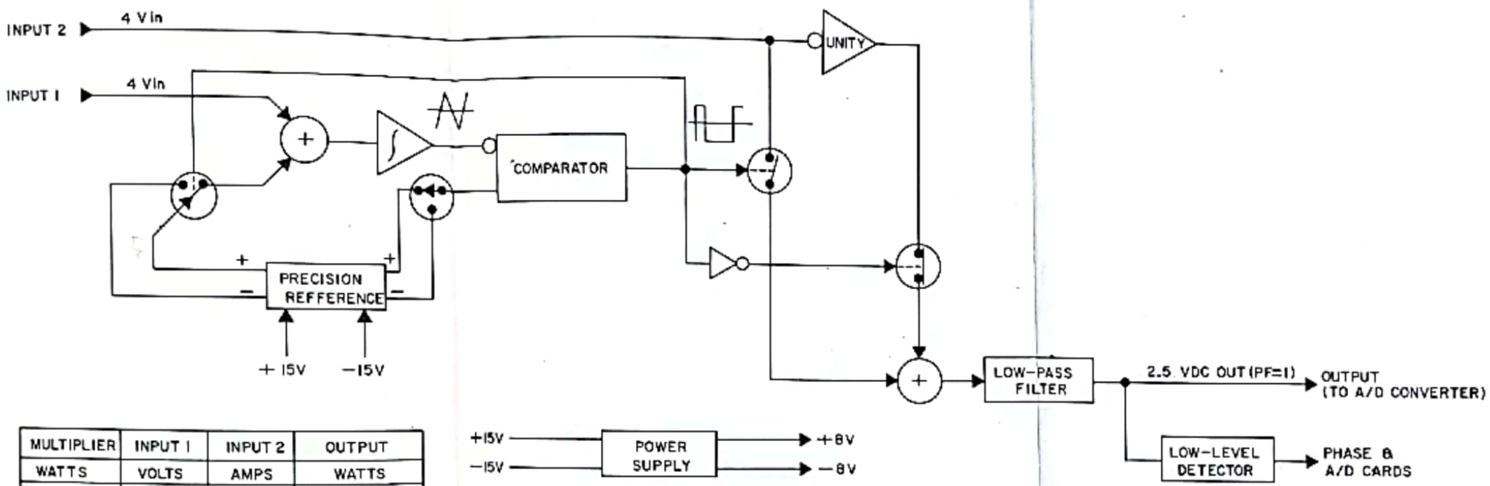



Figure 17. Functional block diagram of analog-to-digital converter, 600 Series.




| MULTIPLIER | INPUT I | INPUT 2 | OUTPUT |
|---|---|---|---|
| WATTS | VOLTS | AMPS | WATTS |
| VOLTS | VOLTS | VOLTS | MEAN SQUARE VOLTS |
| AMPS | AMPS | AMPS | MEAN SQUARE AMPS |

Figure 18. Functional block diagram of multiplier cards, 700 and 800 Series.

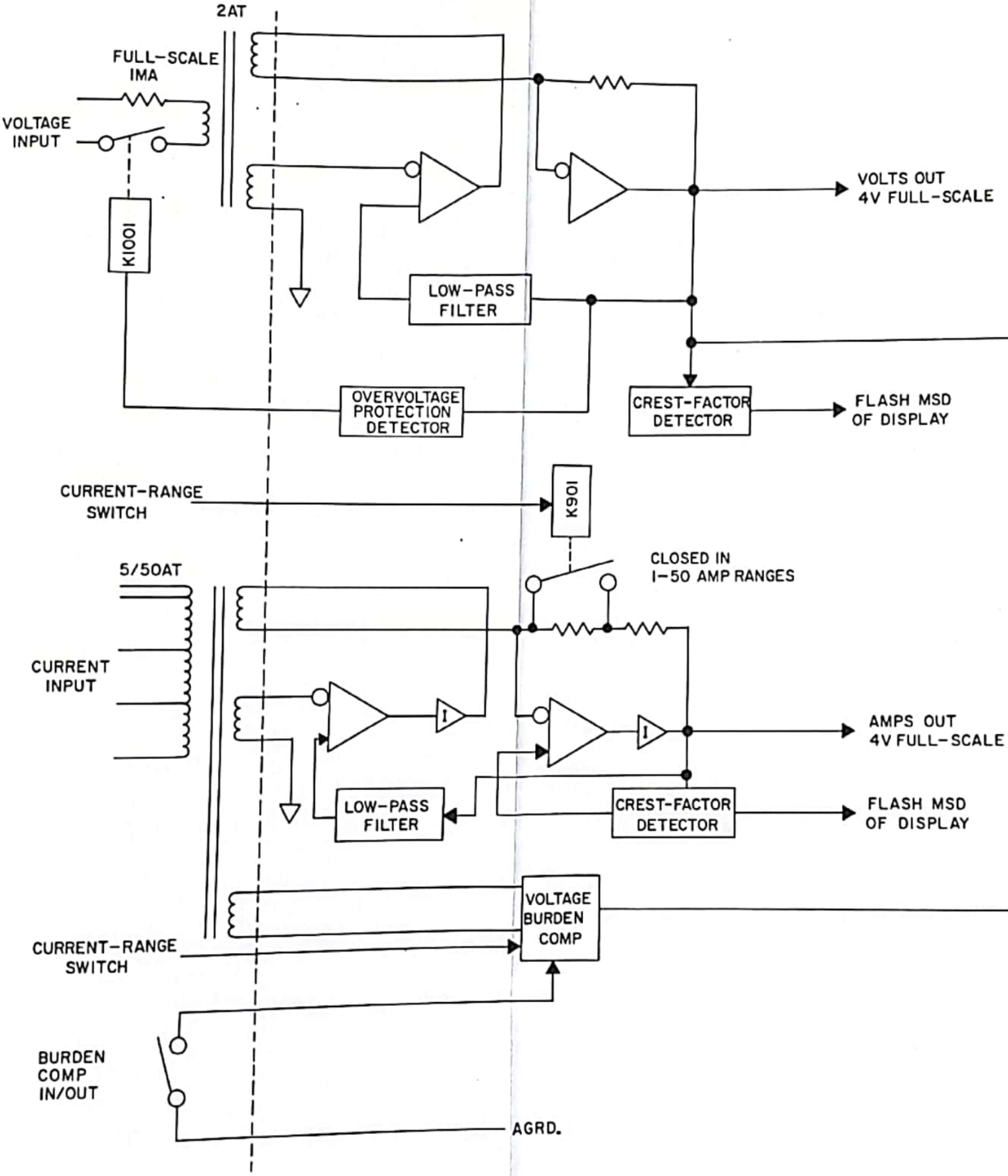



Figure 19. Functional block diagram of transformer electronics card, 900 Series.

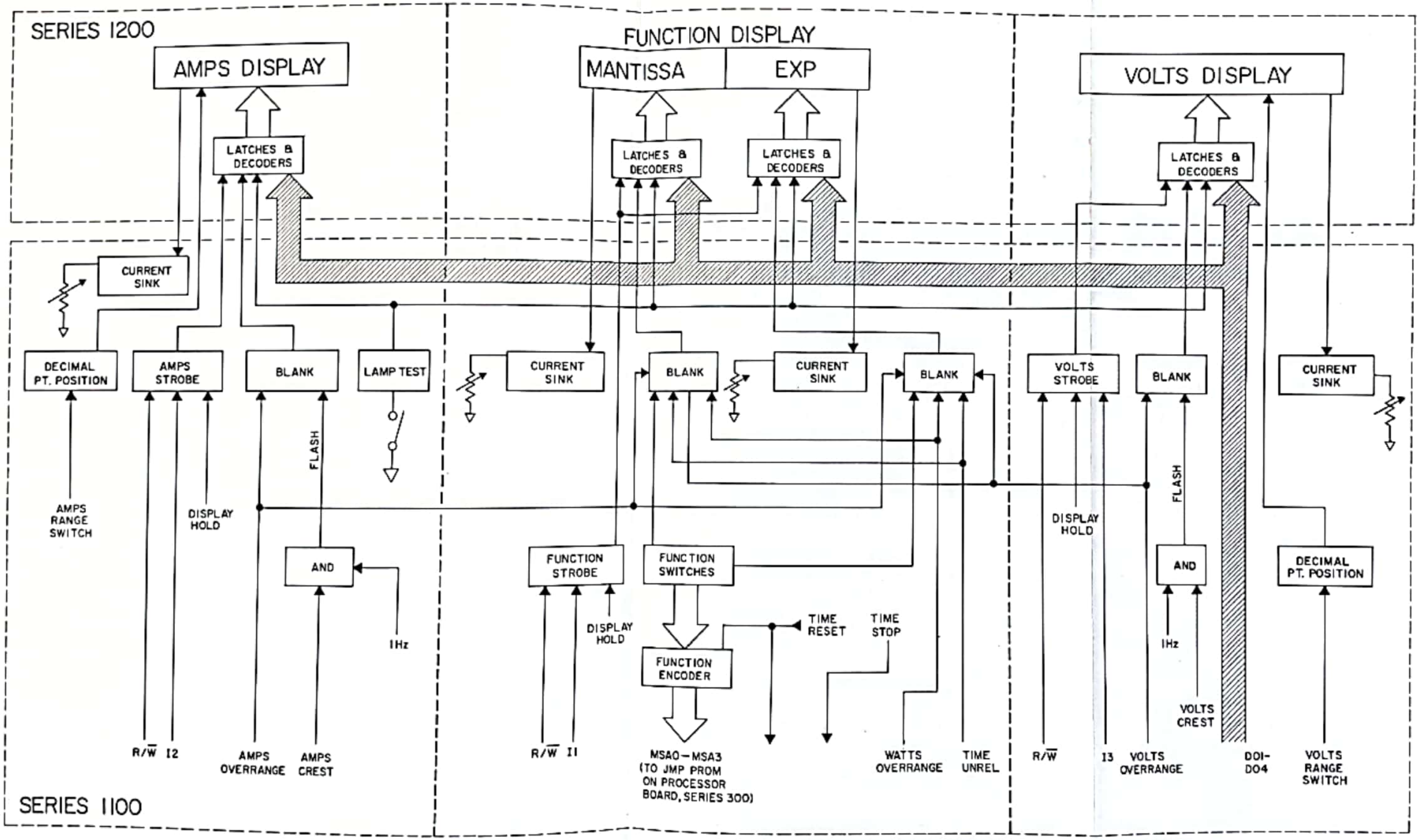



Figure 20. Combined functional block diagram of switch and display cards, 1100 and 1200 Series.

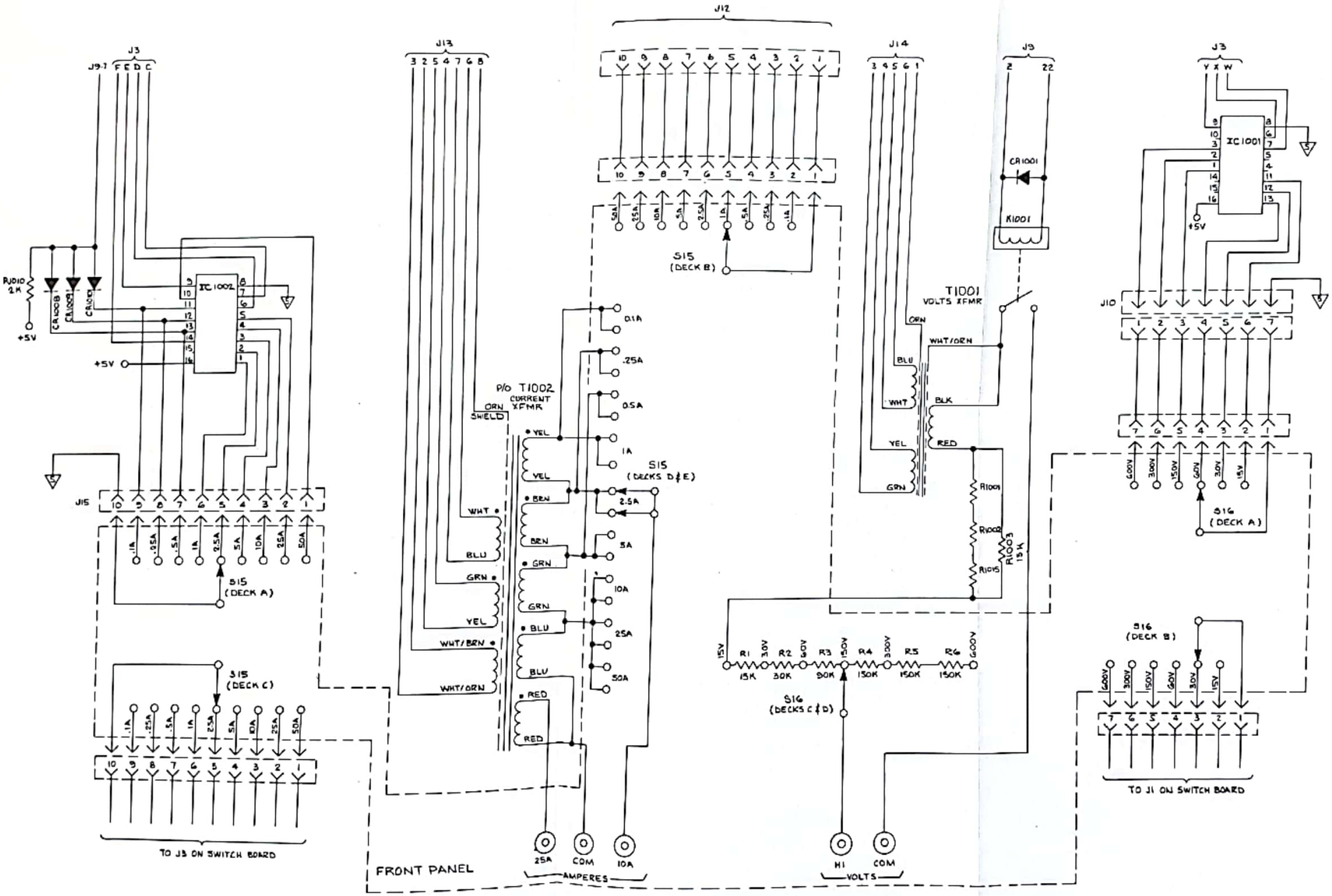
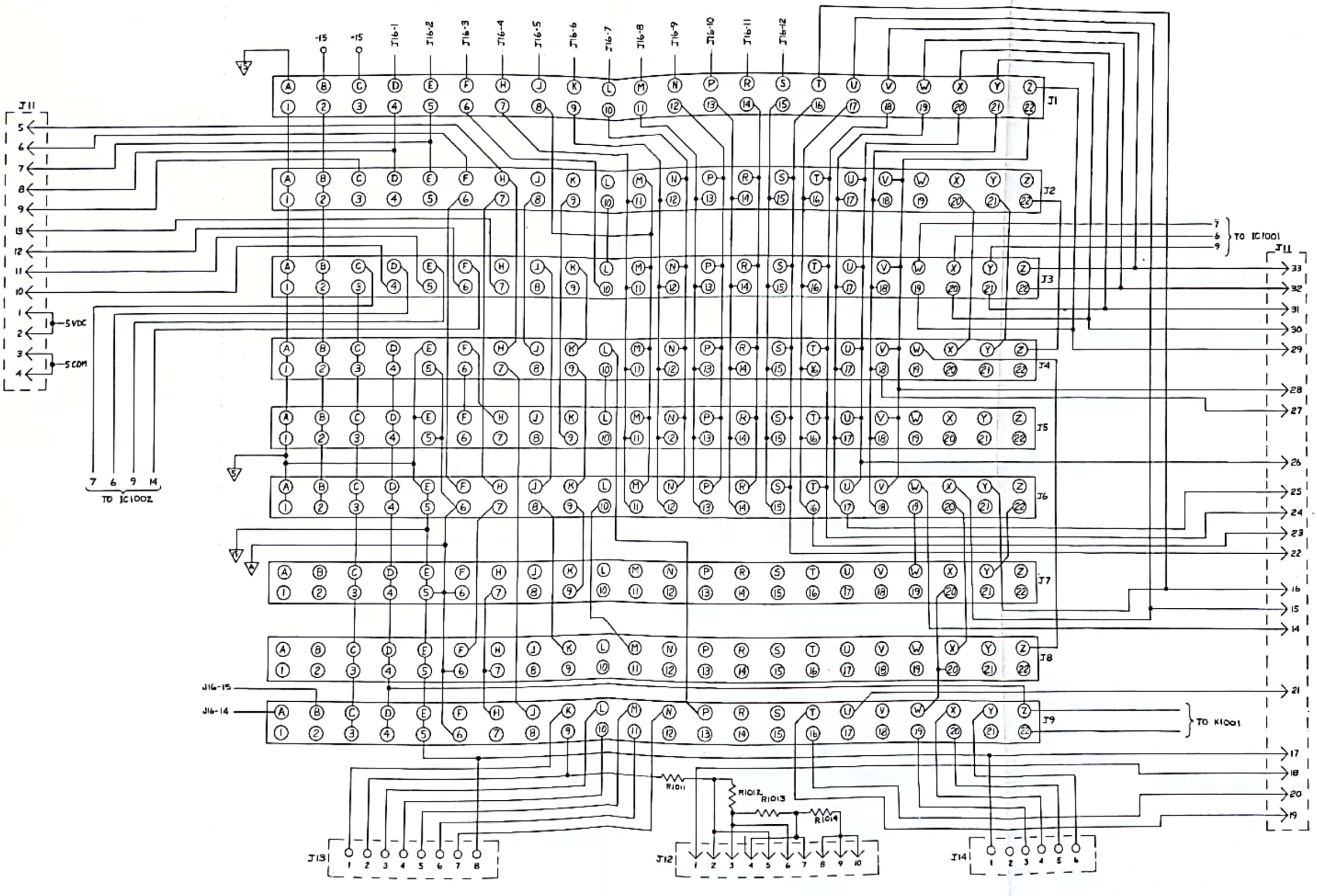
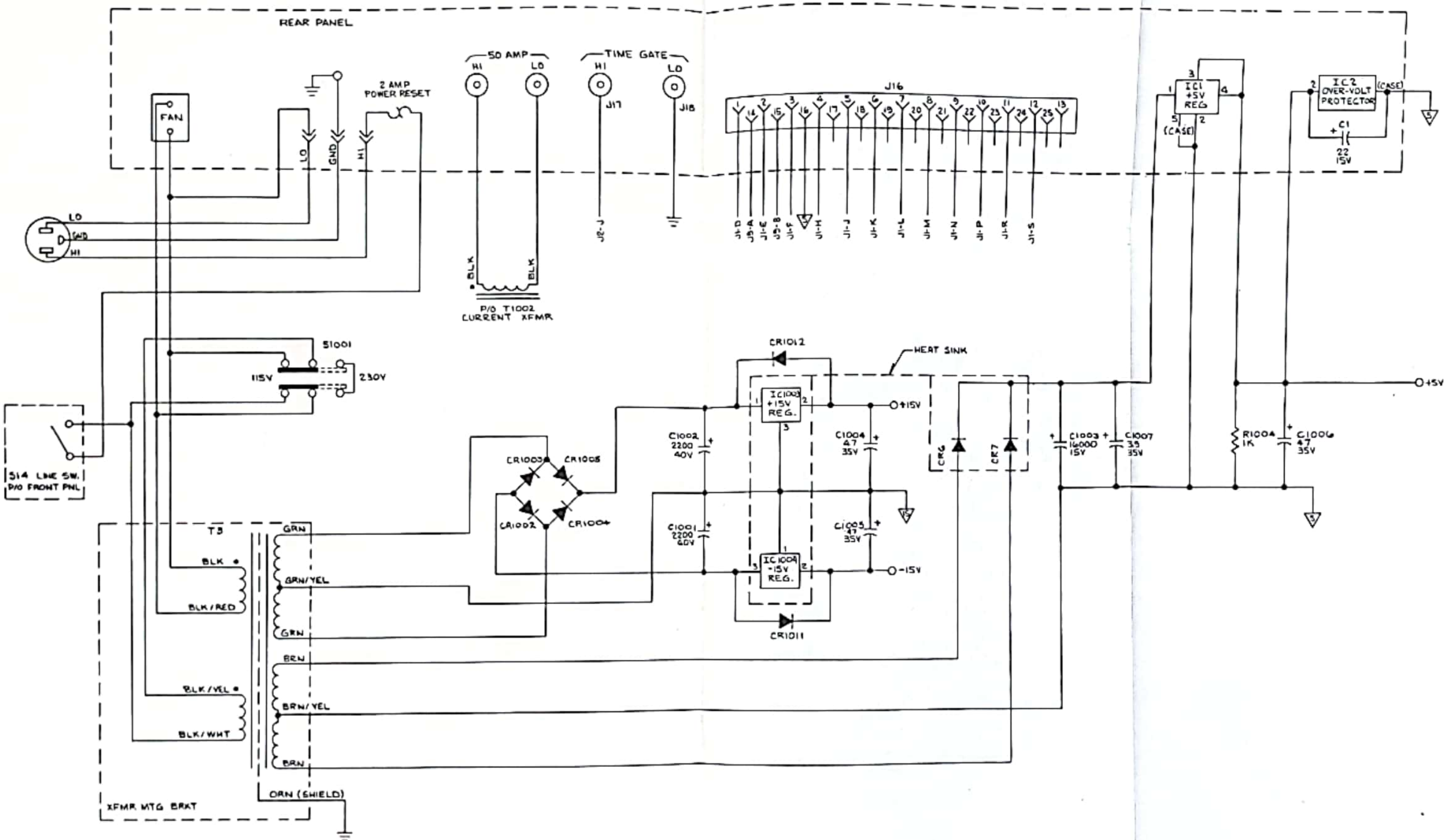



Figure 21. Schematic of power supply/mother board. (Sheets 1, 2, and 3)



-15
J16-1
J16-2
J16-3
J16-4
J16-5
J16-6
J16-7
J16-8
J16-9
J16-10
J16-11
J16-12
J1
J2
J3
J4
J5
J6
J7
J8
J9
J11
5VDC
5COM
TO IC1001
TO IC1002
TO K1001
J16-15
J16-14
R1011
R1012
R1013
R1014
J13
J12
J14



REAR PANEL
FAN
2 AMP POWER RESET
LO
GND
HI
50 AMP
HI
LO
TIME GATE
HI
LO
J17
J18
J16
J2-J
J1-D
J5-A
J1-E
J5-B
J1-F
J1-H
J1-J
J1-K
J1-L
J1-M
J1-N
J1-P
J1-R
J1-S
BLK
BLK
P/O T1002 CURRENT XFMR
S1001
115V
230V
S14 LINE SW. P/O FRONT PNL
T3
BLK
BLK/RED
BLK/YEL
BLK/WHT
GRN
GRN/YEL
GRN
BRN
BRN/YEL
BRN
ORN (SHIELD)
XFMR MTG BRKT
CR1003
CR1005
CR1002
CR1004
CR1012
CR1011
HEAT SINK
C1002 2200 40V
C1001 2200 40V
IC1003 +15V REG.
IC1004 -15V REG.
C1004 47 35V
C1005 47 35V
+15V
-15V
CR6
CR7
C1003 16000 15V
C1007 33 35V
R1004 1K
C1006 47 35V
+5V
IC1 +5V REG
(CASE)
IC2 OVER-VOLT PROTECTOR
(CASE)
C1 22 15V

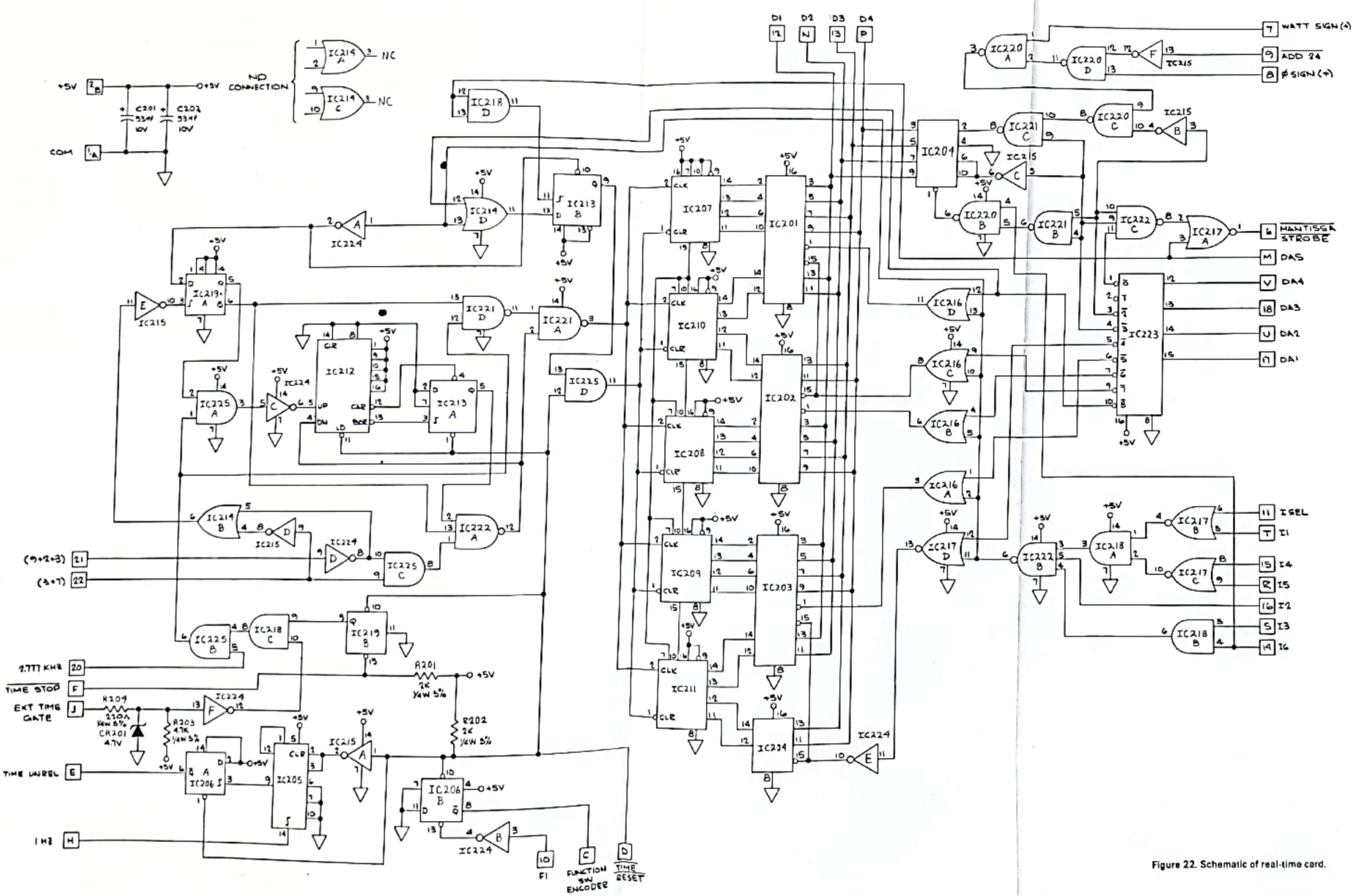



Figure 22. Schematic of real-time card.

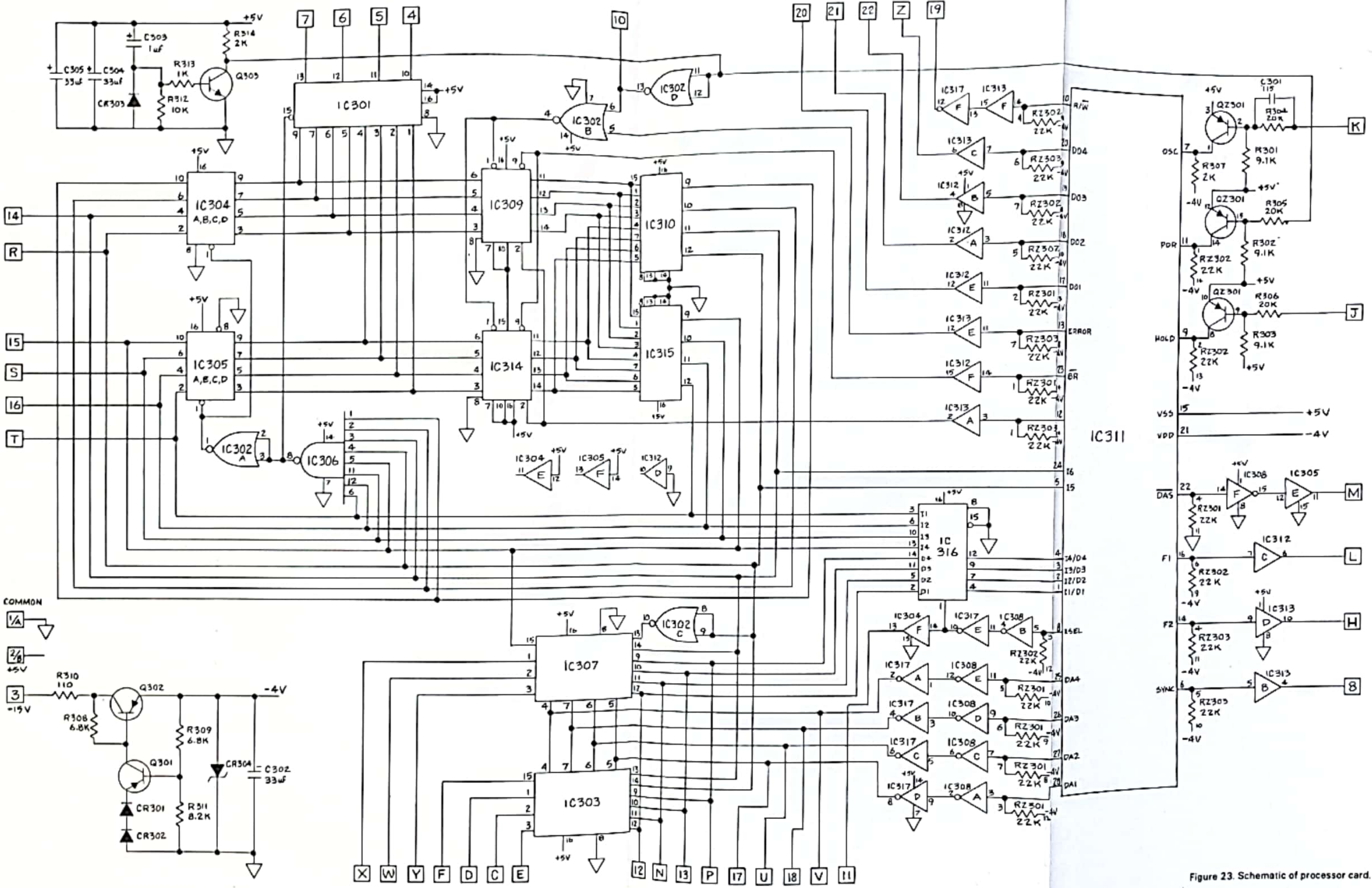



Figure 23. Schematic of processor card.

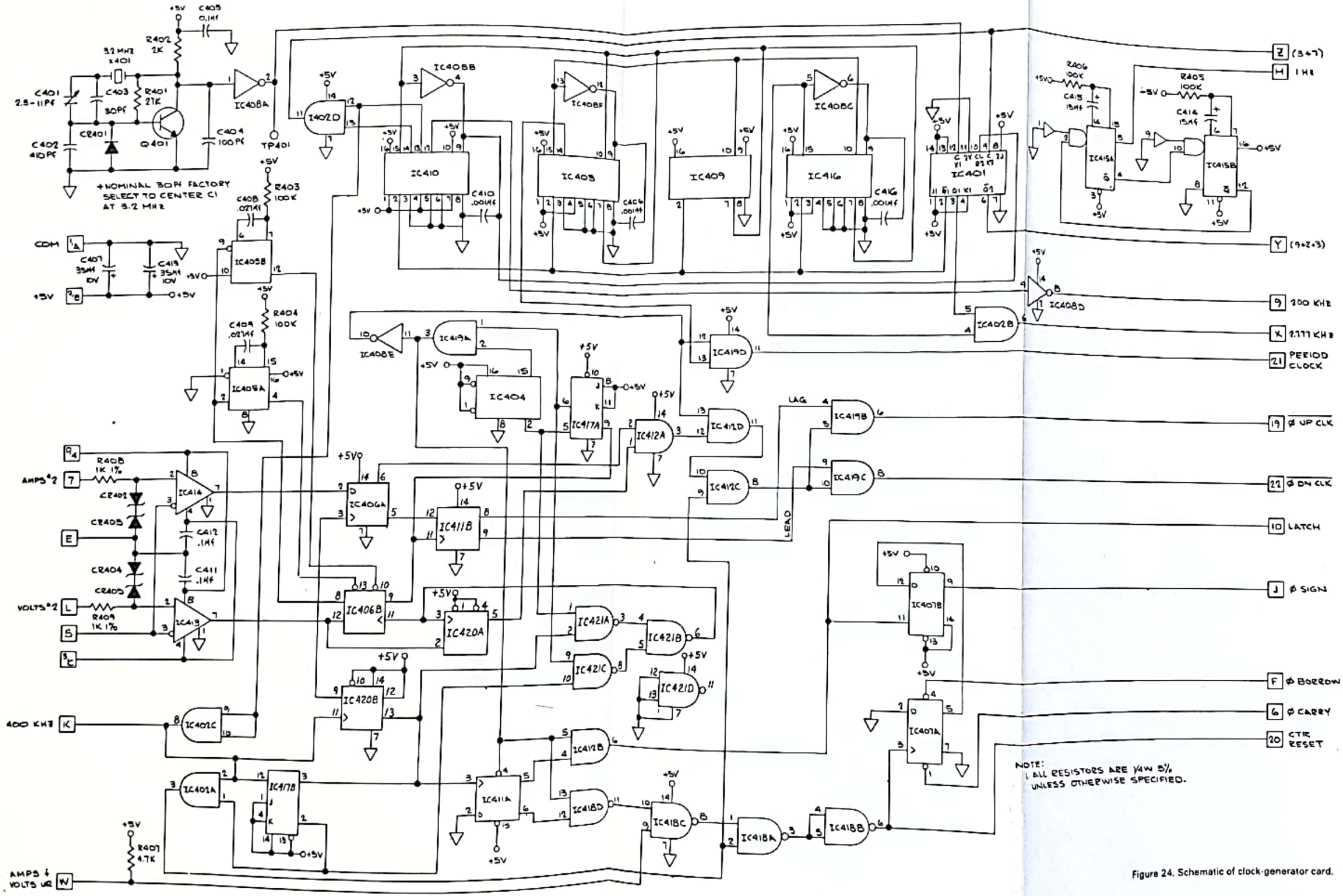



Figure 24. Schematic of clock-generator card.

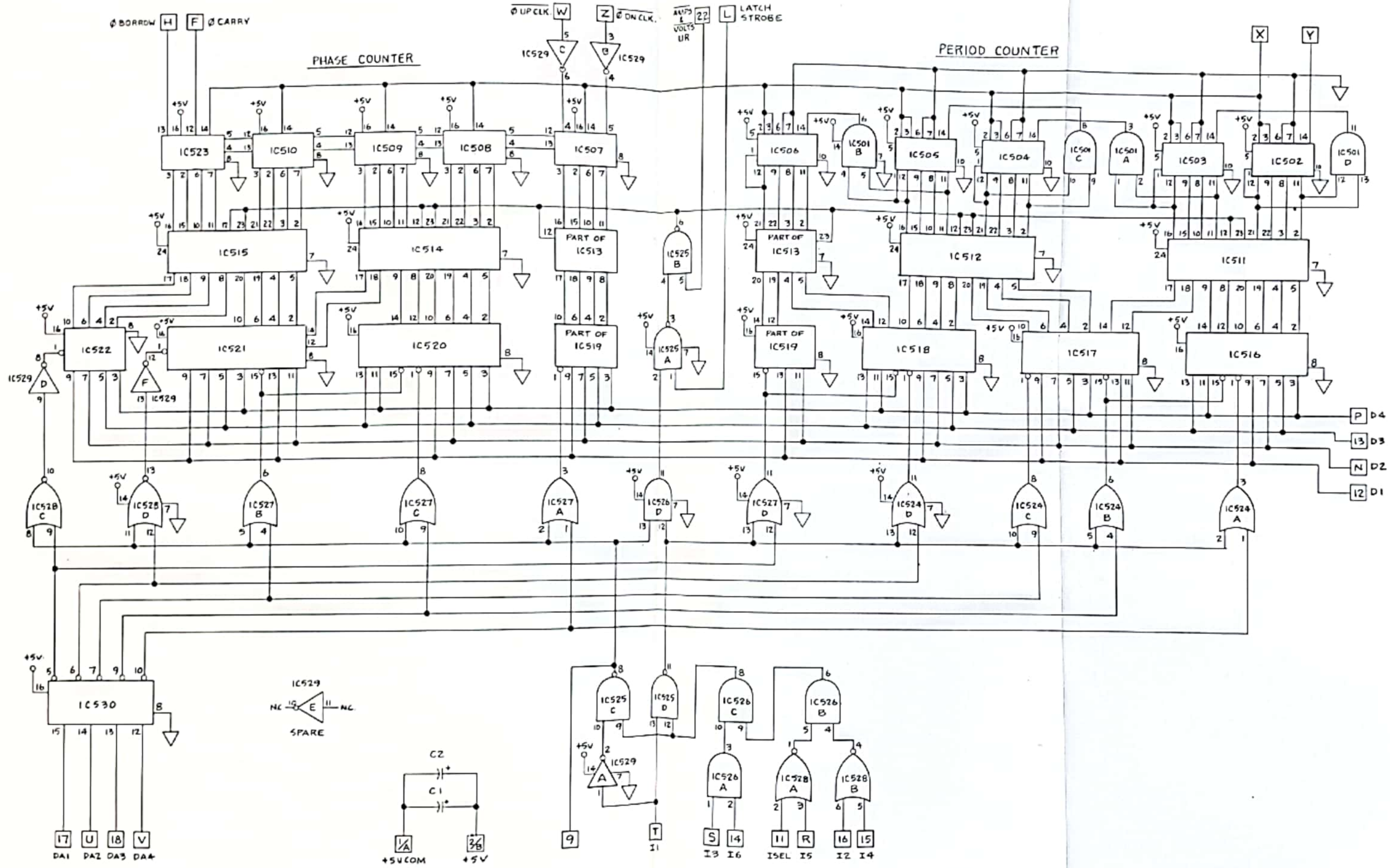



Figure 25. Schematic of phase card.

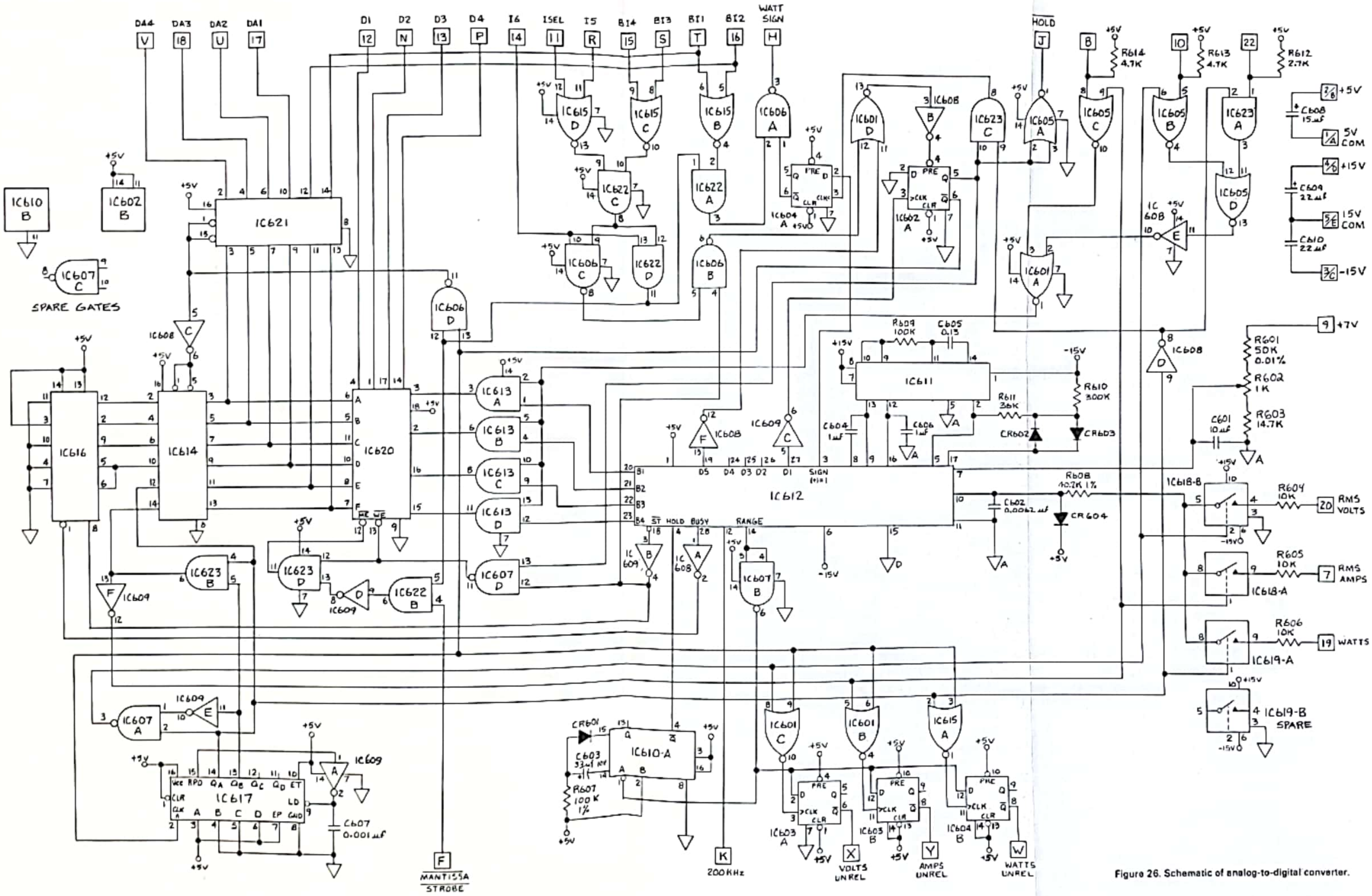


Figure 26. Schematic of analog-to-digital converter.

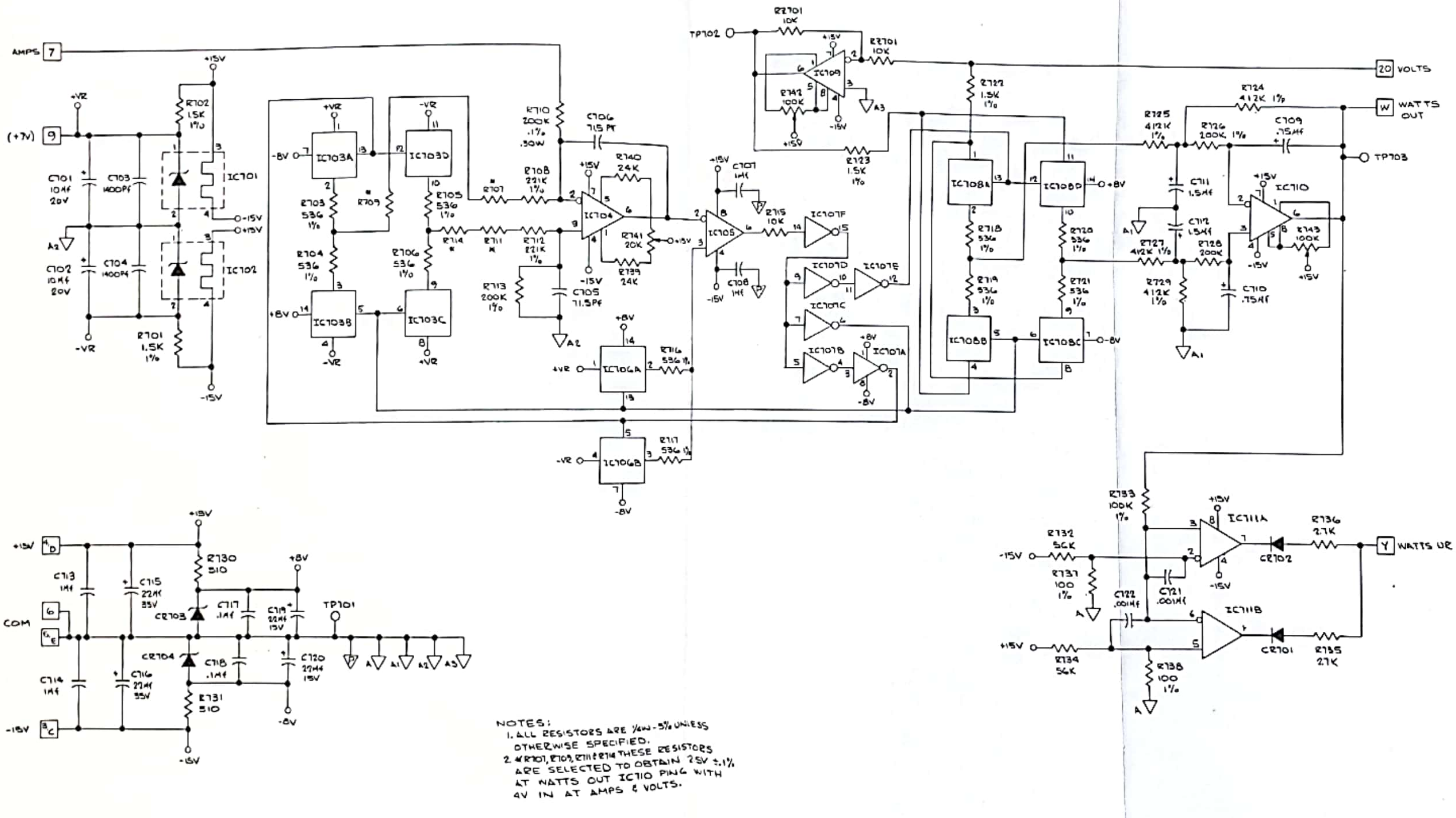



Figure 27. Schematic of watts multiplier.

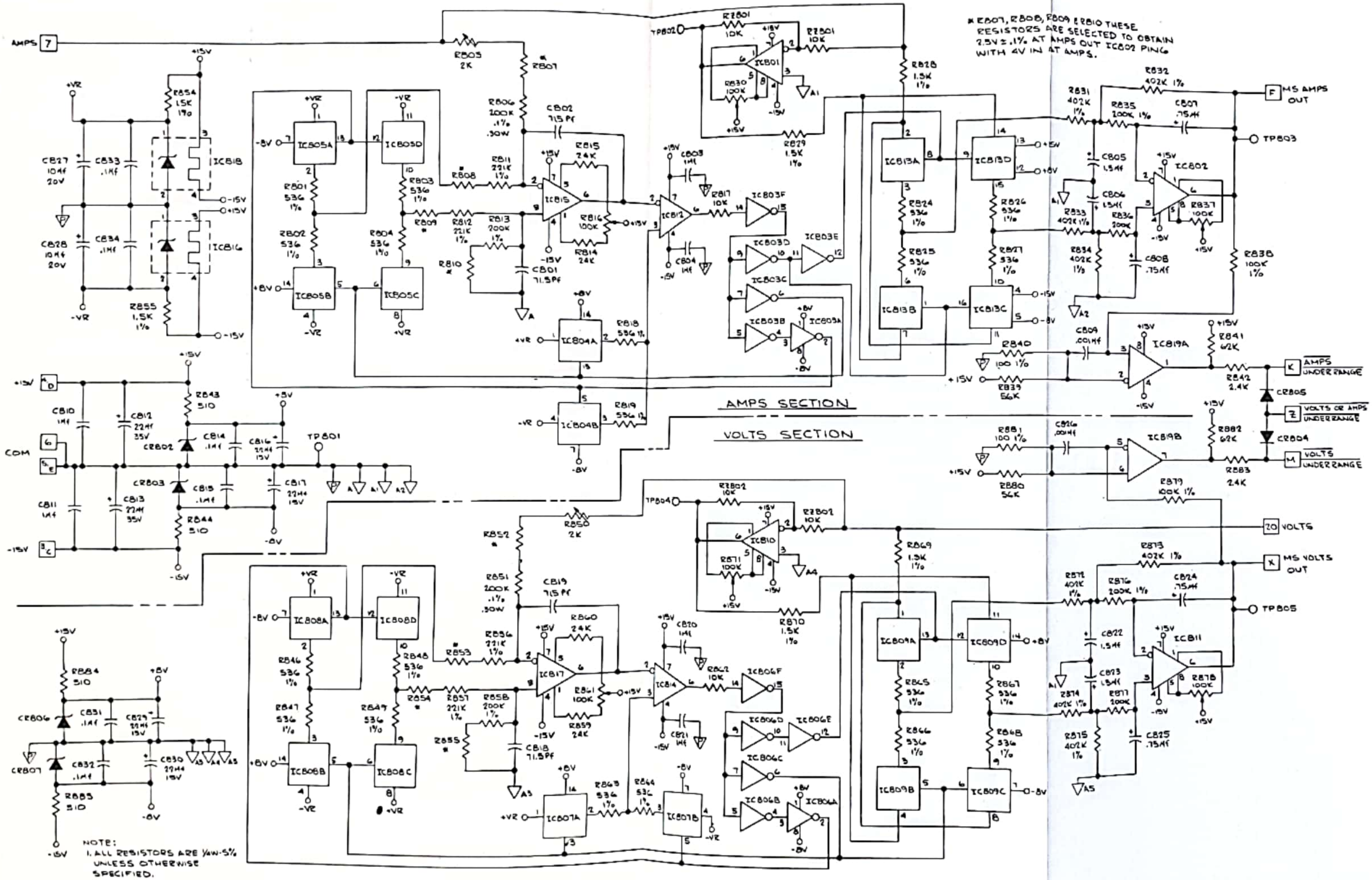



Figure 28. Schematic of volts and amperes multipliers.

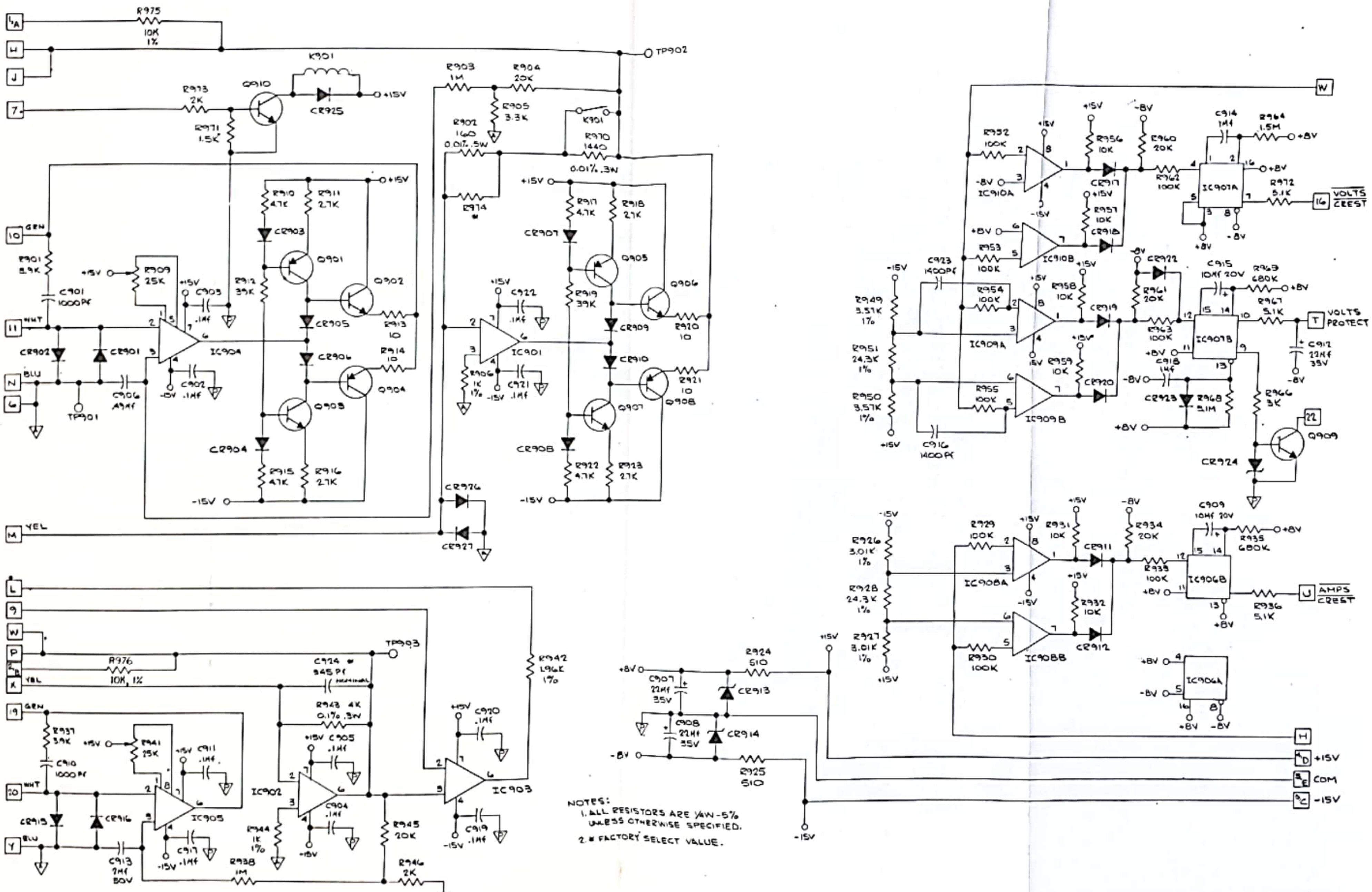



Figure 29. Schematic of electronic circuits for volts and amperes channels.

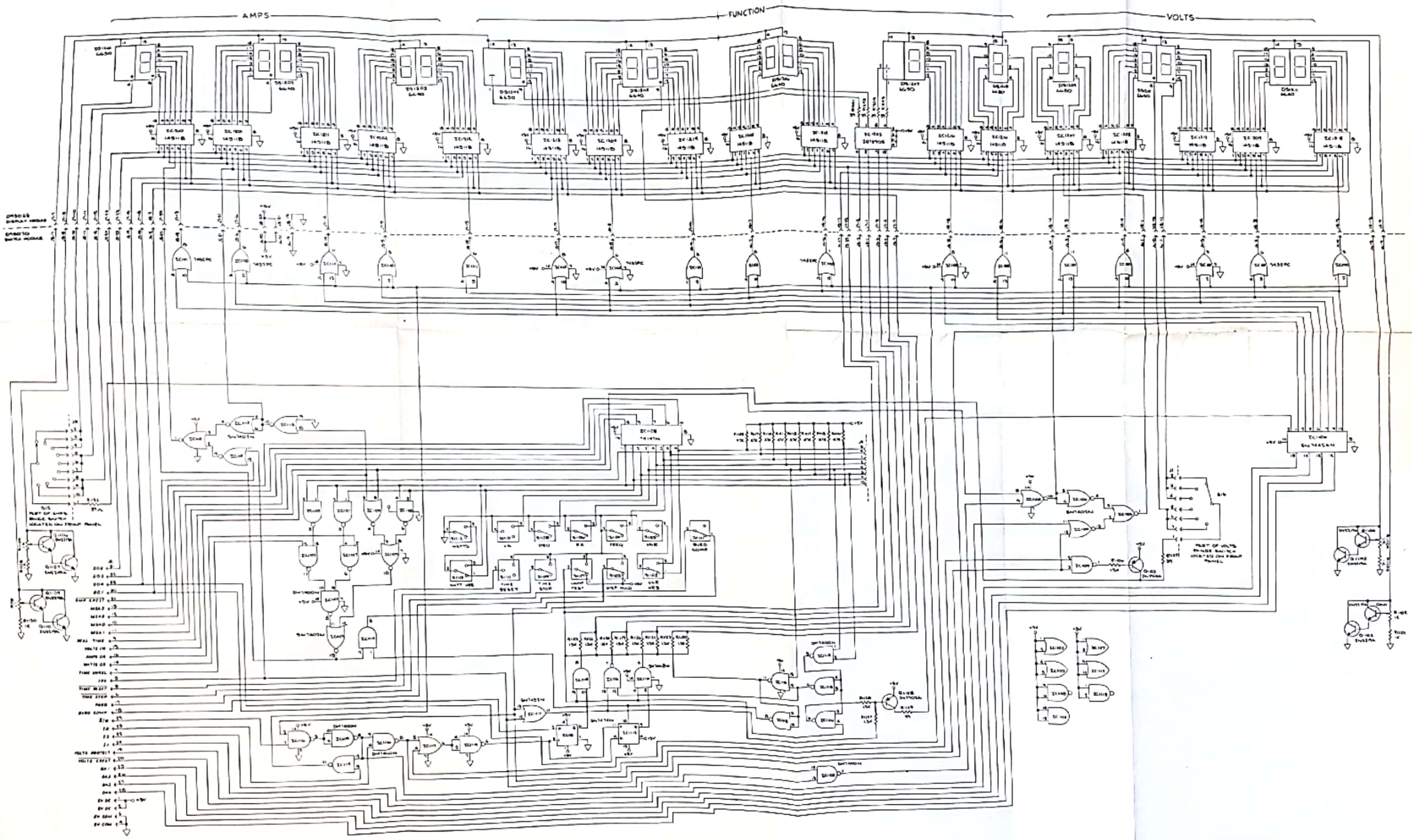



Figure 30. Schematic of display and switchboard circuits.

# TABLE OF REPLACEABLE PARTS

## Front Panel, Assembly HB-95201

| CIRCUIT SYMBOL | DESCRIPTION | PART NUMBER |
|---|---|---|
| R1 | Resistor, metal-film, 1K, 1%, 0.25W, Type RN¼, RFL Spec HA-38328 | H-0410-1288 |
| R2 | Resistor, metal-film, 30K, 0.01%, 0.3W, Vishay S102C30K, or eq. | H-1510-2100 |
| R3 | Resistor, metal-film, 90K, 0.01%, 0.5W, Vishay S104D150K, or eq. | H-1510-2102 |
| R4, 5, 6 | Resistor, metal-film, 150K, 0.1%, 0.75W, Vishay S105D150K, or eq. | H-1510-2103 |
| ——— | Schematic (Figure 21) | H-95064 |

## Rear Panel, Assembly HB-95240

| CIRCUIT SYMBOL | DESCRIPTION | PART NUMBER |
|---|---|---|
| CB1 | Circuit breaker, 2-amp, FTA Products 45-700-P2, or eq. | HB-11665 |
| CR1-5 | Not used | ——— |
| CR6, 7 | Rectifier, 12A, 600V, Motorola MR1126, or eq. | HA-27699 |
| IC1 | Linear, voltage regulator, 5V, Lambda LAS3905, or eq. | H-6020-189 |
| IC2 | Overvoltage protector, 6A, 5V, Lambda L-6-OV-5, or eq. | H-46567 |
| T1, 2 | Not used | ——— |
| T3 | Transformer, power | HA-44577 |
| ——— | Schematic (Figure 21) | H-95064 |

## Real-Time Board, Assembly HB-95230

| CIRCUIT SYMBOL | DESCRIPTION | PART NUMBER |
|---|---|---|
| C201, 202 | Capacitor, tantalum, 33μF, 20%, 10V, Kemet T322D336M010AS, or eq. | H-1007-653 |
| CR201 | Diode, zener, 4.7V, 5%, 1W, Type 1N4732A | HA-37939 |
| IC201-204 | TTL Tri-state Hex Buffer, National DM8097N, or eq. | H-0610-55 |
| IC205 | TTL Decode Counter, Texas Instruments SN7490AN, or eq. | H-0620-28 |
| IC206, 213 219 | TTL Dual flip-flop, Texas Instruments SN7474N, or eq. | H-0610-36 |
| IC207-211 | TTL Synchronous, four-bit, decade counter, Texas Instruments SN74160N, or eq. | H-0610-88 |
| IC212 | TTL Synchronous, four-bit, up-down counter | H-0610-59 |
| IC214, 216 | TTL Quad, 2-input OR gate, Texas Instruments SN7432N, or eq. | H-0610-64 |
| IC215, 224 | TTL Hex Inverter, National DM7404N, or eq. | H-0610-9 |
| IC217 | TTL Quad, 2-input, NOR gate | H-0610-44 |
| IC218, 225 | TTL Quad, 2-input, AND gate National DM7408N, or eq. | H-0610-24 |
| IC220, 221 | TTL Quad, 2-input, NAND gate, National DM7400N, or eq. | H-0610-8 |
| IC222 | TTL, Triple, 3-input, NAND gate, Texas Instruments SN7410, or eq. | H-0610-27 |
| IC223 | TTL, BCD-to-decimal decoder, Texas Instruments SN7442N, or eq. | H-0610-54 |
| R201-204 | Resistor, fixed, composition, 5%, 0.25W, value on schematic, Allen Bradley CB, or eq. | H-1009-(XXX) |
| ——— | Schematic (Figure 22) | H-95234 |

## Processor Board, Assembly HB-95225

| CIRCUIT SYMBOL | DESCRIPTION | PART NUMBER |
|---|---|---|
| C301 | Capacitor, dipped mica, 1.5pF, 2%, 500V, Electro Motive DM-19, or eq. | H-16603 |
| C302,304,305 | Capacitor, tantalum, 33μF, 10%, 10V, Kemet T322D336M010AS, or eq. | H-1009-653 |
| C303 | Capacitor, tantalum, 1μF, 10%, 35V, Kemet T110A105K035AS, or eq. | H-1007-1156 |
| CR301-303 | Diode, silicon, Type 1N914B/1N448 | HA-26482 |
| CR304 | Diode, zener, 4.3V, 5%, 1W, Type 1N4731A | HA-29750 |
| IC301 | Custom bipolar PROM | H-0630-10 |
| IC302 | TTL, Quad, 2-input, NOR gate, Texas Instruments SN7402N, or eq. | H-0610-44 |

| CIRCUIT SYMBOL | DESCRIPTION | PART NUMBER |
|---|---|---|
| IC303, 307, 310-315 | Custom bipolar PROM | H-0630-11 |
| IC304, 305 | TTL, Tri-stable Hex Buffer, National DM8097N, or eq. | H-0610-55 |
| IC306 | 8-input, NAND gate, Texas Instruments SN7430N, or eq. | H-0610-30 |
| IC308 | CMOS Hex Inverter-Buffer, RCA CD4049BE, or eq. | H-0615-7 |
| IC309-314 | TTL Synchronous, four-bit, binary counter, Texas Instruments SN74161N, or eq. | H-0610-89 |
| IC311 | CMOS NUMBER ORIEN PRCS, National MM57109N, or eq. | H-0615-97 |
| IC312, 313 | CMOS Hex Buffer-converter, RCA CD4050BE, or eq. | H-0615-11 |
| IC316 | TTL, Quad two-line to one-line multiplexer, Texas Instruments SN7415N, or eq. | H-0610-60 |
| IC317 | TTL Hex Inverter, National DM7404N, or eq. | H-0610-9 |
| IC301, 302 | Transistor, silicon, PNP, Type 2N2905A | HA-39567 |
| Q303 | Transistor, silicon, NPN, Type 2N2222A | HA-37445 |
| QZ301 | Transistor array, four, Type 2N2905 per package, Texas Instruments Q2T2905, or eq. | HA-49479 |
| R301-312, 314 | Resistor, fixed, composition, 5%, 0.25W, value on schematic, Allen Bradley CB, or eq. | H-1009-(XXX) |
| R313 | Resistor, metal-film, 1K, 1%, 0.25W, Type RN¼ per RFL Spec HA-38323 | H-0410-1288 |
| RZ301-303 | Resistor network, 22K, 2%, 1.5W, Helipot 899-3-R22K, or eq. | HA-38959 |
| ——— | Schematic (Figure 23) | H-95229 |

## Clock-Generator Board, Assembly-95220

| CIRCUIT SYMBOL | DESCRIPTION | PART NUMBER |
|---|---|---|
| C401 | Capacitor, ceramic variable, 2.5-11pF, 200V, Erie 538-006 B2.5-11, or eq. | HA-13149 |
| C402 | Capacitor, dipped mica, 410pF, 2%, 500V, Electro Motive DM-19, or eq. | HA-16629 |
| C403 | Capacitor, dipped mica, 30pF, 5%, 100V, Electro Motive DM-10, or eq. | H-1080-391 |
| C404 | Capacitor, dipped mica, 100pF, 10%, 100V | H-1080-328 |
| C405, 411, 412 | Capacitor, ceramic 0.1µF, GMV, 50V, Kemet C320C104P5U5EA, or eq. | H-1007-1366 |
| C406, 410, 416 | Capacitor, dipped mica, 0.001µF, 5%, 100V, Electro Motive DM-19, or eq. | H-1080-395 |
| C407, 413 | Capacitor, tantalum, 33µF, 20%, 10V, Kemet T322D336M010AS, or eq. | H-1007-653 |
| C408, 409 | Capacitor, metallized polycarbonate, 0.027µF, 2%, 200V, Wesco 32MPC, or eq. | H-1007-1186 |
| C414, 415 | Capacitor, tantalum, 15µF, 20%, 20V, Kemet T322D156M020AS, or eq. | H-1007-716 |
| CR401 | Diode, silicon, Type 1N914B/1N4448 | HA-26482 |
| CR402-405 | Diode, zener, 8.2V, 400mW, Type 2N756A | HA-37441 |
| IC401, 417 | TTL Dual J-K, flip-flop, National DM74107N, or eq. | H-0610-31 |
| IC402, 412, 419 | TTL Quad 2-input AND gate, National DM7408N, or eq. | H-0610-24 |
| IC403, 409, 410, 416 | TTL Synchronous, four-bit, decade counter, Texas Instruments SN74160N, or eq. | H-0610-88 |
| IC404 | TTL Synchronous, four-bit, binary counter, Texas Instruments SN71461N, or eq. | H-0610-89 |
| IC405, 415 | TTL Retriggerable monostable multivibrator, Texas Instruments SN74123N | H-0610-47 |
| IC406,407,411 | TTL Dual, D-type, flip-flop, Texas Instruments SN7474N, or eq. | H-0610-36 |
| IC408 | TTL Hex Inverter, National DM7404N, or eq. | H-0610-9 |
| IC413, 414 | Linear comparator, Precision Monolithics CMP-D2EP, or eq. | H-0620-190 |
| IC418 | TTL Quad 2-input NAND gate, National DM-7400N, or eq. | H-0610-8 |
| Q1 | Transistor, silicon, NPN, Type 2N2222A | HA-37445 |
| R401-407 | Resistor, fixed, composition, 5%, 0.25W, value on schematic, Allen Bradley CB, or eq. | H-1009-(XXX) |



| CIRCUIT SYMBOL | DESCRIPTION | PART NUMBER |
|---|---|---|
| R408, 409 | Resistor, metal-film, 1K, 1%, 0.25W, Type RN¼, RFL Spec HA-38328 | H-0410-1288 |
| Y401 | Crystal, Piezo electric, 3.2mHz | HA-37440-50 |
| ——— | Schematic (Figure 24) | H-95224 |

## Phase Board, Assembly HB-95095

| CIRCUIT SYMBOL | DESCRIPTION | PART NUMBER |
|---|---|---|
| C501, 502 | Capacitor, tantalum, 10µF, 10%, 10V, Corning CCM -010-106-10, or eq. | H-1007-1245 |
| IC501, 526 | TTL Quad 2-input AND gate, National DM7408N, or eq. | H-0610-24 |
| IC502-506 | TTL Decade counter, Texas Instruments SN7490AN, or eq. | H-0610-28 |
| IC507-510, 523 | TTL Synchronous, four-bit, up-down counter, Texas Instruments SN74192N, or eq. | H-0610-69 |
| IC511-515 | TTL 8-bit bistable latch, Texas Instruments SN74100N, or eq. | H-0610-86 |
| IC516-522 | TTL Tri-state hex buffer, National DM8097N, or eq. | H-0610-55 |
| IC524, 527 | TTL Quad, 2-input OR gate, Texas Instruments SN7432N, or eq. | H-0610-64 |
| IC525 | TTL Quad, 2-input NAND gate, National DM7400N, or eq. | H-0610-8 |
| IC528 | TTL Quad, 2-input NOR gate, Texas Instruments SN7402N, or eq. | H-0610-44 |
| IC529 | TTL Hex Inverter, National DM7404N, or eq. | H-0610-9 |
| IC530 | TTL BCD-to-decimal decoder, Texas Instruments SN7442N, or eq. | H-0610-54 |
| ——— | Schematic (Figure 25) | H-95099 |

## Analog-to-Digital Board, Assembly HB-95090

| CIRCUIT SYMBOL | DESCRIPTION | PART NUMBER |
|---|---|---|
| C601 | Capacitor, tantalum, 10µF, 10%, 10V, Corning CCM-010-106-10, or eq. | H-1007-1245 |
| C602 | Capacitor, polystyrene, 0.0062µF, 2%, 100V, Wesco 32P, or eq. | H-5115-25 |
| C603 | Capacitor, tantalum, 100µF, 20%, 10V, Corning CCZ-010-107-20, or eq. | H-1007-887 |
| C604, 606 | Capacitor, metallized polycarbonate, 1µF, 2%, 100V, Wesco 32MPC, or eq. | H-1007-966 |
| C605 | Capacitor, polypropylene, 0.13µF, 2%, 100V, F-Dyne, PPA-11-13-100-2, or eq. | H-0105-24 |
| C607 | Capacitor, dipped mica, 0.001µF, 2%, 500V, Electro Motive DM-19, or eq. | H-1080-286 |
| C608 | Capacitor, tantalum, 15µF, 20%, 20V, Kemet T322D156M020AS, or eq. | H-1007-716 |
| C609, 610 | Capacitor, tantalum, 22µF, 10%, 35V, Kemet T110C226K035AS, or eq. | H-1007-666 |
| CR601-603 | Diode, silicon, Type 1N914B/1N4448 | HA-26482 |
| CR604 | Diode, silicon, Type 1N914B/1N4448 FD333 | HA-31049 |
| IC601, 605, 615 | TTL Quad, 2-input NOR gate, Texas Instruments SN7402N, or eq. | H-0610-44 |
| IC602-604 | TTL Dual D-Type, flip-flop, Texas Instruments SN7474N, or eq. | H-0610-36 |
| IC606, 607 | TTL Quad, 2-input NAND gate, Texas Instruments SN7400N, or eq. | H-0610-8 |
| IC608, 609 | TTL Hex inverter, Texas Instruments SN7404N, or eq. | H-0610-9 |
| IC610 | TTL Retriggerable, monostable multivibrator, Texas Instruments SN74123N, or eq. | H-0610-47 |
| IC611 | Analog signal conditioner, Intersil ICL8052ACPD, or eq. | H-0625-2 |
| IC612 | 4½ digit A/D converter, Intersil ICL 71C03APCI, or eq. | H-0625-5 |
| IC613, 622, 623 | TTL Quad, 2-input AND gate, Texas Instruments SN7408N, or eq. | H-0610-24 |
| IC614, 621 | TTL Tri-state hex buffer, National DM8097N, or eq. | H-0610-55 |
| IC616 | TTL Presettable decade counter, Texas Instruments SN74197N, or eq. | H-0610-22 |
| IC617 | Synchronous, four-bit binary counter, Texas Instruments SN74161N, or eq. | H-0610-89 |
| IC618, 619 | CMOS Dual analog switch, Siliconix DG200BA, or eq. | H-0605-3 |
| IC620 | CMOS 256-bit, tri-state RAM, National MM74C910N, or eq. | H-0615-96 |
| R601 | Resistor, metal-film, 50K, 0.01%, 0.3W, Vishay S102C50K, or eq. | H-1510-2101 |
| R602 | Resistor, variable, metal-film, 1K, 10%, 0.5W, Vishay 1202P-1K, or eq. | HA-37423 |

| CIRCUIT SYMBOL | DESCRIPTION | PART NUMBER |
|---|---|---|
| R603 | Resistor, metal-film, 14.7K, 1%, 0.125W, Type RN60E, RFL Spec HA-38305 | H-1510-1895 |
| R604-606 | Resistor, metal-film, 10K, 1%, 0.125W, Type RN55D, RFL Spec HA-38301 | H-1510-775 |
| R607, 609-614 | Resistor, fixed, composition, 5%, 0.25W, value on schematic, Allen Bradley CB, or eq. | H-1009-(XXX) |
| R608 | Resistor, metal-film, 40.2K, 1%, 0.125W, Type RN55D, RFL Spec HA-38301 | H-1510-720 |
| —— | Schematic (Figure 26) | H-95095 |

## Watts-Multiplier Board, Assembly HB-95075

| CIRCUIT SYMBOL | DESCRIPTION | PART NUMBER |
|---|---|---|
| C701, 702 | Capacitor, tantalum, 10μF, 10%, 20V, Kemet T322C106D020AS, or eq. | H-1007-955 |
| C703, 704 | Capacitor, dipped mica, 0.0014μF, 2%, 500V Electro Motive DM-19, or eq. | HA-16215 |
| C705, 706 | Capacitor, dipped, mica, 71.5pF, 5%, 500V, Electro Motive DM-15, or eq. | H-1080-301 |
| C707, 708, 713, 714 | Capacitor, ceramic, 1.0μF, +80 -20%, 50V, Illinois Tool 5030ES50RD105M, or eq. | H-1007-1153 |
| C709, 710 | Capacitor, metallized polycarbonate, 0.75μF, 2%, 100V, Wesco 32MPC, or eq. | H-1007-1018 |
| C711, 712 | Capacitor, metallized polycarbonate 1.5μF, 2%, 100V, Wesco 32MPC, or eq. | H-1007-1319 |
| C715, 716 | Capacitor, tantalum, 22μF, 10%, 35V, Kemet T110C222K035AS, or eq. | H-1007-666 |
| C717, 718 | Capacitor, ceramic, 0.1μF, GMV, 50V, Kemet C320C104PU5EA, or eq. | H-1007-1366 |
| C719, 720 | Capacitor, tantalum, 22μF, 20%, 15V, Kemet T322D226M015AS, or eq. | H-1007-656 |
| C721, 722 | Capacitor, dipped mica, 0.001μF, 2%, 500V, Electro Motive DM-19, or eq. | H-1080-286 |
| CR701, 702 | Diode, silicon, Type 1N914B/1N4448 | HA-26482 |
| CR703, 704 | Diode, zener, 8.2V, 400mW, Type 1N756A | HA-37441 |
| IC701, 702 | Linear voltage reference, National LM399H, or eq. | H-0620-172 |
| IC703, 706, 708 | CMOS Quad, bilateral switch, Fairchild F4066PC only | H-0615-65 |
| IC704 | Linear opamp, National LF355N, or eq. | H-0620-139 |
| IC705 | Linear opamp, National LF375H, or eq. | H-0620-147 |
| IC707 | CMOS Hex inverter, RCA CD4049AE, or eq. | H-0615-7 |
| IC709, 710 | Linear opamp, Prec. Monolithics OP-05CV, or eq. | H-0620-114 |
| IC711 | Linear, dual comparator, National LM393AN, or eq. | H-0620-144 |
| R701-706, 708, 712, 713, 716-723, 726, 728, 733, 737, 738 | Resistor, metal-film, 1%, 0.125W, value on schematic, Type RN55D, RFL Spec HA-38301 | H-1510-(XXX) |
| R707, 709, 711, 714 | Not used | —— |
| R710 | Resistor, wirewound, 200K, 0.1%, 0.3W, Gamble 1608AL, or eq. | H-1780-232 |
| R715 | Resistor, wirewound, 5%, 0.25W, value on schematic, Allen Bradley CB, or eq. | H-1009-(XXX) |
| R724, 725, 727, 729 | Resistor, metal-film, 412K, 1%, 0.125W, Type RN60E, RFL Spec HA-38305 | H-1510-206 |
| R741 | Resistor, variable, metal-film, 20K, 10%, 0.75W, Helipot 78PR20K, or eq. | H-43047 |
| R742, 743 | Resistor, variable, metal-film, 100K, 20%, 0.75W, Helipot 78PR 100K, or eq. | HA-31791 |
| RZ701 | Resistor network, 20K, 0.01% matched | HA-44266 |
| —— | Schematic (Figure 27) | H-95079 |



## Volts and Amps Multiplier Board, Assembly HB-95080

| CIRCUIT SYMBOL | DESCRIPTION | PART NUMBER |
|---|---|---|
| C801, 802, 818, 819 | Capacitor, dipped mica, 71.5pF, 5%, 500V, Electro Motive DM-15, or eq. | H-1080-301 |
| C803, 804, 810 811, 820, 821 | Capacitor, ceramic, 1.0μF, +80 -20%, 50V Illinois Tool 5030ES50RD105M, or eq. | H-1007-1153 |
| C805, 806, 822, 823 | Capacitor, metallized, polycarbonate, 1.5μF, 2%, 100V, Wesco 32 MPC, or eq. | H-1007-1319 |
| C807, 808, 824, 825 | Capacitor, metallized polycarbonate, 0.75μF, 2%, 100V, Wesco 32 MPC, or eq. | H-1007-1018 |
| C809, 826 | Capacitor, dipped mica, 0.001μF, 2%, 500V, Electro Motive DM-19, or eq. | H-1080-286 |
| C812 | Capacitor, tantalum, 22μF, 10%, 35V, Kemet T110C226K035AS, or eq. | H-1007-666 |
| C814, 815, 831, 832, 833, 34 | Capacitor, ceramic, 0.1μF, GMV, 50V, Kemet C320C104P5U5EA, or eq. | H-1007-1366 |
| C816, 817, 829, 830 | Capacitor, tantalum, 22μF, 20%, 15V, Kemet T322D226M015AS, or eq. | H-1007-656 |
| C827, 828 | Capacitor, tantalum, 10μF, 10%, 20V, Kemet T322C106K020AS, or eq. | H-1007-955 |
| CR801 | Not used | —— |
| CR802, 803, 806, 807 | Diode, zener, 8.2V, 400mW, Type 1N756A | HA-37441 |
| CR804, 805 | Diode, silicon, Type 1N914B/1N4448 | HA-26482 |
| IC801, 802, 810, 811 | Linear, opamp, Precision Monolithics OP-05CJ, or eq. | H-0620-114 |
| IC803, 806 | CMOS Hex Inverter, RCA CD4049AE, or eq. | H-0615-7 |
| IC804, 805, 807, 808, 809 | Quad bilateral switch, Fairchild F4066PC only | H-0615-65 |
| IC812, 814 | Linear opamp, National LF357H, or eq. | H-0620-147 |
| IC813 | CMOS, Quad, switched analog gate, Internal IH5052-CJE, or eq. | H-0615-98 |
| IC815, 817 | Linear opamp., National LF-355N, or eq. | H-0620-139 |
| IC816, 818 | Linear voltage reference, National LM399H, or eq. | H-0620-172 |
| IC819 | Linear, dual comparator, National LM393AN, or eq. | H-0620-144 |
| R801804, 806, 811-813, 818, 819, 824-829, 831-836, 838, 846-849, 851, 856-858, 863-870, 872-877, 879, 881, 886, 887 | Resistor, metal-film, 1%, 0.125W, value on schematic, Type RN55D, RFL Spec HA-38301 | H-1510-(XXX) |
| R805, 850 | Resistor, variable, metal-film, 2K, 20%, 0.75%, Helipot 78PR2K, or eq. | HA-31854 |
| R807-810, 852-855 | Resistor, metal-film, 1%, 0.125W, factory selected value, Type RN55D, RFL Spec HA-38301 | H-1510-(XXX) |
| R814, 815, 817, 839, 841-844, 859, 860, 862, 880, 882-885 | Resistor, fixed, composition, 5%, 0.25W, value on schematic, Allen Bradley, CB, or eq. | H-1009-(XXX) |

| CIRCUIT SYMBOL | DESCRIPTION | PART NUMBER |
|---|---|---|
| R816, 830, 837, 861, 871, 878 | Resistor, variable, metal-film, 100K, 10%, 0.5W | HA-49996 |
| R820-823, 845 | Not used | ——— |
| RZ801, 802 | Resistor network pair, 20K, 0.01% matched | HA-44266 |
| ——— | Schematic (Figure 28) | H-95084 |

## Volts and Amperes Electronic Board, Assembly HB-95085

| CIRCUIT SYMBOL | DESCRIPTION | PART NUMBER |
|---|---|---|
| C901, 910 | Capacitor, dipped mica, 0.001μF, 2%, 500V, Electro Motive DM-19, or eq. | H-1080-286 |
| C902-905, 911, 917, 919-922 | Capacitor, ceramic, μF, GMV, 80V, Kemet C320C104P5U5EA, or eq. | H-1007-1366 |
| C906 | Capacitor, metallized polycarbonate, 0.49μF, 2%, 200V, Wesco 32MPC, or eq. | H-1007-1224 |
| C907, 908, 912 | Capacitor, tantalum, 22μF, 10%, 35V, Kemet T110C226K035AS, or eq. | H-1007-666 |
| C909, 915 | Capacitor, tantalum, 10μF, 10%, 20V, Kemet T322C106K020AS, or eq. | H-1007-955 |
| C913 | Capacitor, metallized polycarbonate, 2μF, 2%, 50V, Wesco 32MPC, or eq. | H-1007-1361 |
| C914, 918 | Capacitor, ceramic, 1.0μF, +80 -20%, 50V, Illinois Tool 5030ES50RD105M, or eq. | H-1007-1152 |
| C916, 923 | Capacitor, dipped mica, 0.001μF, 2%, 500V, Electro Motive DM-19, or eq. | HA-16215 |
| CR901, 912, 915, 920, 922, 923 925 | Diode, silicon, Type 1N914B/1N448 | HA-26482 |
| CR913, 914 | Diode, zener, 8.2V, 400mW, Type 1N756A | HA-37441 |
| CR916-919 | Not used | ——— |
| IC901, 902 | Linear opamp, National LF355N, or eq. | H-0620-139 |
| IC903 | Linear opamp, National LM741CN, or eq. | H-0620-52 |
| IC904, 905 | Linear opamp | H-0620-114 |
| IC906, 907 | Dual monostable multivibrator, RCA CD4098BE, or eq. | H-0615-95 |
| IC909-910 | Dual, linear comparator, National LM393AN, or eq. | H-0620-144 |
| K901 | Relay, mercury-wetted Form A, Fifth Dimension 5K-VD-22-0-1, or eq. | HA-44547 |
| Q901, 905 | Transistor, silicon, PNP, Type 2N2907A | HA-37439 |
| Q902, 906, 909, 910 | Transistor, silicon, NPN, Type 2N2219A | HA-39569 |
| Q903, 907 | Transistor, silicon, NPN, Type 2N2222A | HA-37445 |
| Q904, 908 | Transistor, silicon, PNP, Type 2N2905A | HA-39567 |
| R901, 903, 905, 913, 914, 920, 921, 924, 925, 929-938, 945 946, 952-968, 971, 972, 973 | Resistor, fixed, composition, 5%, 0.25W, value on schematic | H-1009-(XXX) |
| R902 | Resistor, metal-film, 106 ohms, 0.01%, 0.3W, Vishay S104D160, or eq. | H-1510-2096 |
| R906, 910-912, 915-919, 922, 923-944 | Resistor, metal-film, 1%, 0.25W, value on schematic | H-0410-(XXX) |



| CIRCUIT SYMBOL | DESCRIPTION | PART NUMBER |
|---|---|---|
| R907, 908, 939, 940, 947, 948, 969 | Not used | ——— |
| R909, 941 | Resistor, variable, metal-film, 20K, 10%, 0.75W, Helipot 78PR20K, or eq. | HA-43047 |
| R926, 927, 928, 942, 949, 950, 951, 974 | Resistor, metal-film, 1%, 0.125W, value on schematic, Type RN55D, RFL Spec HA-38301 | H-1510-(XXX) |
| R943 | Resistor, metal-film, 4K, 0.01%, 0.3W, Vishay S102C4K, or eq. | H-1510-2098 |
| R970 | Resistor, metal-film, 1.44K, 0.01%, 0.3W, Vishay S102C1440, or eq. | H-1510-2097 |
| ——— | Schematic (Figure 29) | H-95089 |

## Main Board and Power Supply, Assembly HB-95060

| CIRCUIT SYMBOL | DESCRIPTION | PART NUMBER |
|---|---|---|
| C1001, 1002 | Capacitor, electrolytic, 2200μF, -10 +50%, 40V, Stettner-Trush EG2T/40, or eq. | H-1007-1172 |
| C1003 | Capacitor, electrolytic, 1600μF, -10 +75%, 15V, Mepco Electra 39CS15UT163, or eq. | H-1007-1384 |
| C1004-1006 | Capacitor, tantalum, 47μF, 20%, 35V, Kemet T110D476M035AS, or eq. | H-1007-660 |
| C1007 | Capacitor, tantalum, 3.9μF, 20%, 35V, Kemet T110B395M035AS, or eq. | H-1007-878 |
| C1008 | Capacitor, tantalum, 22μF, 20%, 15V, Kemet T322D226M015AS, or eq. | H-1007-656 |
| CR1001, 1008, 1009, 1010 | Diode, silicon, Type 1N914B/1N4448 | HA-26482 |
| CR1002-1005, 1011, 1012 | Diode, Type 1N4001 | HA-38876 |
| CR1006,1001 | Not used | ——— |
| IC1001, 1002 | TTL Encoder, 10-line decimal to 4-line BCD, Texas Instruments SN74174N, or eq. | H-0610-87 |
| IC1003 | Linear voltage regulator, 15V, Motorola MC7815CP, or eq. | H-0620-82 |
| IC1004 | Linear voltage regulator, -15V, National LM320T, or eq. | H-0620-177 |
| K1001 | Relay, mercury-wetted, SPST, normally open, 12-Vdc coil, Fifth Dimension SK-YC-22-0-1, or eq. | HA-44548 |
| R1001, 1002, 1015 | Resistor, fixed, composition, 5%, 0.25W, selected value, Allen Bradley CB, or eq. | H-1009-(XXX) |
| R1003 | Resistor, metal-film, 15K, 0.01%, 0.3W, Vishay S102015K, or eq. | H-1510-2099 |
| R1004-1009 | Not used | ——— |
| R1010 | Resistor, fixed, composition, 2K, 5%, 0.25W, Allen Bradley CB, or eq. | H-1009-760 |
| R1011 | Resistor, metal-film, 4.02K, 1%, 0.125W, Type RN55D, RFL Spec HA-38301 | H-1510-1211 |
| R1012 | Same as R1011, 6.04K | H-1510-1279 |
| R1013 | Same as R1011, 10K | H-1510-775 |
| R1014 | Same as R1010, 20K | H-1009-773 |
| T1001 | Input transformer, voltage | HB-95214 |
| T1002 | Input transformer, current | HB-91579 |
| ——— | Schematic (Figure 30) | H-95064 |

## Switch Board, Assembly HB-95070

| CIRCUIT SYMBOL | DESCRIPTION | PART NUMBER |
|---|---|---|
| IC1101-1103, 1110, 1111, 1117 | TTL Quad, 2-input OR gate, Texas Instruments SN7432N, or eq. | H-0610-64 |
| IC1104, 1109, 1112 | TTL Quad, 2-input NOR GATE, Texas Instruments SN7402N, or eq. | H-0610-44 |

| CIRCUIT SYMBOL | DESCRIPTION | PART NUMBER |
|---|---|---|
| IC1105, 1107, 1116, 1118, 1119 | TTL Quad, 2-input NAND gate, Texas Instruments SN7400N, or eq. | H-0610-8 |
| IC1106 | TTL BCD-to-decimal decoder, Texas Instruments SN7442N, or eq. | H-0610-54 |
| IC1108 | TTL 10-line decimal to 4-line BCD decoder, Texas Instruments SN74147N, or eq. | H-0610-87 |
| IC1113 | Not used | ---- |
| IC1114 | TTL Quad, 2-input AND gate, Texas Instruments SN7408N, or eq. | H-0610-24 |
| IC1115 | TTL Quad, D-type, flip-flop, Texas Instruments SN7474N, or eq. | H-0610-36 |
| Q1101, 1102, 1104-1107, 1109, 1110 | Transistor, silicon, NPN, Type 2N2219N | HA-39569 |
| Q1103, 1108 | Transistor, silicon, PNP, Type 2N2905A | HA-39567 |
| R1101, 1103, 1108, 1130 | Resistor, metal-film, 1K, 1%, 0.25W, Type RN¼ RFL Spec HA-38328 | H-0410-1288 |
| R1102, 1104, 1109, 1131 | Resistor, variable, metal-film, 1K, 10%, 0.5W, Helipot 78PR1K, or eq. | HA-453412 |
| R1115, 1118 | Not used | ---- |
| R1106, 1107, 1110-1117, 1119-1129, 1132 | Resistor, fixed, composition, 5%, 0.25W, value on schematic, Allen Bradley CB, or eq. | H-1009-(XXX) |
| ---- | Schematic (Figure 30) | H-95074 |
| | **Display Board, Assembly HB-95065** | |
| DS1201, 1204, 1207 | Optical display device, Gen. Inst. MAN6650F, or eq. | HA-91958 |
| DS1202, 1203, 1205, 1206, 1210, 1211 | Optical display device, Gen. Inst. MAN6640F, or eq. | HA-91957 |
| DS1208, 1209 | Optical display device, Gen. Inst. MAN6680F, or eq. | HA-44568 |
| IC1201, 1202, 1204-1218 | CMOS 7-segment latch, counter, and driver, Motorola MC14511CP, or eq. | H-0615-45 |
| IC1203 | Transistor array, PNP, four per package, Texas Instruments, Q2T2905, or eq. | HA-49479 |
| R1201-1204 | Resistor, fixed, composition, 39 ohms, 5%, 0.25W, Allen Bradley CB, or eq. | HA-1009-831 |
| ---- | Schematic (Figure 30) | H-95069 |



# APPENDIX A

## DC Calibration Module

## Model HB-95260

# DC CALIBRATION MODULE
# HB-95260

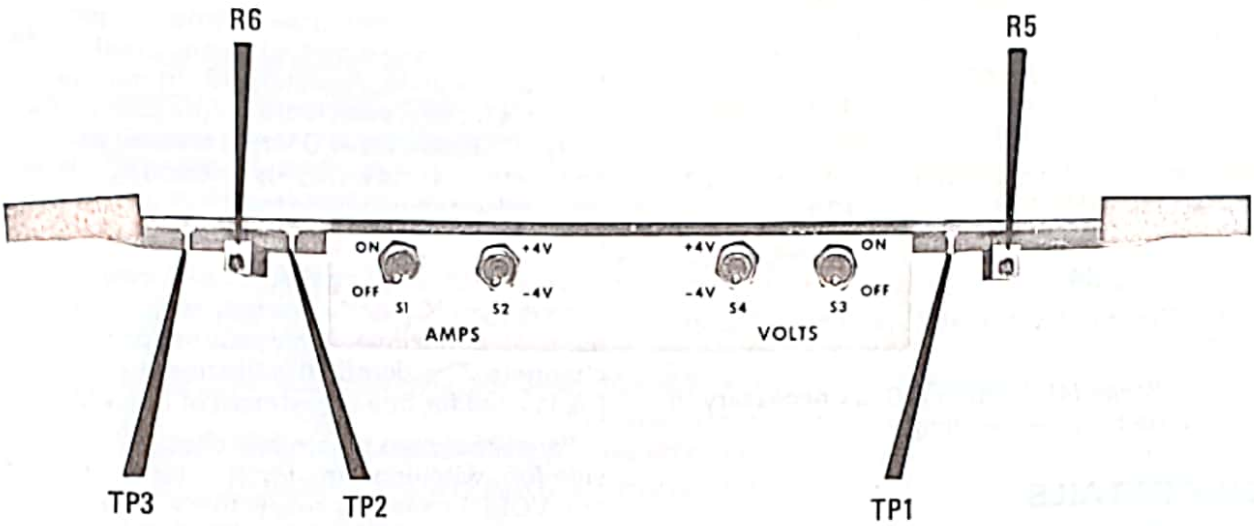



Figure 1-1. Model HB-95260 DC Calibration Module.

## DESCRIPTION

The Model HB-95260 DC Calibration Module, shown in Figure 1-1, is available as an aid for the calibration of the Model 636 Multifunction Power Analyzer. It does not certify the accuracy of the Model 636. It is a dc-to-dc converter type of power supply, using a switching circuit for ±4 Vdc. It will provide all voltages necessary to test and calibrate the power analyzer.

The calibration module derives its operating power from the Model 636, into which it is installed for operation. Outputs from the module are two channels of regulated, positive or negative 4 Vdc, one for input to the VOLTS channel of the Model 636, one for input to the AMPERES channel. Polarity of either input may be selected independently, and the input of either channel may be grounded independently.

## TECHNICAL DATA

**Output Voltage**
Two adjustable, positive or negative, 4-volt outputs, one for each input channel of the Model 636

**Output Current**
5mA, maximum

**Operating-Temperature Range**
0 to 40°C

**Input Voltage**
Both plus and minus 14.0 to 15.8 Vdc, taken from the Model 636

**Size**
The calibrator module is built on a circuit card 5.5 inches high, 9 inches long, and 0.625 inches wide, (140 x 230 x 16 mm).

## INSTALLATION and MAINTENANCE

When used to calibrate the Model 636, the Model HB-95260 DC Calibration Module replaces the Series 900 Transformer Electronics Card, and it is plugged in to Connector J9, from which the Transformer Electronics Card is removed. After installation, the module should be calibrated according to the procedure given in the following section.

For maintenance, Figure 1-2 will be helpful in identifying socket terminals. A suitable mating connector is TRW-Cinch Part 251-22-30-260. A schematic of the circuit is shown as Figure 1-3.

## CALIBRATION PROCEDURE

**Test Equipment Required**

(1) Fluke Model 887A Differential Voltmeter, or equal.

(2) RFL Model 636 Multifunction Power Analyzer.

**Procedure**

The Model HB-95260 DC Calibration Module should be calibrated each time it is to be used, because neither its accuracy nor its stability are specified on a long-term basis. Use the following procedure:

(1) Remove the Series 900 Transformer Electronics Card from the Model 636 and install the calibration module in the card slot thereby vacated.

(2) On the calibration module, select -4 Vdc for the AMPERES channel, using S2.

(3) Measure the voltage between TP2 (HI) and TP1 (LO) with the differential voltmeter.

(4) Adjust R5 to obtain -4000 ±0.05 mV.

(5) Select 4 Vdc on the AMPERES channel, using S2.

(6) Adjust R6 to obtain 4000 ±0.05 mV.

(7) On the Model 636, select the 1-AMPERE range, the 15-VOLT range, and the WATTS function. On the calibration module select 4 VOLTS input, using S4.

(8) Connect the differential voltmeter between TP1 (LO) and TP3 (HI). It should read 4000 ±0.1 mV.

(9) On the calibration module, select -4 VOLTS input, using S4.

(10) The differential voltmeter should real -4000 ±0.1 mV.

(11) Repeat Steps (4) through (10) as necessary to obtain the required readings.

## CIRCUIT DETAILS

The components of the Model HB-95260 DC Calibration Module are mounted on a plug-in circuit card. The schematic, of its circuit is shown as Figure 1-3.

IC1 is basically a temperature-compensated zener diode which provides a stable, dc reference voltage of 6.9 ±0.69 Vdc to the inverting input of opamp IC2. This opamp, operating as a buffer amplifier, establishes a precise -4 Vdc source for both AMPS and VOLTS channels. Resistor, R3, in parallel with R2 which is factory-selected, sets the gain of IC2, nominally at 0.5, so that -4.0 Vdc is present at IC2-6. Fine adjustment of this voltage is effected by adjusting R5, which also compensates for the inherent dc offset of the opamp.

Opamp IC3, with a gain of unity, accepts the -4 Vdc output from IC2 and inverts it to provide a precise, adjustable, positive 4-Vdc source for the two input channels. The dc-offset adjustment potentiometer, R6, is used for fine adjustment of the 4-Vdc output.

Panel-mounted toggle switches, S2 and S4, provide for switching the output polarity of the AMPS and VOLTS channels respectively. Similarly, toggle switches S1 and S3 provide ON-OFF control of their respective channels.

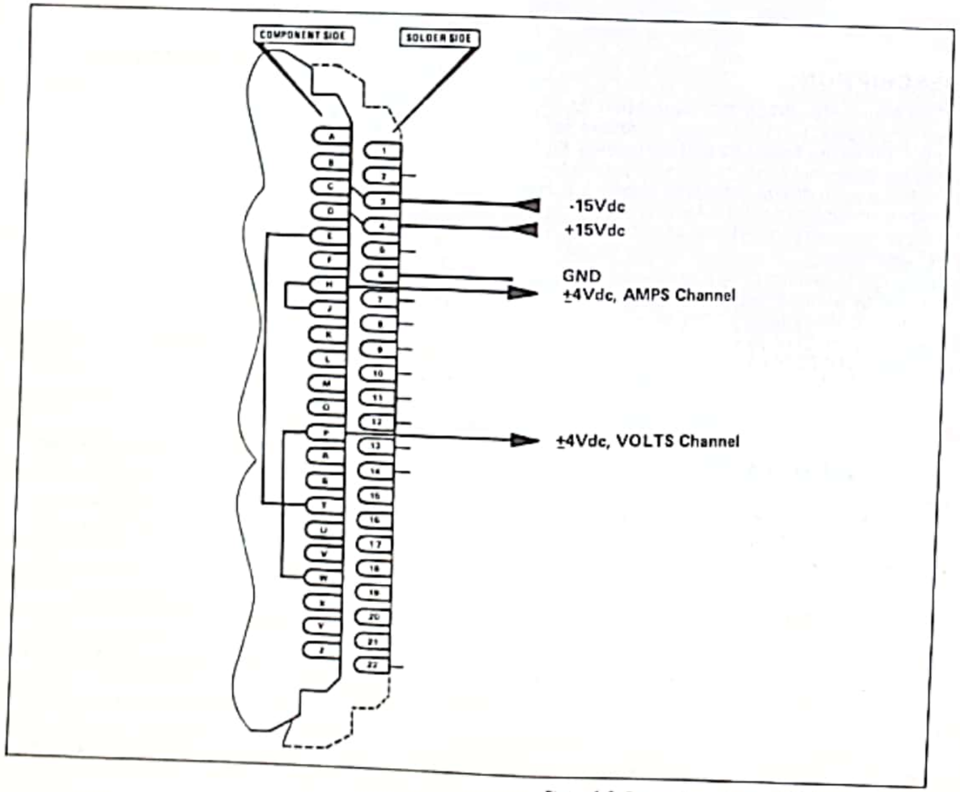



Figure 1-2. Connection Diagram, DC Calibration Module.



## TABLE OF REPLACEABLE PARTS

| CIRCUIT SYMBOL | DESCRIPTION | PART NUMBER |
|---|---|---|
| IC1 | Linear voltage reference, 0+70°C, National LM399H, or eq. | H-0620-172 |
| IC2, 3 | Linear opamp, 0+70°C, Precision Monolithics OP-05CP, or eq. | H-0620-180 |
| R1 | Resistor, metal-film, precision, 2.49K ohms, 1%, ¼ watt, type RN ¼ per spec HA-38323, or eq. | H-0410-1326 |
| R2 | Resistor, metal-film, precision, 73.2K ohms, 1%, ¼ watt, type RN ¼ per spec HA-33828, or eq. | H-0410-1467 |
| R3 | Resistor, metal-film, precision value selected by factory | H-0410-(XXXX) |
| R4 | Resistor, metal-film, precision, 39.2K ohms, 1%, ¼ watt, type RN ¼ spec HA-38328, or eq. | H-0410-1441 |
| R5, 6 | Resistor, variable, metal-film, 25K ohms, 10%, 0.75 watt, Beckman 89PHR25K, or eq. | HA-45829 |
| RZ1 | Resistor, metal-film, precision value selected at factory | HA-44266 |
| S1-4 | Switch, toggle, SPDT, C & K Component 7101-D-AV2, or eq. | H-95249 |
| —— | Schematic (Figure 1-3) | H-95264 |

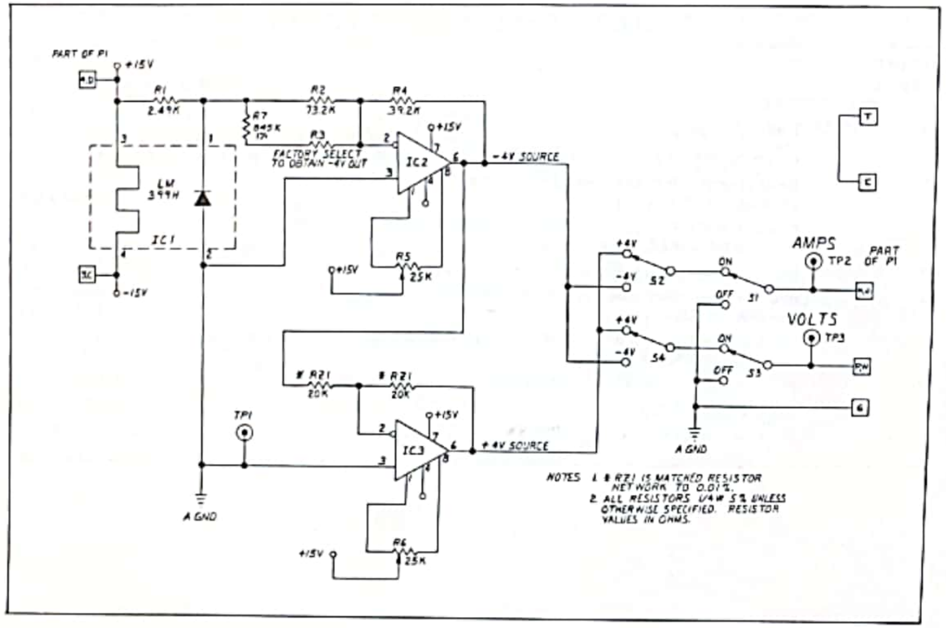



Figure 1-3. Schematic, DC Calibration Module.



## CERTIFICATE OF CALIBRATION
## FOR
## Model 636 Multifunction Power Analyzer

**Serial Number** ______________________

This instrument was calibrated at RFL Industries, Inc., Boonton, N.J. on ______________ at an ambient room temperature of ______________ °C. Calibration included all ranges provided by the instrument. Calibration instruments used have accuracy traceable to the National Bureau of Standards either directly or indirectly in an unbroken chain.

**Certified by** ______________________

**Date** ______________________

**RFL Industries, Inc.**
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