105A WATTMETER

OPERATING INSTRUCTIONS

Infratek

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1. INTRODUCTION AND SPECIFICATIONS

1.1. Introduction

This manual provides complete operating instructions and service information for the 105A Wattmeter.

1.2. The 105A Wattmeter

The Infratek 105A Digital Wattmeter is a high performance 5 digit instrument for general-purpose applications. Features of the basic 105A include:

- Power measurement
- True RMS voltage measurement
- True RMS current measurement up to 25A
- Highly legible vacuum fluorescent display
- Easy front panel operation
- Simple calibration, no internal adjustment
- Sequential display of all measured quantities
- Non-volatile memory for scaling factors

1.3. Options

A number of options are available for the 105A which can be easily installed at any time. The options include:

IEEE-488 Interface (Option 01), featuring:

- Complete programmability
- Adapts to other installed options
- Simple command set
- Galvanically isolated

Energy Converter (Option 02), featuring:

- Background energy computation
- Power factor computation

Recorder Output (Option 04), featuring:

- Output proportional to average power
- Output proportional to RMS current
- Output proportional to RMS voltage
- All three outputs galvanically isolated

Broad band recorder output (Option 05), featuring:

- Output proportional to instantaneous power
- DC-10kHz bandwidth
- Galvanically isolated

High current broad band input transformer (Option 07), featuring:

- High current up to 1500A
- DC to 20kHz

1.4. Definition of Measured Quantities

The wattmeter determines rms-values of current and -voltage, power, and energy by means of converters. Power factor (PF) and apparent power (VA) are computed.

RMS current: $(1/T \int_0^T i^2 \ dt)^{1/2}$

RMS voltage: $(1/T \int_0^T v^2 \ dt)^{1/2}$

Power: $1/T \int_0^T i \cdot v \cdot dt$

Energy: $\int_0^{te} \text{power} \cdot dt$

Power factor: $\dfrac{\text{power}}{\text{Arms} \cdot \text{Vrms}}$

1.5 SPECIFICATIONS 105A

CURRENT

Ranges:	1A, 5A, 25A; Rm=25mOhm; 20A cont., 25A 2 minutes
Option 07:	10A, 50A, 150A (current multiplier = 10) Current ranges are multiplied by current multiplier.
Current Scaling: (Option 03)	Current multipliers for standard current transformers can be programmed (1, 2, 4, 10, 20, 40, 100, ...) and are stored in non-volatile memory. The displayed values are scaled accordingly.
Display:	0-99999
Frequency Range:	DC+AC-Coupling: DC-20kHz; AC-Coupling: 15Hz-20kHz
Accuracy:	True RMS; 1 year, 18-25 deg.C (0.1 % of input + 0.15 % FS) 40Hz-60Hz (0.2 % of input + 0.25 % FS) 15Hz-5kHz (2.0 % of input + 0.35 % FS) DC, 5kHz-20kHz
Crest Factor:	Exceeds 3:1 at full scale, increasing down-scale
Temp. Coefficient:	0.01 % of range/deg.C

VOLTAGE

Ranges:	120V, 240V, 480V; max. 700V RMS or 1000V peak
Display:	0-99999
Frequency Range:	DC+AC-Coupling: DC-20kHz; AC-Coupling: 15Hz-20kHz
Accuracy:	True RMS, 1 year, 18-25 deg.C (0.1 % of input + 0.15 % FS) 40Hz-60Hz (0.2 % of input + 0.25 % FS) 15Hz-5kHz (2.0 % of input + 0.35 % FS) DC, 5kHz-20kHz
Crest Factor:	Exceeds 3:1 at full scale, increasing down-scale
Temp Coefficient:	0.01 % of range/deg.C
Input Impedance:	1MOhm, 20pF
Volt-Hertz Product:	2'000'000VHz

POWER

Ranges:	120W, 240W, 480W, 600W, 1200W, ..., 12kW Ranges are multiplied by current multiplier.
Display:	0-99999
Maximum Input:	As in current- and voltage section
Frequency Range:	As in current- and voltage section
Accuracy:	1 year, 18-25 deg.C, power factor 0.5 to 1.0 (0.1 % of input + 0.2 % FS) 40Hz-60Hz (0.2 % of input + 0.3 % FS) 15Hz-5kHz (0.5 % of input + 0.4 % FS)* DC,5kHz-10kHz (2.0 % of input + 0.5 % FS)* 10kHz-20kHz

For power factor <0.5 multiply accuracy percentage figures by 2.
*Specified at power factor 1.

Temp. Coefficient:	0.03 % of range/deg.C
Crest Factor:	Same as for current- and voltage section
Power Factor:	Option 2: Add accuracy percentage figures given for power current, and voltage.
Energy:	Option 2: Same accuracy percentage figures as given for power.

General

Input Type:	Floating type input.
Common Mode:	Common mode voltage: 700V peak from any input to earth. Common mode rejection ratio: Current input: 140dB at 50/60Hz, 120dB at 1kHz Voltage input: 100dB at 50/60Hz, 80dB at 1kHz Max. slew rate of Lo-terminal voltage: 150V/microsec.
Display:	5 digit, 12.5mm vacuum fluorescent display. Green Led annunciators. Cyclic display mode allows sequential display of all measured quantities.
Control Functions:	The 105A features 5 controls for voltage- and current range selection, for display selection, and for mode selection (AC- /AC+DC-coupling, auto, trig., and scaling).

Response time:	For all functions 1 second to rated accuracy.
Ranging:	Automatic or manual.
Temperature Range:	0-40 deg.C operating, -30 to 60 deg. C storage
Humidity:	80 % RH from 0 to 35 deg.C
Warmup time:	10 minutes to rated specification
Power:	220V (110V) +20 %/-10 %, 50-400Hz, 15VA
Size:	H x W x D; 132mm x 236mm x 300mm
Weight:	3.7kg
IEEE-488 interface:	Interface is galvanically isolated from 105A inputs. Option allows complete control and data output capabilities, and supports the following interface function subsets: SH1, AH1, T5, L4, SR1, RL1, DC1, and DT1.
Energy Converter:	Option allows simultaneous computation of energy (Wh), and power factor (PF).
Current Scaling:	Option allows current scaling for typical transformer ratios (1, 2, 4, 10, 20, 40, 100, ...). Factors are stored in non-volatile memory.
Recorder Output:	Three isolated recorder outputs for RMS current, RMS voltage, and average power.
Broad band recorder output:	Option allows measurement of instantaneous power. Frequency response DC-10kHz. Output is galvanically isolated.
High current input transformers:	Options allows broad band current measurement up to 1500A. The frequency range is DC to 20kHz. The current probe requires the scaling option. Current and power are multiplied accordingly.

Specifications
<u>(Option 07):</u>

Ranges:	0-10A, 0-50A, 0-150A Scaling factor = 10/number of windings Max. 150A continuous

Accuracy: (Current and power)

Transformer Input: (current x windings >25A)

±(0.2 % of input + 0.3 % of range)	40Hz-60Hz
±(0.4 % of input + 0.4 % of range)	15Hz-1kHz
±(2.0 % of input + 0.4 % of range)*	DC, 1kHz-10kHz
±(3.0 % of input + 0.5 % of range)*	10kHz-20kHz

DC: DC Offset error max +0.2A
*Power factor >0.7

Option 08: 0-20A, 0-100A, 0-450A
Accuracy: 1 %, 50/60Hz

Option 09: 0-100A, 0-500A, 0-1500A
Accuracy: 1 %, 50/60Hz

2. OPERATING INSTRUCTIONS

2.1. Introduction

This section provides operating instructions for the 105A. Refer to section 3 for measurement considerations.

2.2. Installation

The 105A has a rear panel power-line fuse in series with the input transformer. A 200mA, 250V slow-blow fuse is installed in the factory for operation from 200V to 250V. For operation with power-line voltages of 90V to 130V, the fuse must be replaced by a 400mA, 250V slow-blow fuse.

WARNING: To avoid electric shock, remove the power cord before replacing the line fuse.

2.3. Connecting to Line Power

WARNING: To avoid instrument damage, check that the rear panel line voltage selector is set to the correct line-voltage.
To avoid shock hazard, connect the 105A power cord to a power receptacle with earth ground.
The 105A accepts line power at 50Hz, 60Hz, or 400Hz.

2.4. Adjusting the Tilt Stand

At the bottom plate of the instrument are two tilt stands to adjust the viewing angle for bench-top use.

2.5. Rack Mounting Kit

You can mount the 105A in a standard 19-inch half rack panel using two rack ears. One rack ear is installed on each instrument side panel.

2.6. Operating Features

When the 105A is turned on, it performs an initialisation of its internal digital and analog circuitry. During start-up all display segments and all Leds are lit for approximately 1 second. The 105A determines the options installed and sets the internal option status accordingly. The 105A then assumes the following configuration:

- Display power
- Autorange (480V→120V/25A →1A)
- AC-Coupling
- Local (front panel) control

2.7. Front and Rear Panel Features

Front panel features are explained in Figure 2.1. Rear panel features are explained in Figure 2.2. Refer to section 1.4 for the definition of the measured quantities.
Note that the Wh, and PF functions are available only with the energy converter option (option 02). If this option is absent, pressing any of these function buttons causes the 105A not to respond and to remain in the current state.

2.8. Display Features

The 105A features a 5 digit 12.5mm high vacuum fluorescent display. The units are displayed by Led annunciators to the right of the numeric field. The operating annunciators are explained in Figure 2.1. The 105A has a unique cyclic display mode. When it is activated, the 105A measures all quantities and then sequentially displays current, voltage, power, and power factor. When finished new measurements are taken to repeat above display cycle.

2.9. Overrange Indication

An input is overrange if it exceeds the full scale display of the selected range or if the signal peaks exceed the linear operating range. This holds for the RMS converters as well as for the multiplier. When a display overrange occurs, the most significant digit and the decimal point are displayed. The remaining digits are blanked. When a peak signal overrange occurs the display flashes. When both, display overrange and peak signal overrange occurs, the most significant digit and the decimal point are flashed.
When using current transformers the current- and voltage wave forms may be such that a negative power signal in the 105A power converter results.

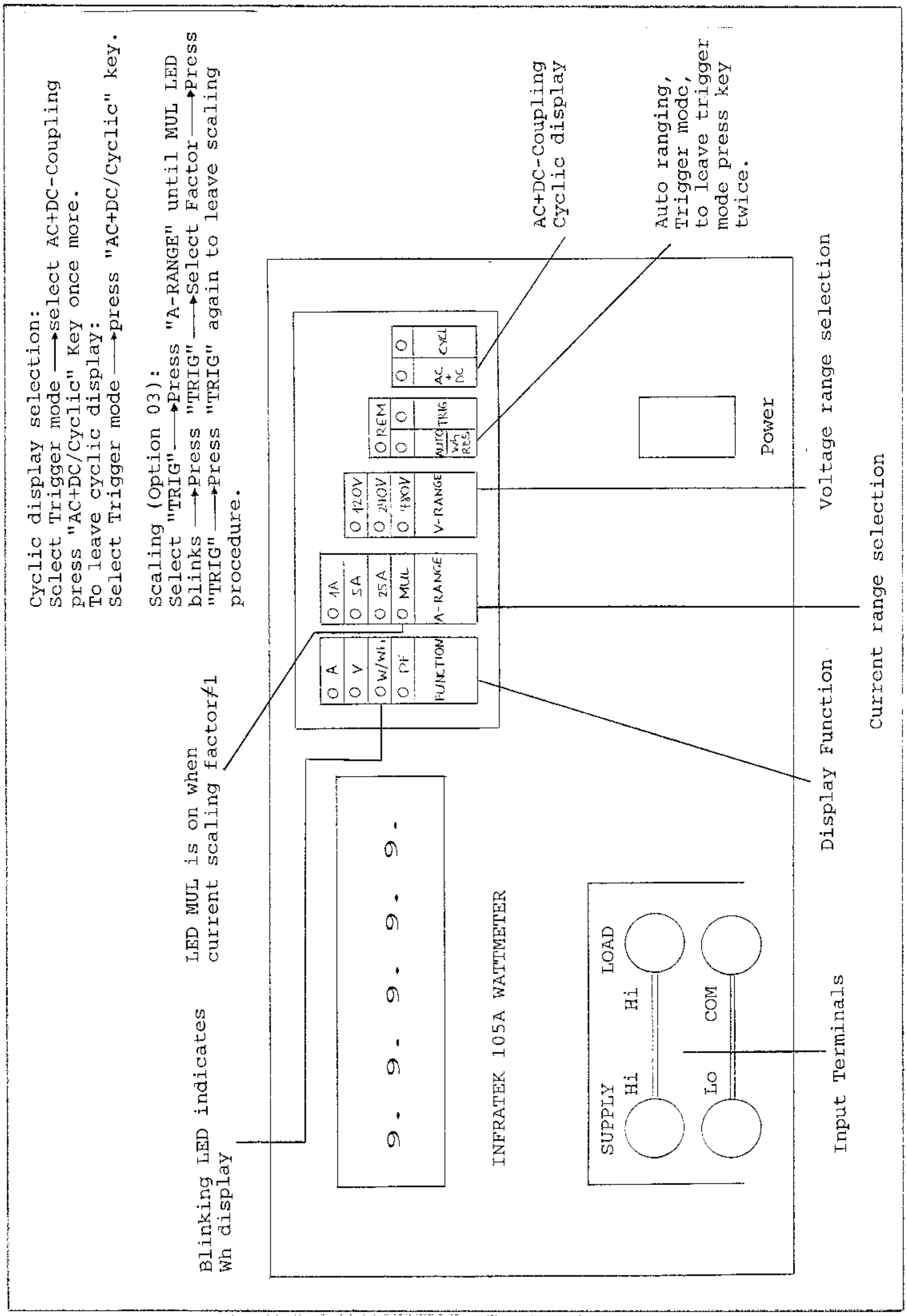


Figure 2.1.   Front Panel Features

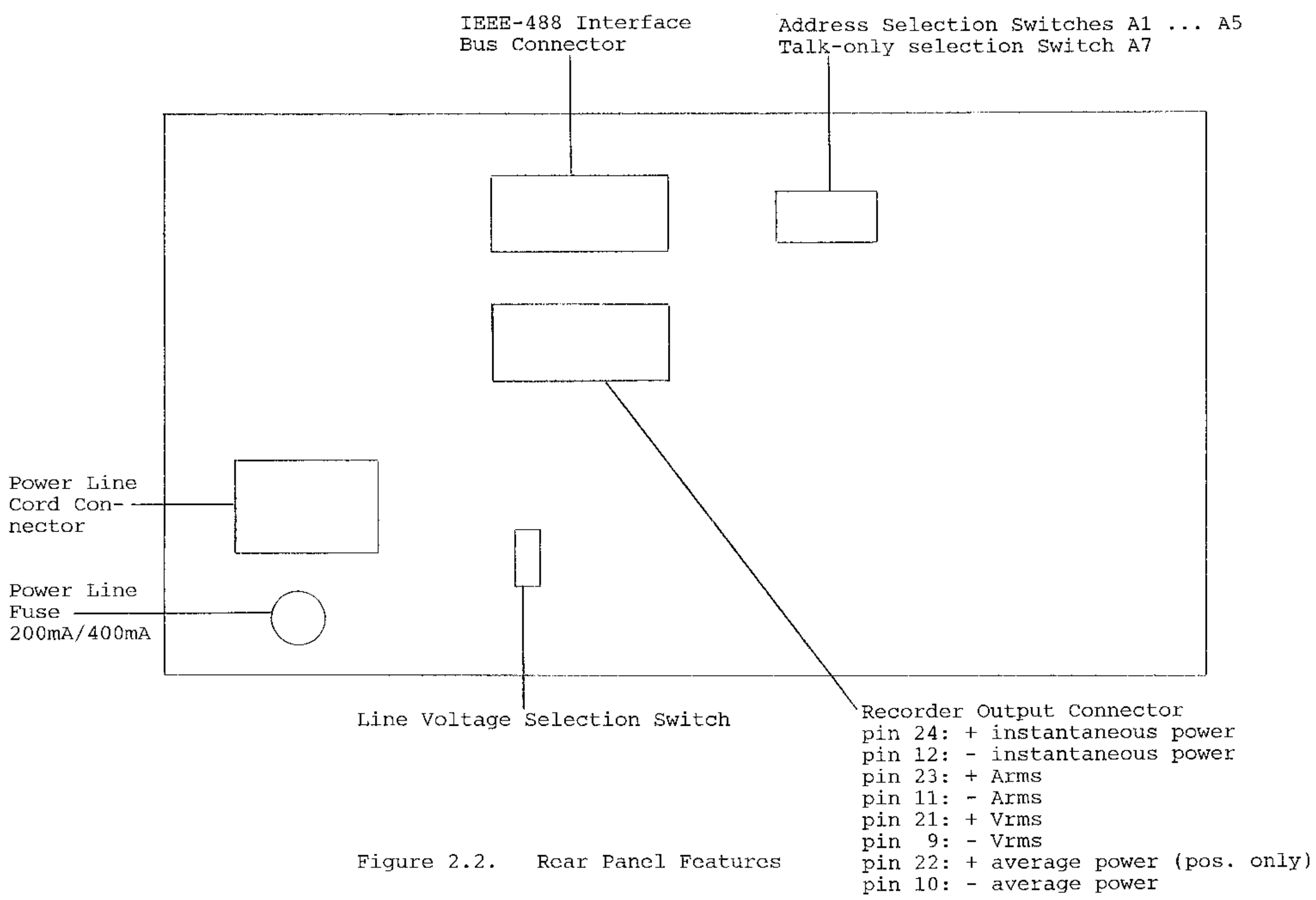


Figure 2.2. Rear Panel Features

In this case zero power display will result. Change the current direction to obtain positive power converter outputs.

CAUTION: There is no additional overrange indication, other than described above, when inputs exceed maximum allowable values.

2.10. Ranging

Measurement ranges can be selected using either autorange (by pressing the AUTO control) or manual range (by pressing another range button). When the 105A is in autorange, then both, the voltage- and current path are in autorange. The 105A displays explicit units in every range, so that the display may be read directly. This is also true, when scaling is in use.

Autorange: In autorange, the 105A goes to a higher range when the input exceeds 105 % to 110 % full scale, and goes to a lower range when the input falls 5 % below full scale of the next lower range (approximate values).

CAUTION: A peak signal overload condition may occur without the 105A ranging to a higher range. In this case we recommend manual ranging.

Manual Range: In manual range, the 105A remains fixed in the selected range until you select another range or press AUTO.
In general, manual ranging gives better accuracy, when the overrange capabilities of the 105A are used.

2.11. Coupling

In normal operating mode the voltage- and current inputs are AC-coupled. All signals above 10Hz are passed and processed in the instrument. When pressing the AC+DC-control the Led lights up indicating AC+DC-Coupling. Signals from DC to 20kHz are passed and processed. This feature allows simple detection of DC-components. The transient power measurements are performed by means of the broad band 105A recorder output, the 105A must be switched to AC+DC-Coupling. If in this case AC-Coupling is used false measurements result.

2.12. Triggering

Triggering causes the 105A to execute a measurement cycle and to display the result.
A measurement cycle is either triggered by pressing the TRIG control or by sending the trigger command from the interface.
When a measurement is triggered, the numeric field is blanked until the new readings are valid. During a measurement cycle all quantities are determined (A, V, W; option 02: power factor). They can be displayed by pressing the appropriate front panel control.
The trigger mode is left by pressing the AUTO control twice in a short sequence.

2.13. Inputs

Load: The load is connected to the load terminals.
Supply: The supply is connected to the supply terminals.

Make sure to always connect the Lo-input terminals of the wattmeter to the Lo-side of the supply. Violation of this rule will expose the 105A to large common mode voltages, and if the Lo-terminal slew rate is greater than 150V/microsecond, the wattmeter circuitry looses synchronisation. The 105A must be turned off and on again to start an initialisation.

Hi-voltage terminal:
The Hi-voltage terminal is connected to the Hi-side of the source/load.

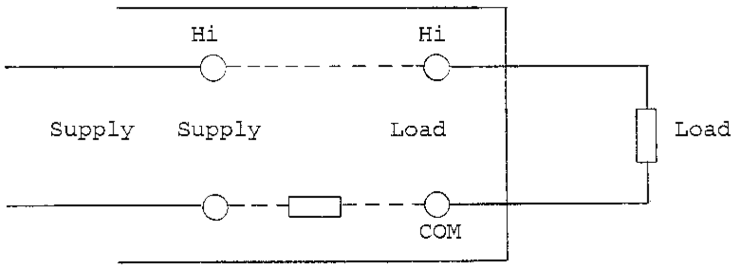


Figure 2.3. 105A Wattmeter Connection

3. MEASUREMENT CONSIDERATION

3.1. Introduction

This section discusses considerations and techniques to help you use the 105A effectively. Among other things, this section discusses sources of error which are an inherrent part of the power measurement process.

3.2. Input Overload Protection Limits

WARNING: To avoid shock hazard and/or instrument damage, do not apply input potentials that exceed the input overload limits shown in table 3.1.

Function	Connectors	Maximum Input
Vrms	Input Hi and Lo	700Vrms, 1000Vp
Arms	Input Hi and Lo	25Arms
All Functions	Lo-terminals to earth	700Vp
All Functions	Lo-terminals to earth	150V/micro second

Table 3.1. Input Overload Limits

The 105A is protected against overloads up to the limits shown. Exceeding these limits may damage the instrument and/or pose a shock hazard.

3.3. Measuring Voltage

To measure voltage, select the desired function and connect the test leads as shown in Figure 3.1.

3.4. Measuring Current

To measure current, select the desired function and connect the test leads as shown in Figure 3.2.

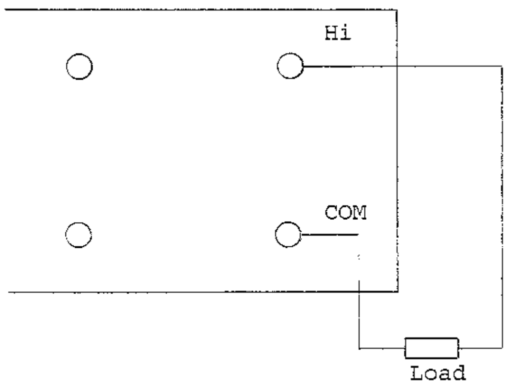


Figure 3.1. Measuring Voltage

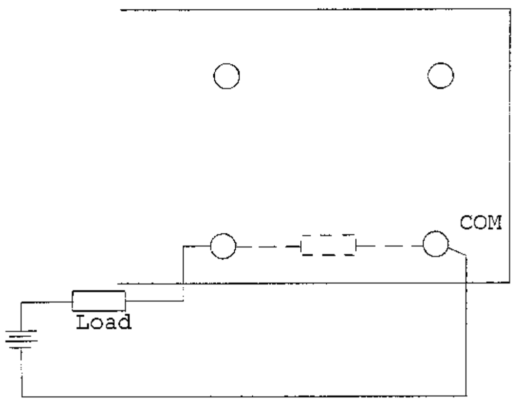


Figure 3.2. Measuring Current

3.5. Measuring Power

To measure power, select the desired function and connect the test leads as shown in Figure 3.3.

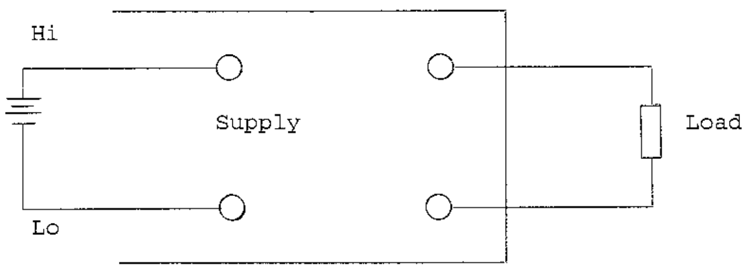


Figure 3.3. Power Measurement

3.6. Circuit Loading Error

Whenever a wattmeter is connected to a circuit, the internal resistors of the wattmeter will load the circuit under test. Although the test lead power loss can be compensated for, there is no way to get around the power loss in the wattmeter input circuitry. Basically, the wattmeter input configuration is fixed, as shown in Figure 3.4

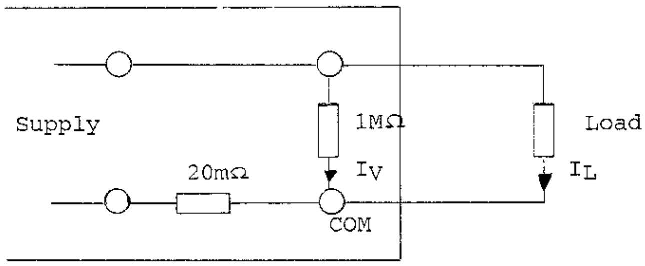


Figure 3.4. Input Configuration

The current flowing in the 1MOhm voltage input resistor presents circuit loading, causing the main circuit loading error. For load resistors >1kOhm the current Iv flowing in the 1MOhm input resistor becomes >0.1 % of the current Il flowing in the load. The current reading and the power reading of the 105A is in error as described below.

Current display = Il + Iv (Il current in load)
Power display = Pl + Pv (Pl power in load)

Approximate circuit loading error for resistive load Rl

Rl < 1kOhm	current- and power error	< 0.1%
Rl = 1kOhm	current- and power error	=+0.1%
Rl = 2kOhm	current- and power error	=+0.2%
Rl = 3kOhm	current- and power error	=+0.3%

3.7. True RMS Voltage and Current Measurement

In physical terms, the root mean square (rms) value of a waveform is the equivalent DC value that causes the same amount of heat to be dissipated in a resistor. The rms value provides a reliable basis for comparing dissimilar waveforms.
The 105A derives the rms value using analog computation. This means that the 105A readings represent rms values for all waveforms as long as the harmonics are within the bandwidth of the 105A.
By contrast, many meters in use today use average responding converters (rectified mean) and are rms calibrated for harmonic-free sinusoids. However, if a signal is not sinusoidal, average-responding meters do not display correct rms readings.

Figure 3.5. illustrates the relationship between different wave forms, and compares true rms values and rectified mean values. Also given are the crest factor and the form factor and their definitions.

Form factor = (rms value)/(rectified mean value)

Crest factor = (peak value)/(rms value)

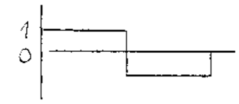
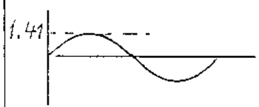
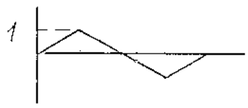
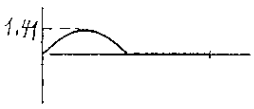
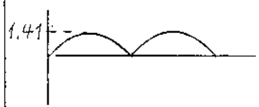
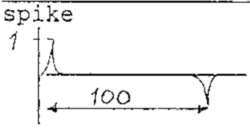
Waveform	RMS	Rectified mean	Crest factor	Form factor
	1.000	1.000	1.000	1.000
	1.000	0.9009	1.414	1.110
	0.577	0.499	1.732	1.155
	0.707	0.637	2.000	1.110
	1.000	0.9009	1.414	1.110
spike 			> 10	> 10

Figure 3.5. Comparison of different Wave Forms

3.8. Crest Factor

Crest factors are useful for expressing the ability of an instrument to measure a variety of waveforms accurately. The crest factor of a waveform is the ratio of its peak value to its rms value. Quite often, there is a trade-off between crest factor and accuracy. The 105A has a full scale crest factor limit of 3 for current and voltage. With the 105A you can hardly make measurement errors due to crest factor overrange. There is a peak overrange indication for voltage and current, warning the user of crest factor overrange.

3.9. Combined AC and DC Measurements

The 105A determines the true rms value of signals with DC-components. Switch the 105A to AC+DC-Coupling. The 105A computes the following rms value:

$$V_{rms} = (V_{ac}^2 + V_{dc}^2)^{1/2}$$

The AC component can be determined by switching the 105A to AC-Coupling.

3.10. Tutorial on Power Measurement

Power measurement is a difficult measurement for several reasons. The instantaneous values of current and voltage must be multiplied without introducing phase errors. Normally, the gain of the current and voltage amplifiers must be switched over a wide range introducing phase errors at frequencies long before amplitude errors are observed. Finally, at low power factor a small value superimposed on a large value needs to me measured accuratly.
The following example demonstrates this situation: Irms·Vrms= 100VA, power factor = 0.01, power = 1W. If the user requires 1% accuracy on displayed power, he is actually asking for an instrument accuracy of 0.01 %. Why? The multiplier must perform its operation on a background signal of 100VA within an error limit of 0.01W. This simply means an instrument accuracy of 0.01%.

Extreme conditions arise when power measurements on frequency inverters are performed. Current and voltage are totally dissimilar signals. The current is more or less sinusoidal, the voltage consists of a train of positive or negative pulses with weighted pulse duration. Voltage transients of more than 500V/us can be observed. Although the fundamental frequency of the flowing current is in the order of 50Hz, the wattmeter must cope with frequencies well over 100kHz. Low power factors further complicate the power measurement.

3.11. Power Contents of a Square Wave Signal

All Infratek wattmeters are broad band. The following discussion shows that accurate power measurements require broad band wattmeters.
We assume a square wave voltage and a square wave current working into a resistive load. We assume a fundamental frequency of 1kHz. To calculate the power contents of the harmonics the square wave signal for voltage and current is expressed in a Fourier series. From the expression for instantaneous power (p =i v), we determine the total power and assume the power contribution of the fundamental to be 100 %. Doing this, we note that only products of the same frequency contribute to power. Table 3.2 shows the relative power content of the harmonics. It demonstrates

Fundamental	100 %	1kHz
3. Harmonic	11 %	3kHz
5. Harmonic	4 %	5kHz
7. Harmonic	2 %	7kHz
9. Harmonic	1.2 %	9kHz
11. Harmonic	0.8 %	11kHz

Table 3.2. Relative Power Content of a Square Wave

that accurate power measurements require broad band wattmeters. A band width of 11kHz would not suffice, since phase errors would introduce measurement errors.
At low power factors (inductive or capacitive loads) matters become worse. Phase errors of 1 degree may introduce 100 % measurement error.

4. REMOTE PROGRAMMING

4.1. Introduction

The IEEE-488 Interface turns the 105A into a fully programmable instrument for use with the IEEE-488 Interface bus. With the interface, the 105A can become part of an automated measurement system. The 105A can be under complete, interactive control from remote bus controller; or it can be set to the talk-only mode, connected to one or more listeners.

4.2. Capabilities

The IEEE-488 Interface provides remote control of the front panel controls except for the POWER. The Wh, and PF controls are accessible only when the energy converter option (Option 02) is installed. The interface is galvanically isolated from the input circuitry. The maximum allowable voltage difference between 105A Lo input terminals and IEEE-488 Interface is 500Vrms.

WARNING: Voltage differences between 105A Lo-terminals and IEEE-488 Interface in excess of 500Vrms may cause damage or present shock hazard.

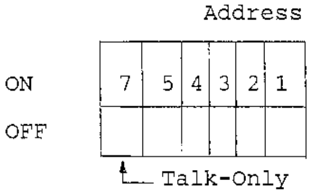
Other features include:

- Full talk/listen capability, including talk-only operation
- Comprehensive command set
- Fast measurement throughput
- Full remote/local capability
- Full serial pol capability, with bit-maskable SRQ
- Interface trigger
- Selectable output terminators

The 105A supports the following interface function subsets: SH1, AH1, L4, SR1, RL1, DC1, DT1, PP0, and C0.

4.3. Bus Set-Up Procedure and Address Selection

a) Turn the 105A Power switch OFF and set the rear panel address switch as shown below.



Address	A5	A4	A3	A2	A1
01	0	0	0	0	1
02	0	0	0	1	0
03	0	0	0	1	1
04	0	0	1	0	0
05	0	0	1	0	1

b) Switch on the 105A
The Address of the 105A is factory set to Address 05 and talk-only mode off.

4.4. Device-Dependent Command Set

Device-dependent commands are the heart of the 105A remote control. They tell the 105A how and when to make measurements, when to put data on the bus, when and under what conditions to make service requests, and what data to put on the display. The complete set of device-dependent commands is listed in Figure 4.1. The commands are entered using upper case letters. For the 105A to receive them, they must be sent over the IEEE bus when the 105A is in remote and has been addressed as a listener.

4.5. Output Function Command Fn

The output function command tells the 105A which quantity to load in the output buffer. When the 105A is addressed to talk, it will put the contents of the output buffer on the bus.

Example	Explanation
"F0"	The output buffer will be loaded with the value of rms current, e.g. 4.7852A.
"F4"	When Option 02 is installed, the 105A outputs the value of energy, e.g. 18152 Wh. If Option 02 is not installed, "F4" will be ignored.

105A IEEE-488 INTERFACE COMMANDS

Output Function Commands

F0	Arms, RMS current	
F1	Vrms, RMS voltage	
F2	W, power	(default)
F3	Wh, energy	
F4	PF, power factor	
G1	Get range I,U; SRQ mask; termin.;	
G2	Get current scaling factor	
G3	Get voltage scaling factor	
G4	Get instrument serial number	

Range Commands

I0	1A	U0	120V
I1	5A	U1	240V
I2	25A	U2	480V

Mode Commands

C1	Autorange	
C2	AC-Coupling	(default)
C3	AC+DC-Coupling	
C4	Triggered measurement on	
C5	Trigger measurement	
C6	Triggered measurement off	
C7	Wh reset	

Display Commands

D0	Arms display
D1	Vrms display
D2	W display (default)
D3	Wh display
D4	PF display
D5	Cyclic display on
D6	Cyclic display off

Set Commands

S1	xxxx.xx	Set current scaling factor: e.g. xxxx = 40.25
S2	xxxx.xx	Set voltage scaling factor: e.g. xxxx = 2.905
S3	xxxxxxx	Set Serial number (7 digits, no leading 0)
S4	xxx	Set Talk-only counter (number of measurement cycles max. 255)

SRQ Mask Command

P0	SRQ disabled
P1	SRQ on current over
P2	SRQ on voltage over
P3	SRQ on current or voltage over
P4	SRQ on power over
P5	SRQ on current or power over
P6	SRQ on voltage or power over
P7	SRQ on current,voltage or power over
P8	SRQ on data available

Terminator Commands

W1	CR/LF/EOI
W2	CR/LF
W3	EOI only
W4	disable terminators

Typical command strings for HP9816 PC and HP-85 calculator.
The address of the 105A Wattmeter is 5.

```
CLEAR 7;                      Clear port
CLEAR 705;                    Clear 105A to default functions
OUTPUT 705;"D0 C3";           Display Arms, AC+DC-Coupling
FOR I=1 TO 8
OUTPUT 705;"F0";              Setup for current output
ENTER 705; R,R$;              Read data from 105A
PRINT I;R;R$;                 HP-85 display
NEXT I
OUTPUT 705;"S1 100";          Scale current by 100
```

4.6. Output Function Command Gn

The G1 command copies the 105A current range, voltage range, SRQ mask, and terminator selected into the output buffer in the format shown below.

Command	Output String	Meaning
G1	frst	f = 1-3 as in I-range commands r = 1-3 as in U-range commands s = 0-8 as in SRQ-mask commands t = 1-4 as in terminator commands
G2	SF A=1.00000	Current scaling factor

4.7. Range Commands In, Un

The range commands tell the 105A which current and voltage range to select. A range command automatically terminates 105A autorange setting. The range setting can be read using the G1 command.

4.8. Display Command Dn

The display commands duplicate of the function control. When Option 02 is installed, the display commands D4, and D5 are executed, otherwise they are ignored.

Example	Explanation
"D1"	Display of Vrms
"D4"	When Option 02 is installed, the power factor will be displayed.

4.9. Mode Command Cn

The mode commands C0, ..., C7 duplicate part of the controls to the right of the display.

Example	Explanation
"C0C2C7"	Selects autorange for voltage and current input, AC-Coupling, and resets the energy reading to zero.

4.10. SRQ Mask Command Pn

The SRQ mask commands P0 through P8 are used to program the 105A to make service requests on user-specified conditions.

Example	Explanation
"P7"	SRQ on current, voltage or power over.

4.11. Terminator Command Wn

The terminator commands select what terminators the 105A appends to every output string. The terminators are: Carriage Return (CR), Line Feed (LF), and EOI (End Or Identify). CR and LF are ASCII control codes, sent over the data bus just like output data. EOI is a uniline message which is sent simultaneously with the last character in the output string. Normally, each output string is terminated with CR followed by LF and EOI.
The terminator selection can be read using the G1 command. The 105A sets to W1 on power-up.

4.12. Input Processing

An input string can contain as many commands as required. The only exception are the S1 and S2 commands. Commands are executed in the sequence they are received. Commands which are not recognized by the 105A will be ignored. A command string must be terminated with CR (Carriage Return), and LF (Line Feed), EOI is optional. Most controllers finish a command string with a CR LF pair. If a controller does not have this feature, the programmer must transmit a terminator explicitly.
The 105A accepts alphabetic characters in upper case. Spaces are ignored, unless a space is required as in S1 and S2.
The exception to the input processing are the numeric set commands S1 and S2. Only one set command may be sent at a time, because a programming command goes with a numeric field.

Example for HP85 Controller

```
OUTPUT 705;"S1 50.08";   current scaling 50.08
OUTPUT 705;"S2  0.5 ";   voltage scaling  0.5
```

4.13. Syntax Rules

Two syntax rules should be followed when writing input command strings. They are:

RULE 1: Read output data only once.
To prevent old data from being read a second time by mistake, the output buffer is always cleared after it has been read. If the output buffer is read twice without an intervening output command, the 105A will not respond to the second attempt to read the output buffer. However, if the 105A is in talk-only, no intervening command is necessary.

RULE 2: Use no more than one output command per input command string.
If an input command string contains more than one output command, only the data from the last command can be read.

4.14. Output Data

The following describes the data that can be loaded into the 105A output buffer and sent to the interface bus. It describes how and when data is loaded into the output buffer, and the types of output data.
The 105A can also send data to the IEEE-488 bus from the serial poll register.
The 105A is programmed to send output data when it receives an output command, e.g. "F2". The data are not actually loaded on the interface bus until the controller addresses the 105A as a talker. This is done by sending the interface message MTA (My Talk Address). The types of output data are shown in Figure 4.2.
Numeric data, including units, are sent to the IEEE-488 bus in the same format as displayed on the display. When data are overrange the suffix "OVER" is appended to the data. When data are called for which are not available because the option is not installed the 105A outputs "NO OPTION".
Status data is the output in response to G1, and G2 commands. The data is formatted as shown in Figure 4.2.
The terminators appended to numeric data and status data are user-selectable by the terminator commands W1...W4.

Output Data Type			Format Examples
Numeric Data	3.0000A		Measured Value
	5.0782A	**Over**	Overrange
	221.78V		Measured Value
	3.8010Wh		Measured Value
Instrument Configuration Data	G1:	3221	→ Terminator W1, SRQ P2 → 240V range → 25A range
	G2:	SF A=50.0000	
Output from SRQ	P1:	Decimal 65 SRQ on current over	

Figure 4.2. Output Data Types

4.15. Service Requests

Service requests let bus instruments get the attention of the system controller. The requests are sent over the SRQ line. If more than one instrument on the bus is capable of sending service requests,the controller can learn which one made the request by taking a serial poll. The 105A responds to the poll by sending the contents of its serial poll register. The serial poll register indicates whether or not the device requests service, and if so, the reason for the request.
The 105A may be programmed to make a service request on user-specified conditions. The conditions are specified by entering a value for the service request mask.

4.16. The Serial Poll Register

The serial poll register is a binary-coded register which contains eight bits, as illustrated in Figure 4.3. The controller can read the 105A serial poll register by taking a serial poll. Because serial poll data is loaded directly on the bus, reading the serial poll register leaves data in the output buffer intact.

The eight bits of the serial poll register are described below. Note that the SRQ mask uses bits 1 through 4 to set bit 7 (the SRQ bit). Bit 7 sets the SRQ line true, which generates a service request. Bits 1 through 4 are set, depending on the selected SRQ mask P0...P8, as follows:

Selected SRQ mask	Decimal value bit 1 through 4
P0	0 SRQ disabled
P1	1 SRQ on current over
P8	8 SRQ on data available

Bit:	8	7	6	5	4	3	2	1
	0	SRQ	0	0	4 bits used for SRQ generation			
Decimal:		64	32	16	8	4	2	1

Figure 4.3. Serial Poll Register

Taking a serial poll clears bit 7 of the serial poll register. Bits 1 through 4 are also set when no SRQ is desired (P0 user-specified). In this case bit 7 is not set and the service request line is not set true.

4.17. Interface Messages

The interface messages understood by the 105A are the following three main classes described in IEEE-488 Standard: address messages, universal commands, and addressed commands. All interface messages described here originate at the controller.

Address Messages

MLA:	My Listen Address	-	Addresses a device to listen
MTA:	My Talk Address	-	Addresses a device to talk
UNL:	Unlisten	-	Addresses all listeners to unlisten
UNT:	Untalk	-	Addresses all talkers to untalk

Universal Commands

ATN: Attention	-	A uniline message which causes the 105A to interpret multiline messages as interface messages. When false, multiline messages are interpreted as device dependent messages.
REN: Remote Enable	-	A uniline message which, when received with MLA, switches the 105A to remote. In remote the 105A front panel controls are deactivated.
DCL: Device Clear	-	A multiline message which is loaded into the input buffer. DCL sets the 105A to the following operating conditions: ● Autorange on, input A ● Display Watt ● AC-Coupling
SPE: Serial Poll Enable	-	A multiline message which causes the serial poll data (rather than the output buffer data) to be transferred on the bus once ATN becomes false.
SPD: Serial Poll Disable	-	Removes the serial poll enable state.

Addressed Commands

GTL: Go To Local	-	Causes the 105A to switch to local (front panel) control.
SDC: Selected Device Clear	-	Identical to DCL, but is accepted by current listeners only.

4.18. Talk-Only Mode

The talk-only mode lets the user take advantage of the remote capability of the 105A without having to use an instrument controller.
To put the 105A in the talk-only mode:

1. Turn the 105A power switch off.
2. Set the rear panel Talk Only switch (bit 7 of address switch) to the up-position (on).
3. Connect the 105A via the IEEE-488 bus to your data receiving device (listener hand-shake capabilities are required).
4. Turn the 105A power switch on.
5. Configure the 105A with the frontpanel controls. (The 105A can also be operated in the Talk-Only Mode when in remote).

The 105A reads the Talk-Only bit switch on power-up and sends data after the preprogrammed number of measurement cycles have been reached. (The Talk-only counter is set with the S3 command. The counter is stored in non-volatile memory and remains stored even when the 105A is turned off). Data are also output everytime the Trig. mode is entered.
The data transmitted are those specified by the output function commands F0 through F2, (Option 02, F0...F5).

5. OPTIONS

5.1. Introduction

Option 01, the IEEE-488 Interface, is described in section 4. This section describes the energy converter (Option 02), the scaling option (Option 03) the recorder output for Arms, Vrms, Watt (Option 04), the broad band recorder output for instantaneous power (Option 05), and the high current wide band transformer (Options 07, 08 and 09).
The installation procedure for all options is described in section 5.6.

5.2. Energy Converter (Option 02)

When the energy converter is installed, the 105A sets the internal status accordingly on power-up. Two additional functions Wh (energy), and PF (power factor) are now available, and also can be transmitted over the IEEE-488 Interface bus.
Positive or negative energy is computed from measured power and elapsed time increments. To start an energy measurement, the stored energy value must first be set to zero. This is done as follows: Display Wh and press the Auto /Wh-Reset control. From now on the energy is computed, and can be viewed on the display if desired. We recommend to use manual ranging and keep the current and voltage ranges fixed during an energy measurement.
When the 105A is switched to triggered operation, the energy value is no longer valid. In triggered mode the time base gets lost.
The power factor is computed from the equations given in section 1.4.

5.3. Current Scaling

Option 03 features current scaling when current is measured by means of current transformers. The following current multipliers can be entered over the 5 front panel keys: 1, 2, 4, 10, 20, 40, 100, 200, 400, 1000, 2000, ..., 100'000. Via the IEEE-488 interface any current ratio can be entered, e.g. 1034.7. Decimal points are allowed.
The scaling via the front panel is done as follows:

→ Select triggered mode → Press the "A-RANGE" control until the LED "MUL" flashes → Press "TRIG" (the scaling factor is now displayed) → Press the numbered keys to yield the desired scaling factor (e.g. 400) → Press "TRIG" (the new scaling factor is entered and displayed) → Press "TRIG" again to leave the scaling procedure. LED "MUL" is illuminated for scaling factors = 1.0.

5.4. Isolated Recorder Output A/V/W (Option 04)

Option 04 features three recorder outputs for rms-current, rms-voltage, and average power. The three recorder outputs are isolated from the 105A input, from the IEEE-488-Interface, and from the broad band recorder output. Furthermore, the three recorder outputs are isolated from each other, and if desired can be connected to a common potential. Figure 5.5. gives specific data of the three outputs.

Specification	Arms	Vrms	Watt
Output/pin Nr	A+/A-;23/11	V+/V-;21/9	W+/W-;22/10
Output impedance	200Ohm	200Ohm	200Ohm
Accuracy	0.5% FS	0.5% FS	0.5% FS
V-A-display full scale	+3V	+3V	
W-display full scale			+3V
Minimum output	+3.5V	+3.5V	+3.5V
Response time	1s	1s	1s
Input Output Isolation	2000Vpeak	2000Vpeak	2000Vpeak
Short Circuit Current	U/200Ohm	U/200Ohm	U/200Ohm

NOTE: Rms current as well as rms voltage are average values and are always positive. On the other hand, average power can become negative by either wrong input connection or by power reversal. In this case, the negative power value will not be transmitted to the recorder output, the output goes to zero.

5.5. Isolated Broad Band Recorder Output (Option 05)

This unique option can be used to measure instantaneous power for complex current- and voltage waveforms, or can be used to measure transient power (maximum and minimum) during a start-up cycle. Valuable information can be obtained from the resulting power waveform.
Figure 5.6. shows the specification of the broad band recorder output.

Specification	Option 05
Output /pin	P+/P-; 24/12
Output impedance	0.5Ohm
W-display	min. 0V, max. 4V, average 3V
Maximum Output	+6V peak
Frequency range	DC-10kHz (-3dB at 10kHz)
Accuracy	0.5% FS
Short Circuit Current	20mA

Figure 5.6. Specification Broad Band Recorder Output

NOTE: For all transient power measurement use AC+DC coupling.

Figure 5.7. shows for several current and voltage waveforms the resulting power waveforms.

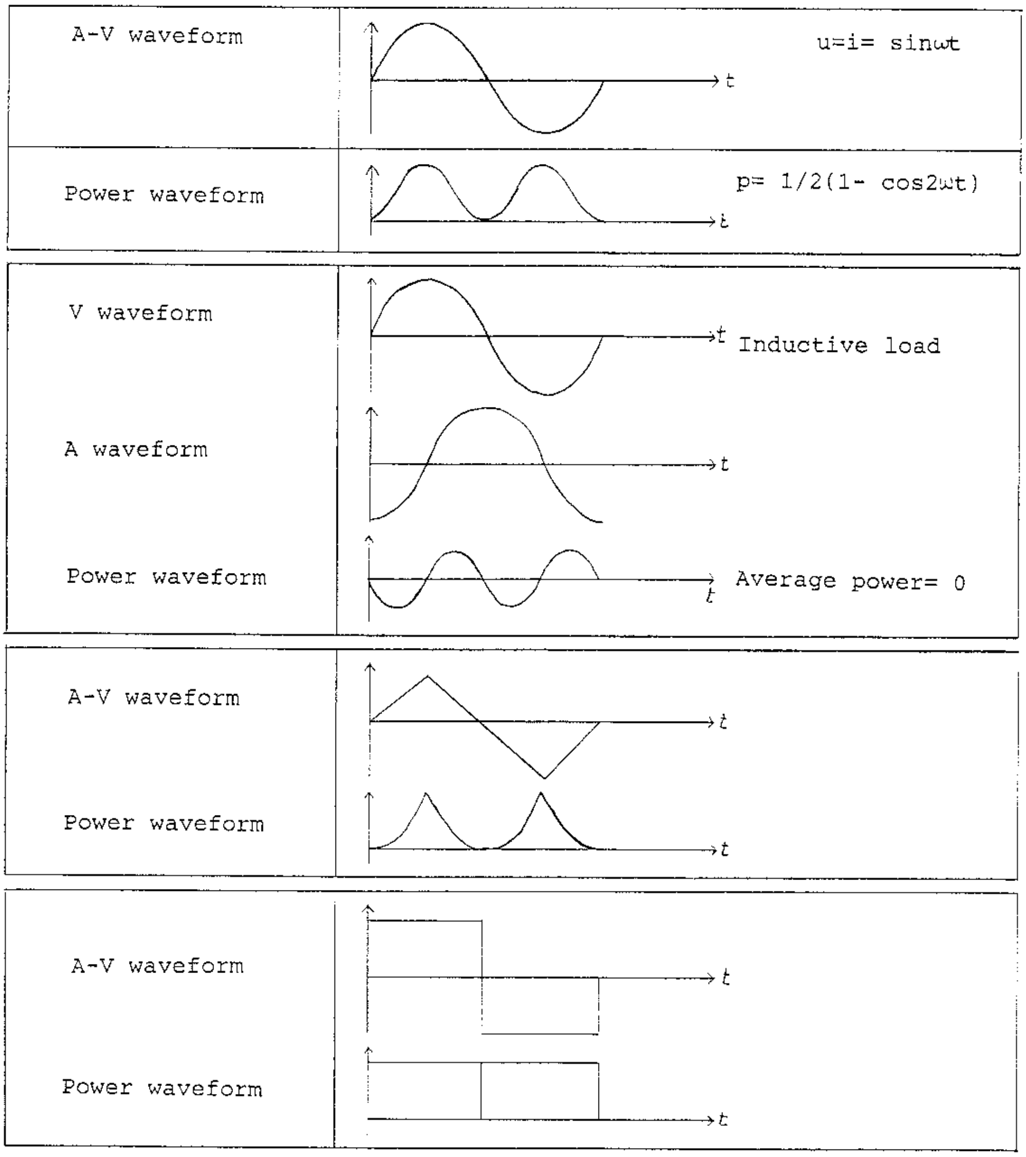


Figure 5.7. Current-, Voltage-, and Power Waveform

5.6. Option Installation

For option installation remove all connections to 105A inputs and disconnect the power-line cord.

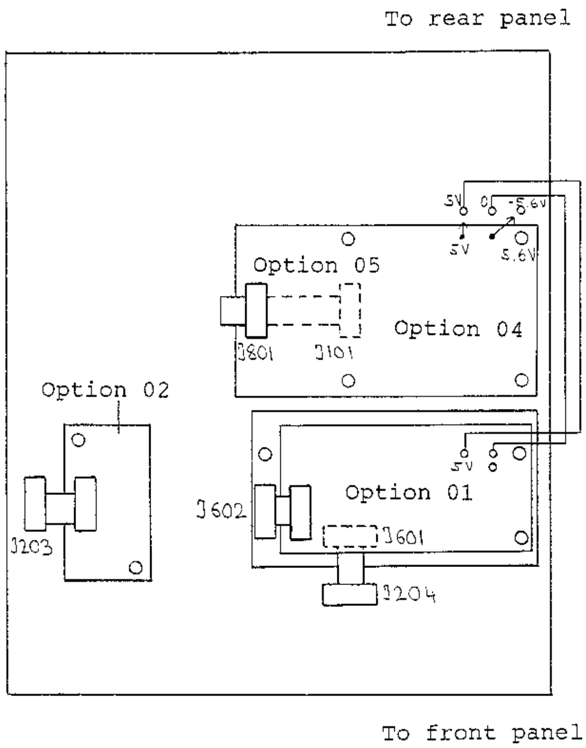


Figure 5.8. Installation of Option 01, Option 02, Option 04, and Option 05.