PMP112: Waveguide Power Meter Probe for 900 MHz ISM Band

General Description

PMP112 (Fig. 1) is a non-directional power meter, or power meter probe, designed for measurement of powers up to 100 kW in 900 MHz industrial applications. It is designed to be installed on a lowered-height R9 (WR975) rectangular waveguide that serves as a quarter-wavelength transformer connecting a standard R9 to a typical circulator waveguide (247.65 × 44.7 mm). Each power meter is calibrated individually. A condition for accurate measurement is that waves can travel in the waveguide in only one direction. A typical application of PMP112 is to measure the power absorbed in a circulator waterload.

Fig. 1. PMP112 power meter probe.

The PMP integrates a single-probe coupler with the following components:

- Zero-bias Schottky diode detector.
- Low noise amplifier.
- 16-bit A/D converter for sampling detector voltages.
- 12-bit D/A converter providing the analog output.
- Microcontroller unit (MCU).

The MCU:

- Controls both A/D and D/A conversions.
- Performs detector nonlinearity and temperature dependence correction.
- Generates the following simultaneous outputs:
  - ✓ An analog output.
  - ✓ A digital output (RS232, RS422, or CAN Bus).

The analog output can be either a

- voltage output 0 – 10 V; or
- current output 4 – 20 mA.

The desired *analog* output type can be switched by the user. The output voltage/current is a linear function of the microwave power propagating in one and only one direction of the parent waveguide. The digital output transmits also the internal power sensor temperature. The RS232 and RS422 outputs have the form of easily readable text streams.

The desired *digital* output type must be specified in the purchase order.

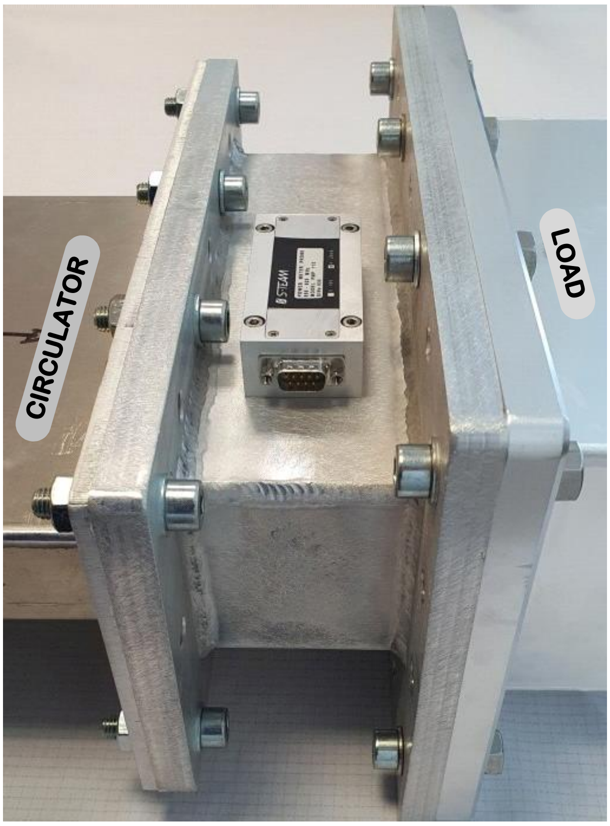

Fig. 2. PMP112 installed on a parent waveguide.

The PMP module is fastened to a parent waveguide by means of four M4 or similar-diameter screws after machining of appropriate holes in the waveguide wall.

Specifications

Waveguide of destination	247.65 × 82.8 mm (9.75 × 3.26 inch)
Waveguide wall thickness	6.35 mm ± 0.025 mm
Waveguide surface flatness required at PMP interface	0.04 mm
Frequency range	895 – 925 MHz
Peak working power	1 kW, 3 kW, 5 kW, 10 kW, 30 kW, 100 kW (Note 1)
Default measurement rate	5 points/s
Max measurement rate	100 points/s (Note 2)
Max sampling duration	5 s (Note 3)
Output voltage polarity	Positive
Power supply voltage	24 V ± 10% DC
Power consumption	4 W
Connector	D-sub 9-pin male (D9m)
Dimensions (L x W x H)	90 x 43 x 34.5 mm
Mass	185 g
Operating temperature range	-10 °C to +65 °C
Storage temperature range	-20 °C to +80 °C

Notes:

1. Peak working power must be specified in the purchase order.
2. High measurement rates can be attained using high sampling rates and short sampling durations. For details about sampling, please refer to section Sampling.
3. Sampling duration or *integration time* is the time over which the samples are acquired for obtaining one measurement data point.

Pin Assignment

Pin	Signal	Description
1		
2	RX/B-/H	RS232: RX RS422: B- CAN: L
3	TX/A+/L	RS232: TX RS422: A+ CAN: H
4	IOUT	Analog current output
5	GND	Signal ground. Negative DC power supply input (0 V)
6	VOUT	Analog voltage output
7		
8	SHLD	Shielding, Mass
9	VPOS	Positive DC power supply input (+24 V)

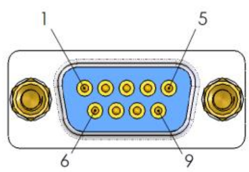

Fig. 3. Pin numbering of D9 connector.

Notes:

- Unassigned pins are not connected.
- All outputs are referred to GND.
- GND (pin 5) is isolated from SHLD (pin 8).
- Although the pins for the analog voltage output and the analog current output are separate, only one output type at a time can be active.

Nominal Transfer Curves for Analog Outputs

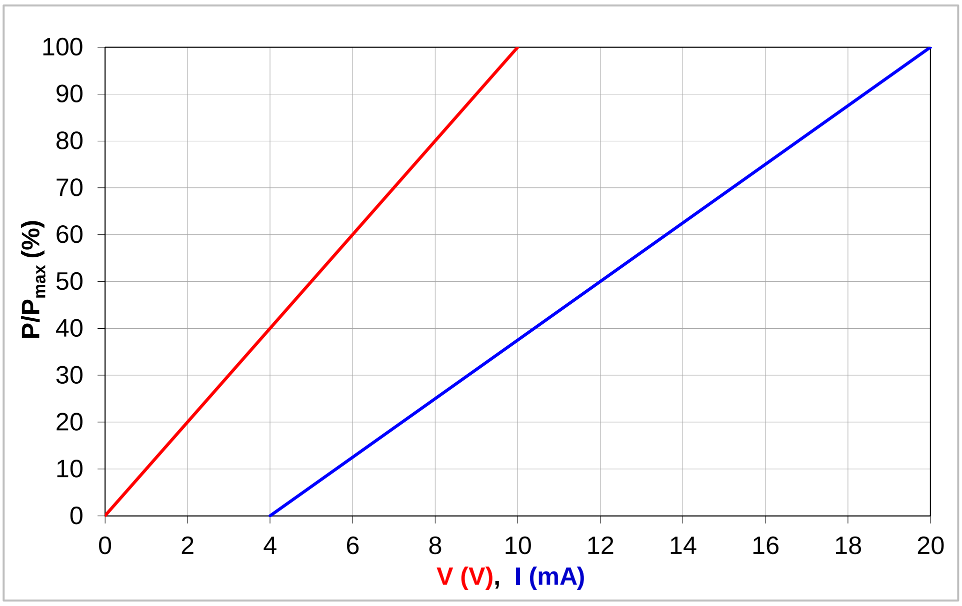

Fig. 4. Nominal PMP transfer curves for analog outputs 0 – 10 V, 4 – 20 mA. P_{max} is the specified maximum working power.

Typical Linearity Errors

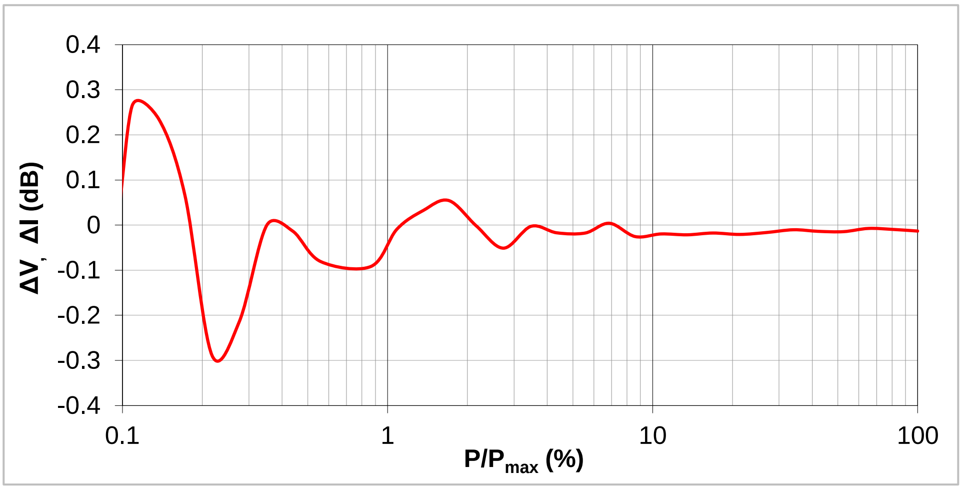

Fig. 5. Typical PMP linearity error for analog outputs 0 – 10 V, 4 – 20 mA. P_{max} is the specified maximum working power.

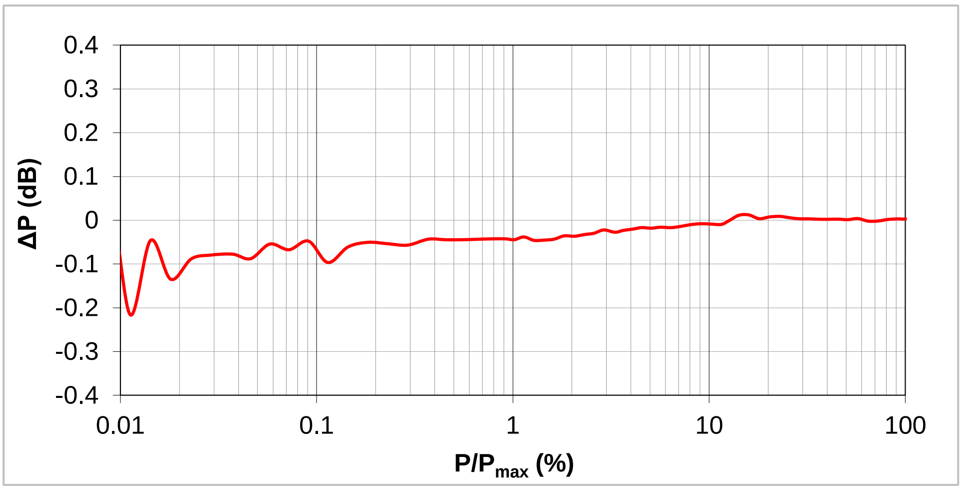

Fig. 6. Typical PMP linearity error for digital outputs. P_{max} is the specified maximum working power.

Sampling

Both analog and digital outputs are obtained as a result of averaging over a number N_s of signal samples taken with a specific *sampling rate* f_s over a specified *sampling time* T_s (sampling duration, integration time). These sampling-governing quantities are constrained by the relation

$$T_s = \frac{1}{f_s}(N_s - 1) = \Delta t_s (N_s - 1)$$

where $\Delta t_s = 1/f_s$ is the *sampling repetition period* (time distance between two consecutive samples). The user controls the sampling by defining Δt_s and N_s; the resulting sampling duration T_s is then computed using the above equation.

The values of Δt_s and N_s can be set via any RS232 terminal installed in a PC (see section PMP User Menu).

The sampling repetition period Δt_s can be varied in the range 12 μs to 10 ms with 1 μs step.

The sample count N_s is defined indirectly in terms of the *averaging exponent* E_s where N_s = 2^E_s. The exponent can assume the values E_s = 0, 1, 2, … 11. Consequently, N_s = 1, 2, 4, … 2048.

To prevent activation of the built-in watchdog (which occurs after 8 seconds of master MCU inactivity), the maximum allowable integration time T_s is 5 seconds. The user is automatically prevented from entering values of Δt_s and N_s that would result in a higher T_s.

Sampling Rules. If the signal level is not steady but fluctuates (e.g., due to ripples in the magnetron power supply voltage and/or periodically varying load), two rules in choosing Δt_s and N_s should be adhered to for accurate and stable mean power display:

1. If the slowest oscillations (ripples) observed in the signal have period $T_{r\,\max}$, the sampling duration T_s should be equal to an integral multiple of $T_{r\,\max}$, i.e.

   $$T_s = n\,T_{r\,\max}, \quad n = 1, 2, \ldots$$

   Alternatively, T_s can be chosen much longer (at least ten times longer) than $T_{r\,\max}$:

   $$T_s \geq 10\,T_{r\,\max}$$

2. The sampling rate f_s should be at least ten times higher than the *highest* ripple frequency observed in the signal. The minimal sampling repetition period is 12 μs (the maximal sampling rate 83 kHz), which enables sampling of amplitude- or pulse-modulated signals with modulation frequencies up to about 10 kHz.

If the signal level is nearly constant (CW, low-ripple), then, theoretically, any sampling settings will do. However, to reduce noise and interference, N_s and T_s should not be set too low. The default settings below are a good compromise.

Default Settings. The default sampling repetition period is Δt_s = 100 μs. This corresponds to a sampling rate of f_s = 1 kHz, which ensures correct sampling of signals with ripple frequencies up to about 100 Hz. The default averaging exponent is E_s = 11, and hence N_s = 2048. These default settings result in an integration time of T_s = 204.7 ms.

Results Refresh Rate. Due to data processing overhead, the maximal cadence of results production is limited to approximately 100 measurements per second, even when sampling with the highest rate f_s and the lowest sample count N_s.

RS232 Digital Output

After switching on the power supply, PMP starts automatically transmitting data in the form of ASCII strings. The COM port default settings are:

- 8 data bits
- 1 stop bit
- No parity
- Baud Rate 112000 bits/s

The baud rate can be set by user to 115200, 57600 and 38400 bits/s via PMP User Menu.

When connecting a PMP with a PLC, please be aware that TX and RX signal leads must be crossed.

The transmitted ASCII strings are lines of readable text separated by a Line Feed character <LF> (ASCII #10). Normally, each line has the following form:

P= 1.189kW T=38.0 P= 60.75dBm<LF>

Each line consists of items of the form **P=*Value+Unit*** (for power in kW and dBm) or **T=*Value*** (for internal temperature in Celsius). The individual items are separated by a space character (ASCII #32).

In the case of internal ADC overflow, an additional OVERRANGE item occurs, such as

P=120.000kW T=38.0 P= 80.79dBm OVERRANGE<LF>

To obtain numerical values for further processing, the recipient should capture these lines and parse them accordingly.

COM Port Terminal

In order to test and configure PMP112 using a PC, one should run a RS232 COM Port terminal program. One possibility is the open-source free terminal emulator **Tera Term**. This program can be downloaded from http://ttssh2.sourceforge.jp/index.html.en (see also http://en.wikipedia.org/wiki/Tera_Term).

An example of RS232 digital output is shown in Fig. 7.

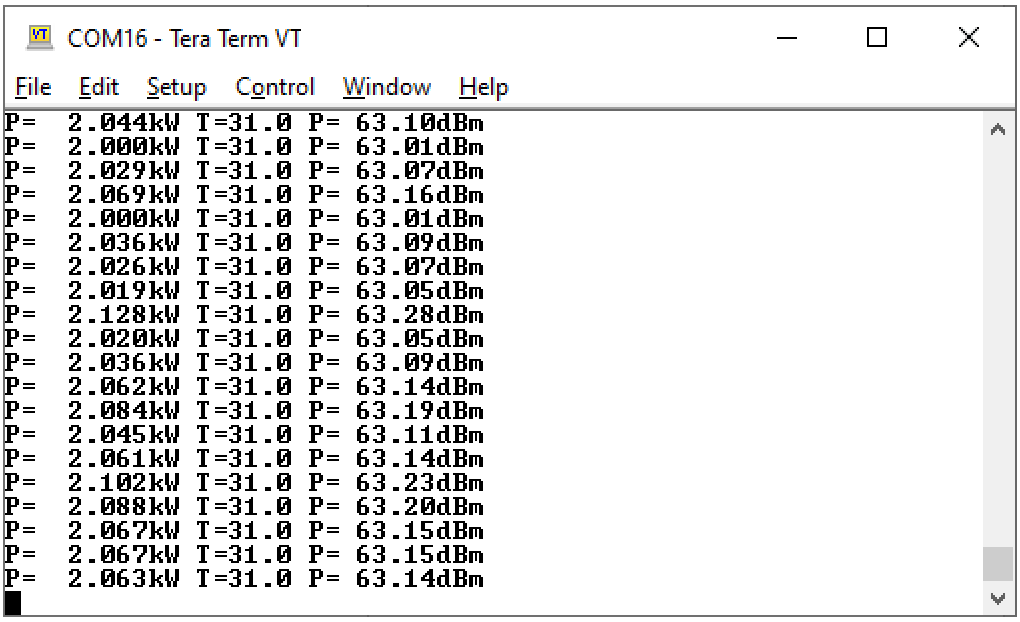

Fig. 7. Example of RS232 digital output.

PMP User Menu

The PMP User Menu supports the following operations:

- Configuration of signal sampling.
- Switching the type of analog output.
- Setting of the RS232 baud rate.
- Scaling of analog outputs.
- Introducing a power offset to measured data (e.g., to correct for a waveguide wall thickness differing from the nominal).

To use the PMP User Menu, an RS232 terminal must be installed in your PC. The PMP User Menu is invoked by transmitting either the ASCII character “x” or “X” (ASCII #120 or #88) from the terminal by pressing the **x** or **X** key on the PC keyboard. An example of the PMP User Menu is shown in Fig. 8. For more details, please refer to the application note **AN1601-PMP_UserMenu.pdf**.

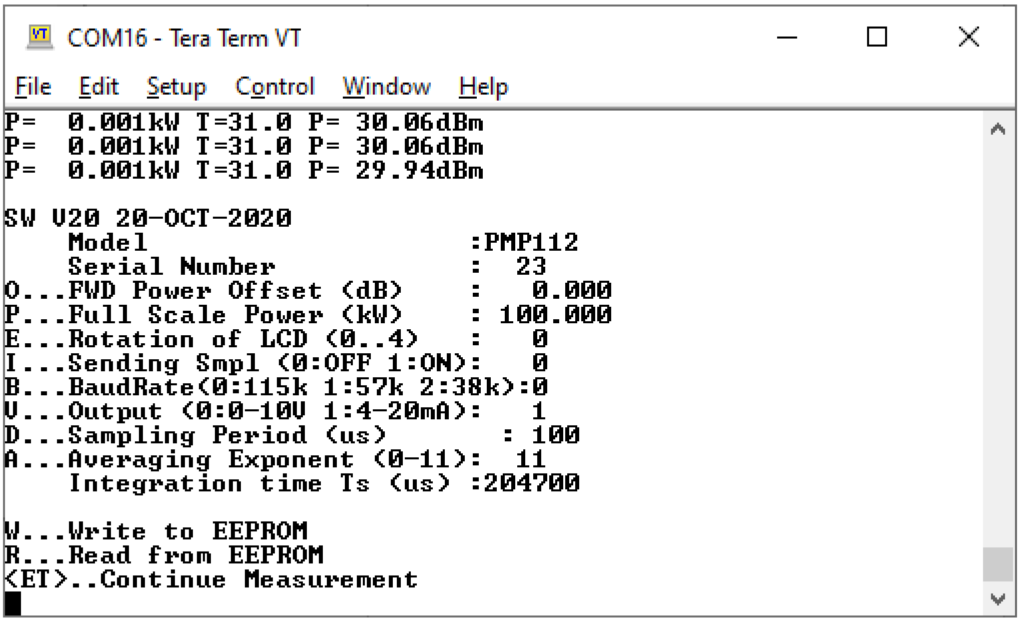

Fig. 8. PMP User Menu.

Dimensional Drawing

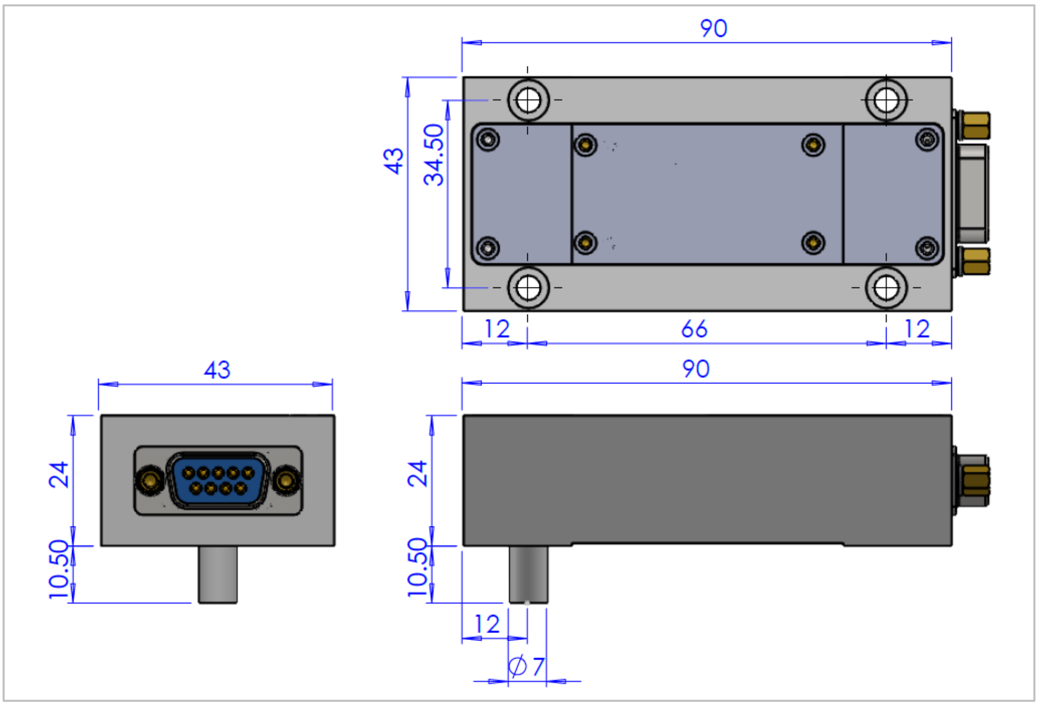

Fig. 9. Basic PMP112 dimensions (in millimeters).

Waveguide Machining Template

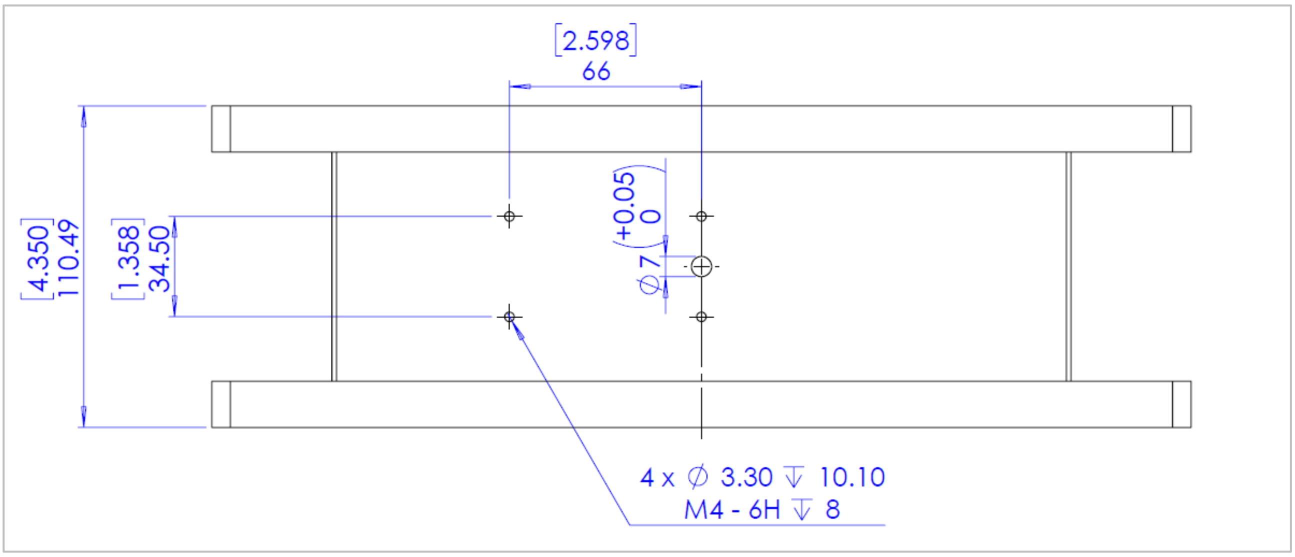

Fig. 10. Waveguide machining template. All dimensions are in millimeters. The waveguide inner dimensions are 247.65 × 82.8 mm, the waveguide wall thickness must be 6.35 mm.

Important Notes

In order to achieve the specified measurement accuracy, it is essential to comply with the specified waveguide wall thickness and flatness of its surface interfacing with the PMP. The slope of the coupling factor as a function of the wall thickness is about 6 dB/mm (i.e., increasing the wall thickness decreases the output power readings).

Owing to its non-directional nature, please do not attempt to use PMP112 in applications where both forward and reverse waves are present, for example, using a PMP112 as substitute for a BPM bidirectional power meter. Doing so can result in gross measurement errors.

Analog Voltage Output Wiring

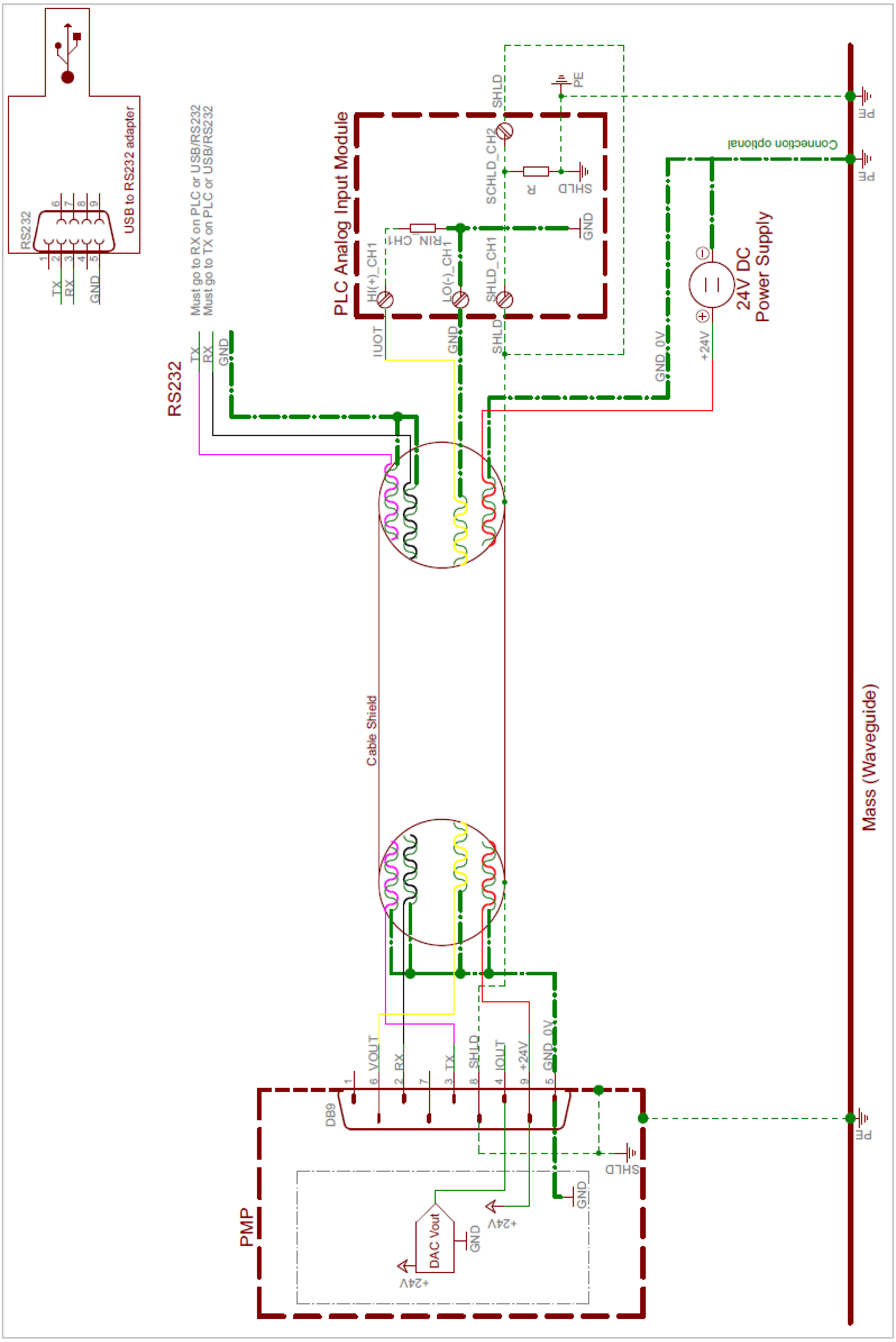

Fig. 11. Example of PMP – PLC wiring for analog voltage output.

Analog Current Output Wiring

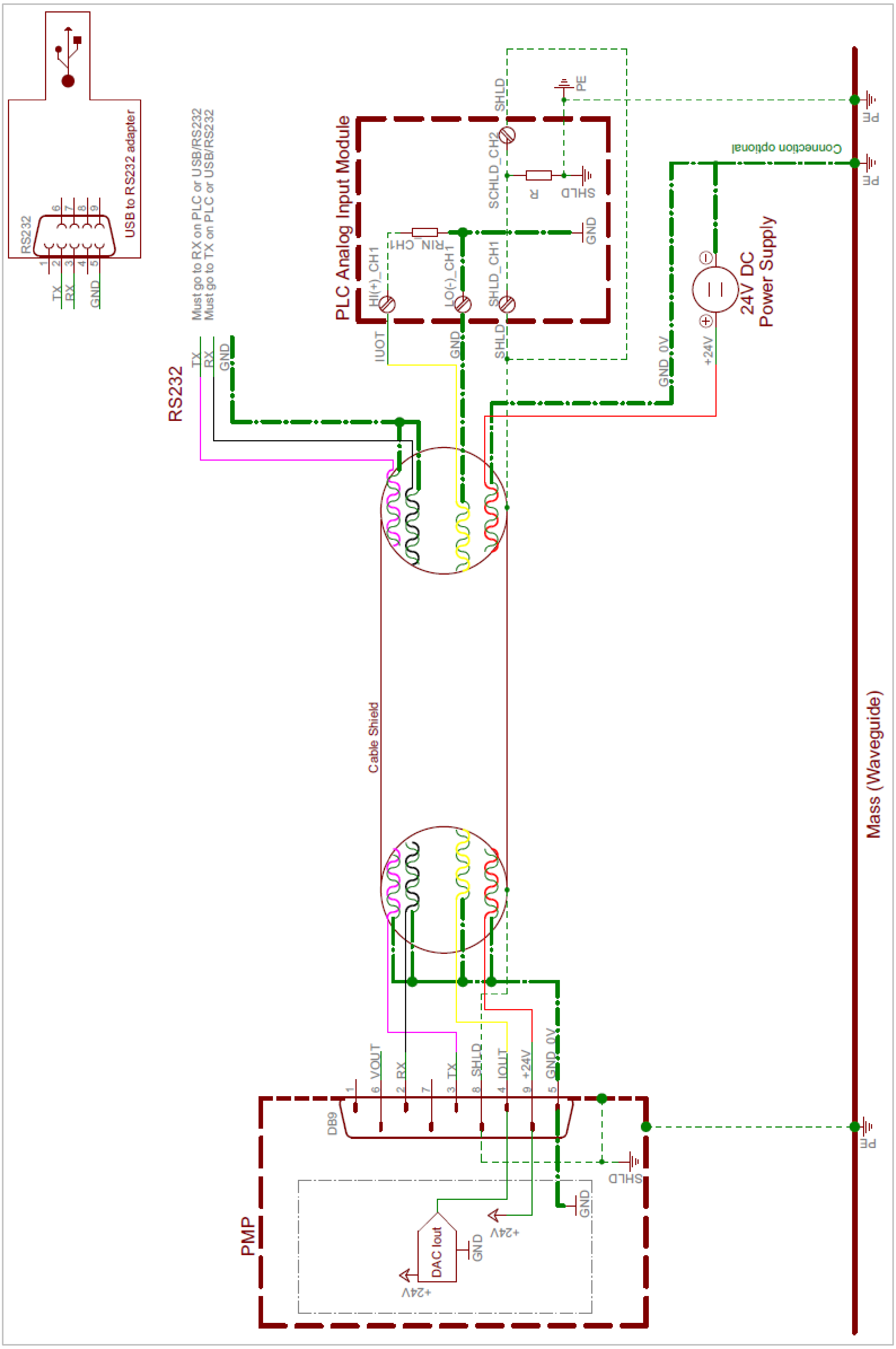

Fig. 12. Example of PMP – PLC wiring for analog current output.