Matching Network Specification

Table of Contents

1 General description

The RF section employs a “T” style impedance transformation network. It is designed to drive very low real part resistances with minimized internal losses. It consists of two variable vacuum capacitors and an inductor.

The matching network may be operated in a “stand-alone” mode, controlled via the analog interface, or via serial commands directly from system control. Additionally, the match can be operated via serial or USB interface by a graphical user interface which is running on a PC.

Available modes of operation include “Manual Mode”, “Auto-Tune / Preset Mode”, and “Auto-Tune / Hold Mode”. Auto-tuning is accomplished through use of the phase and magnitude error signals. Error signal control method, loop gain, motor speed versus error amplitude and amplitude settling window are all configurable software settings. Manual capacitor positions and preset capacitor positions can be entered through the analog, RS-232, or USB interface.

A graphical user interface (GUI) software is provided to allow direct access to and monitoring of the matching network. The GUI allows the user to set the mode of operation, the capacitor preset or manual positions, and the RF ON threshold power.

The GUI software also provides a performance monitoring screen that operates much the same as a digital oscilloscope. Eight parameters (forward power, reflected power, phase error, magnitude error, C1 position, C2 position, and two optional auxiliary signals) can be monitored simultaneously. The data collected can be saved as a chart in “wmf” format, or as an “ASCII” data file. Data can be sampled at rates up to 100 samples per second for all eight channels.

A number of serial commands are implemented in the firmware of the match which the customer can directly send from his system to the match via the RS-232 interface. Full details of the serial command set can be found in [3].

2 Design / document control

The matching network and this document are under strict revision control. No changes will be allowed to the design without prior notification and approval. This document may be revised as more data or information becomes available. Any changes to this document will be detailed as a revision change and will be provided to Novellus in a timely manner.

This product is manufactured in compliance to copy exact rules. All component level, assembly level or manufacturing process changes will be submitted to customer for approval.

3 Specifications

3.1 RF power and tuning

3.1.1 Frequency of operation

Frequency of operation is 13.56MHz +/- 1.0%.

3.1.2 RF input power range

RF input power range is 20 watts to 2,000 Watts CW (see section 3.1.11 for details)

3.1.3 Input impedance

The input impedance of the matching network is 50 Ohm.

3.1.4 RF input connector

The RF input connector is a straight Type “HN” female.

3.1.5 RF output connector

The RF output connector is a Multi-Contact BL-20N (inner diameter 20-mm Female receptacle) set into a PEEK insulator.

3.1.6 Tuning accuracy and repeatability

Tuning accuracy and repeatability (auto-tune mode, matched condition) from a load dependent starting position is: (the following are different nomenclatures for describing the same specification).

Impedance at RF input connector is a nominal 50Ω, VSWR≤1.2222:1.

Reflected power is ≤ 1.0% of forward power.

Return loss is ≤ -20dBc.

3.1.7 Reflected power

Up to 500 Watts of reflected power with infinite VSWR from the load can be handled by the match.

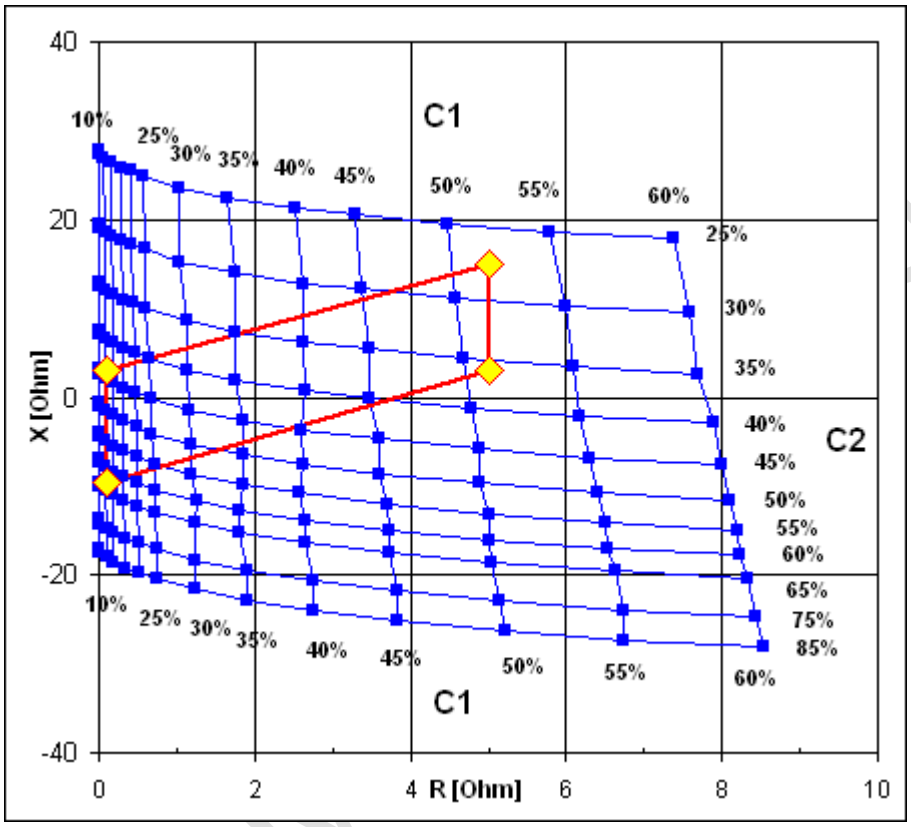
3.1.8 Tuning range

The measured corners of the load range (conjugate of match tuning range) are:

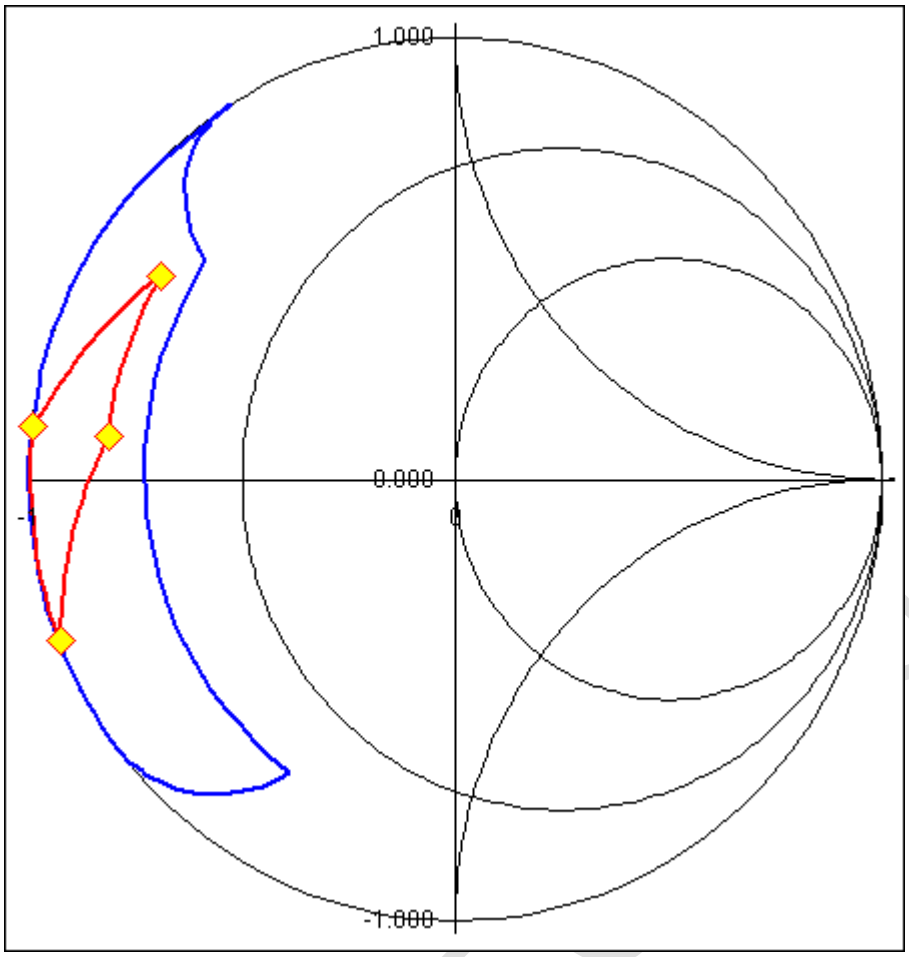
0.1Ω + j28Ω, 0.1Ω – j17Ω, 8.5Ω - j28Ω, 7.4Ω + j18Ω

The chart below is a graph of the measured load impedance range which the match can tune to with C1 and C2 varied over the accessible range as defined by the factory limits (see section 3.1.10).

The chart below is a graph of the measured tuning range (blue lines). The red box is the specified range [1].



The chart below displays the load impedance range in Smith Chart format.



The impedances for match-to-match repeatability testing with fixed load assemblies as agreed with the customer are:

(**0.3 – 3j) Ω** and **(1.5 + 5j) Ω**

3.1.9 Repeatability of capacitor positions

The matching network is calibrated such that when it tunes into a fixed load of (0.3 – 3j) Ω the respective capacitor positions are

C1 = **21.1% ± 0.5% (absolute)**

C2 = **51.7% ± 0.5% (absolute)**

3.1.10 Factory set limits and preset positions of the capacitors

The factory set limits of the capacitance range are:

C1 = **10%** to **60%**

C2 = **25%** to **85%**

The matching network has internal factory presets for the two variable capacitors of C1=**50%** and C2=**50%**. In “Auto-Tune / Preset Mode”, the capacitors are set to these positions whenever RF is turned off.

3.1.11 Input power rating

For load resistance values lower than 0.5 Ohm, the input power has to be reduced to limit the current and voltages in the matching network. For higher real part impedances >0.5 Ohm, the match can be operated at the full specified power of 2,000 W.

3.1.12 RF output voltage and current rating

RF output terminal voltage rating is 2500Vrms.

RF output current rating is 70 Arms.

3.1.13 Power efficiency and equivalent series resistance (ESR)

The measured efficiency when driving a real part resistance of 1.0 Ω is ≥ 90%.

In order to meet the customer's tight requirements in terms of power loss, the following specifications apply for power efficiency and equivalent series resistance (ESR) of the matching network when tuned into a fixed precision load impedance of 0.3 – 3.0j Ohm at 1200 W forward power:

Power efficiency	=	**76.7% ± 1.45%**
ESR	=	**91 ± 7 mOhm**

3.1.14 Manual position change

The maximum time to move from 90% to 10% via preset position change request is ≤ 1.5 seconds.

3.1.15 Automatic tuning speed

The tuning speed (on system measurement from optimized preset to a reflected power ≤1%) is ≤ 1 second.

3.1.16 Settling time

The settling time of the match (defined as the time for the match to re-establish a return loss ≤-20dBc when load reactance is shifted sufficiently to introduce an instantaneous rise in return loss to -10dBc) is ≤ 500ms.

3.1.17 Stability of the match

The match network remains stable without any oscillations when matched into any stable load condition within the specified tuning range.

3.2 Primary power

3.2.1 Power requirements

Required power for proper operation is 24Vdc +/-5% at <3.5 A (peak current = 2.2A, idle current = 600mA).

3.2.2 Primary power connector

The DC input connector is a male, 9 pin CPC, with the following pin-out:

Pin #	Name	Description
1	N/C	
2	+24 VDC	Input DC power
3	+24 VDC	Input DC power
4	N/C	
5	N/C	
6	N/C	
7	24 V Common	DC return, tied to chassis ground
8	24 V Common	DC return, tied to chassis ground
9	N/C	

3.3 Safety interlock string

3.3.1 Interlock string properties

The safety interlock string is a series, normally closed, circuit rated for ≤1A at ≤30V. The interlock string is connected to pin 1 and 2 of the analog interface.

3.3.2 Installed safety interlocks for this product

This matching network contains a safety interlock string with several switches which will open in the following critical situations:

- RF input cable not in place
- Enclosure interlock
- Overtemperature switch in the electronics compartment.
- No power to the control PCB (i. e. matching network functions disabled)

Details on the safety elements are given in the following sections.

3.3.2.1 RF input interlock

The RF coax interlock is mounted to a hinged cover. The coax must be in place and the cover closed to close this switch.

This safety interlock is in series with the interlock chain on pins 1 and 2 of the 25-pin DSUB analog interface connector.

3.3.2.2 Enclosure interlock

An interlock switch is used to sense the presence of the top cover. This is the only cover that could be removed while mounted to the system.

This safety interlock is in series with the interlock chain on pins 1 and 2 of the 25-pin DSUB analog interface connector.

3.3.2.3 Temperature switch

A snap-acting, bi-metallic, temperature switch is employed for over-temperature protection. The switch is mounted to the DC-DC converter and is used to monitor the electronics compartment.

This safety interlock is in series with the interlock chain on pins 1 and 2 of the 25-pin DSUB analog interface connector.

3.3.2.4 Control PCB interlock

A “No-Power” to the match interlock is provided on the control PCB. This is a relay closure connected in series with the safety interlocks on pins 1 and 2 of the 25-pin DSUB analog interface connector.

3.3.3 Compliance of safety interlocks

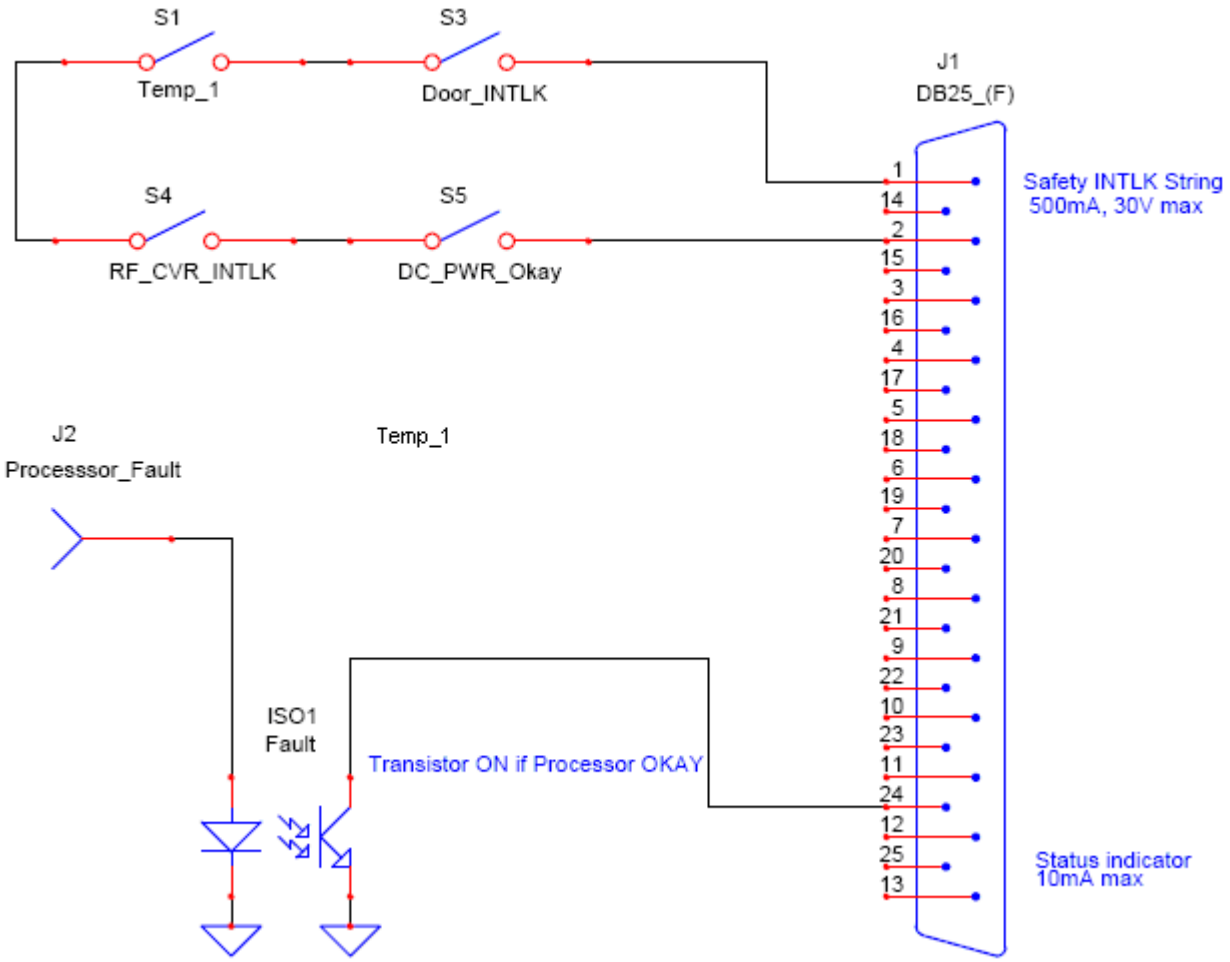
All of the employed safety mechanisms meet the SEMI S2 requirements for non-silicon / non-software based safety interlocks.

3.3.4 Status indicator

A status indicator (non-safety) is provided to pin 24 of the 25-pin DSUB analog interface. This indicator is an open-collector, pull-down circuit that is low if the processor is functioning properly.

3.3.5 Interlock string schematic

The following schematic details the interlock string.



3.4 Safety features, certifications and compliance to standards

3.4.1 Primary DC input

The primary DC input is fused. The fuse holder is panel mounted and CE certified. It is user accessible.

3.4.2 Internal over-current protection

The internal operating voltages are derived by a DC-DC converter. This converter has input over-voltage protection and output over-current protection.

3.4.3 RF protection from short and open circuit condition

The design of the RF circuitry provides sufficient over-head to protect the match from RF output short or open circuit conditions.

3.4.4 Flammability

All materials within the RF cabinet that are subject to arcing are constructed with non-flammable materials.

3.4.5 Cooling

Air cooling is the only cooling method employed. There are no connections provided for water or any other coolant.

3.4.6 NRTL and CE certification

NRTL testing by ETL Intertek and CE certification for product variant p/n 10007862 are attained. Part numbers 20045667 and 10007862 are mechanically and electrically very similar, and the results of the compliance tests with p/n 10007862 are valid for p/n 20045667 as well. A copy of the CE certificate is given in Appendix 1.

3.4.7 Compliance to SEMI safety directives

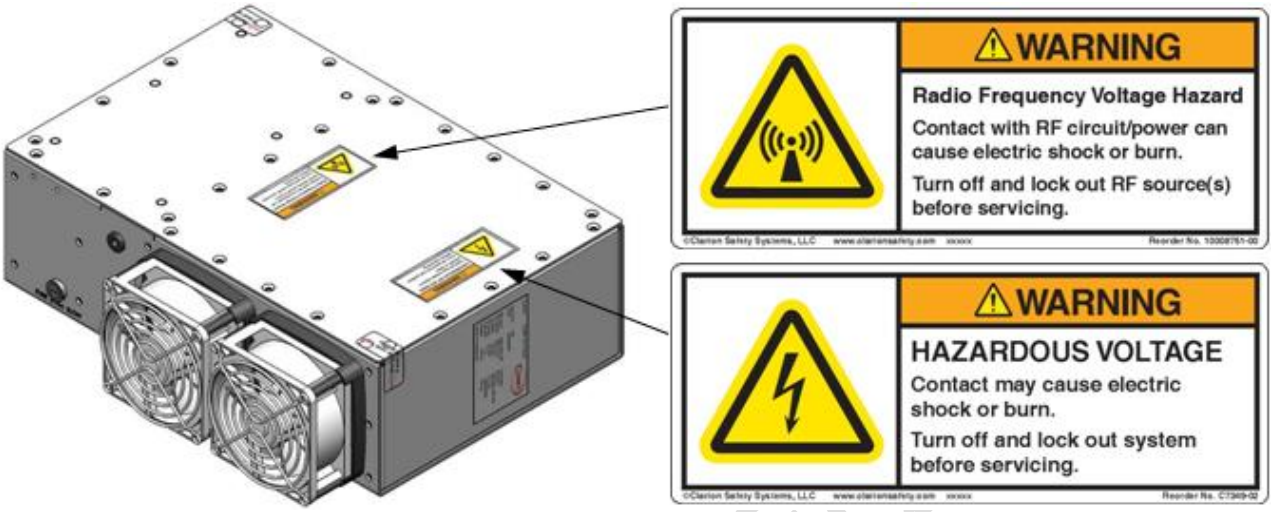
The matching network p/n 10007862 passed SEMI S2 compliance testing by ETL Intertek. Since part numbers 20045667 and 10007862 are mechanically and electrically very similar, the results of the compliance tests with p/n 10007862 are valid for p/n 20045667 as well.

The match operates on low voltage DC provided by the system. SEMI F-47 compliance is not required.

3.4.8 Hazard labels

All required hazard labels are placed appropriately on the covers.

The location of the label on the match and the label text are shown below:

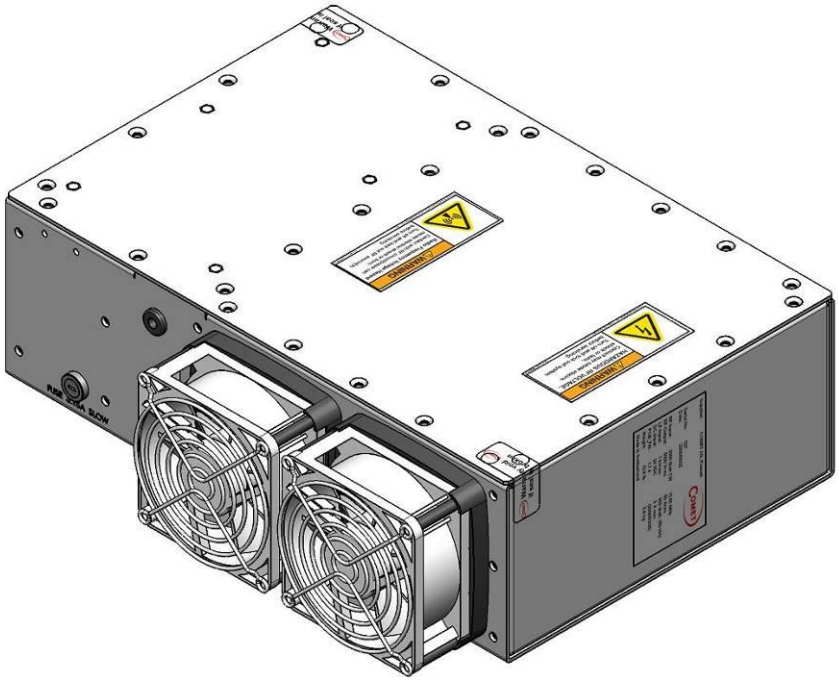


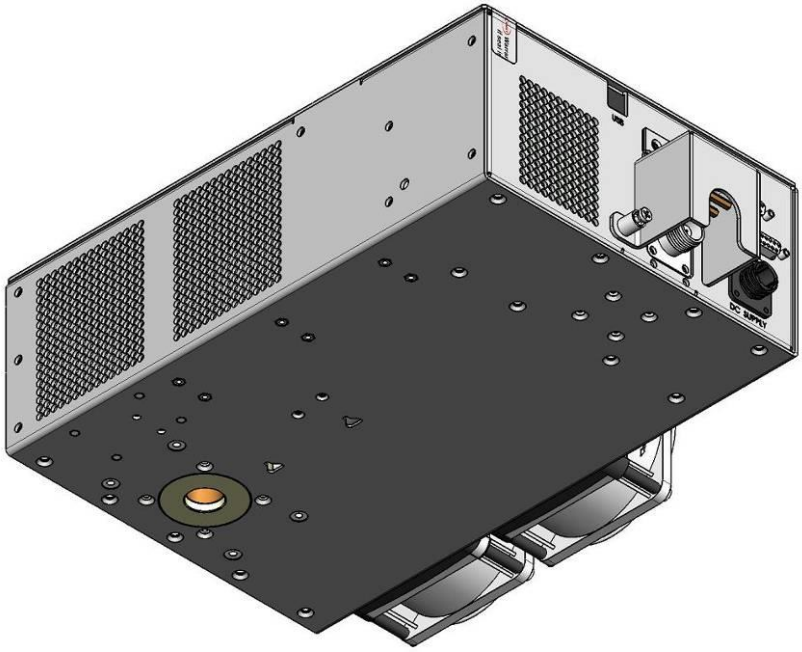
3.5 Mechanical

3.5.1 Match network outline

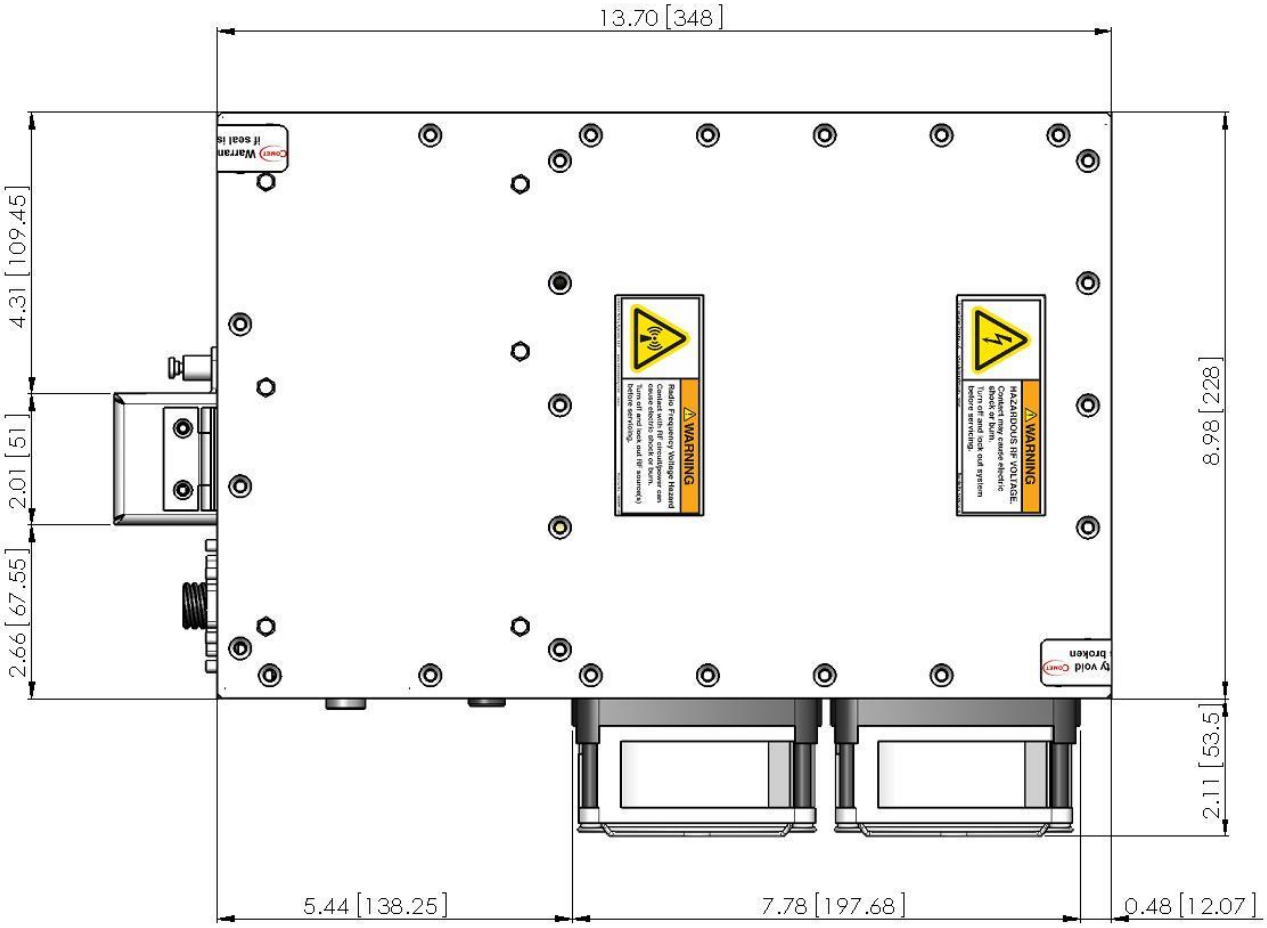
Match dimensions (excluding fans and connectors) are: 8.97” W x 13.7” H x 4.3” D (228 mm x 348 mm x 109 mm).

3-D views

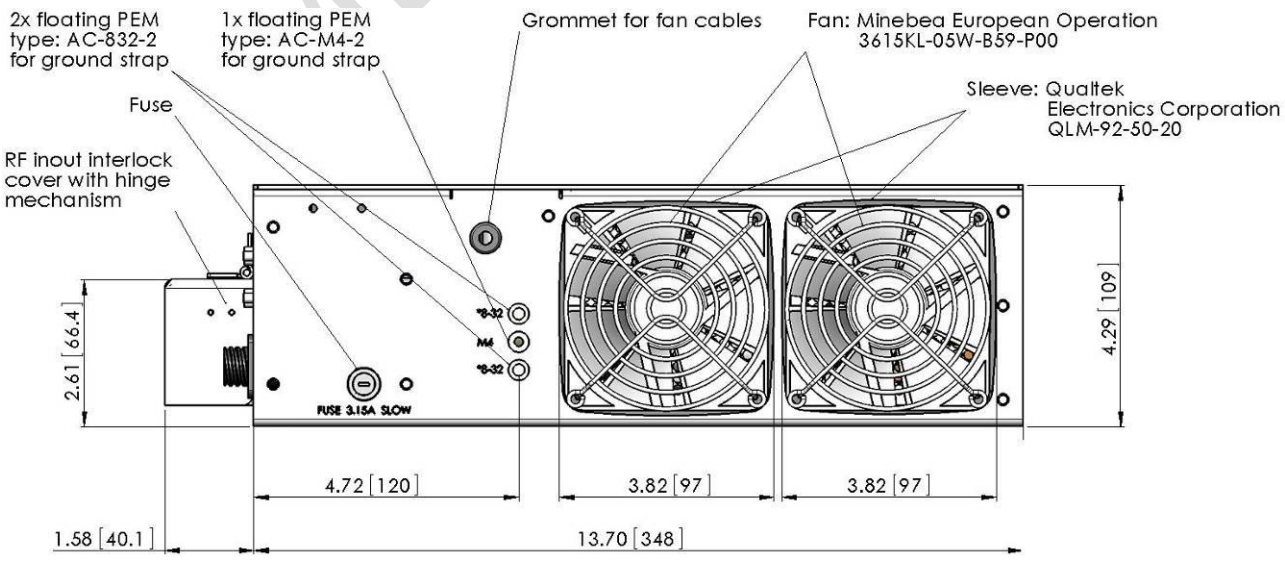




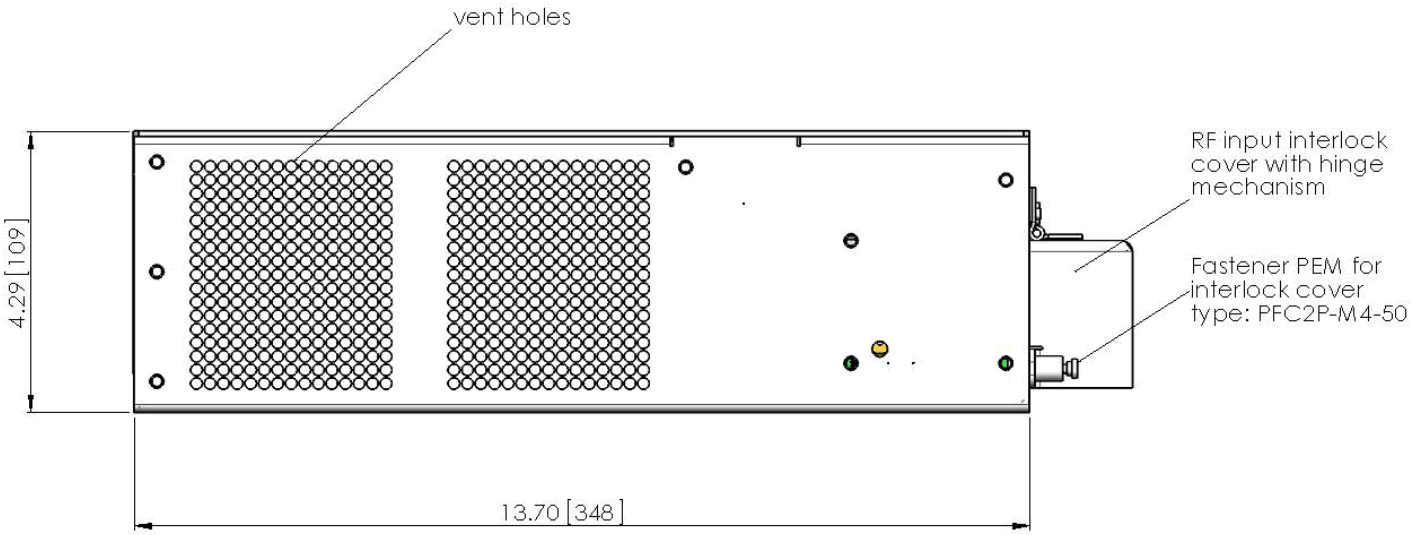
Top view



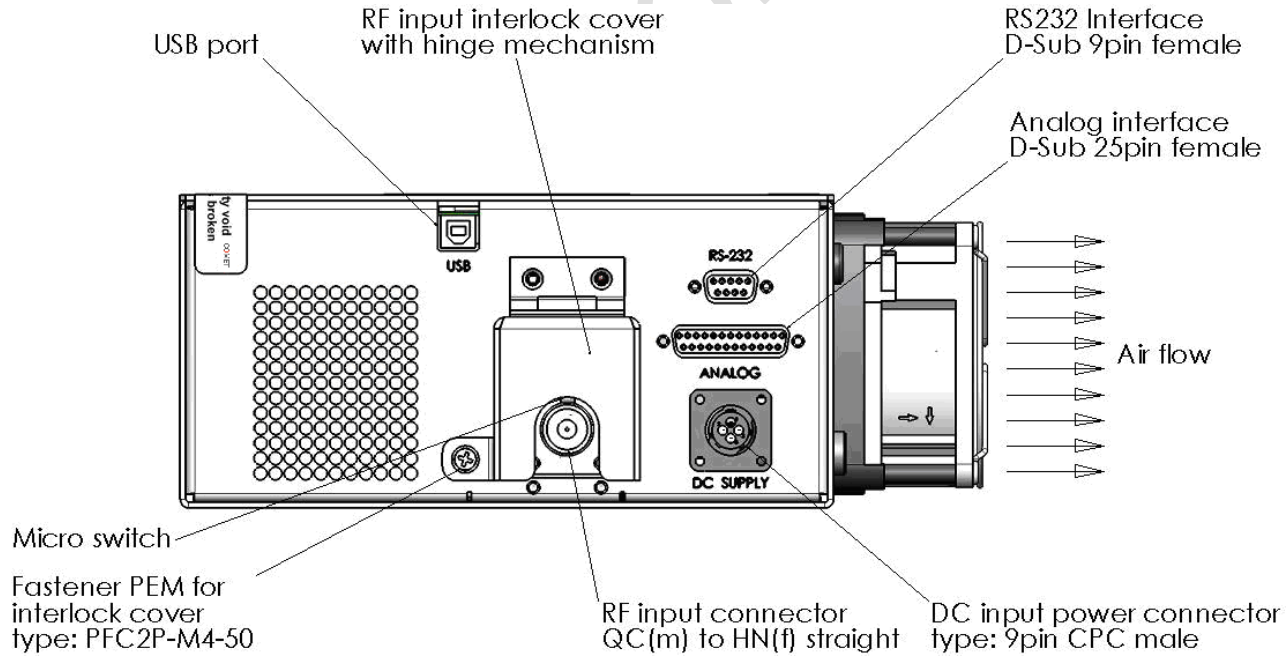
Right side view



Left side view



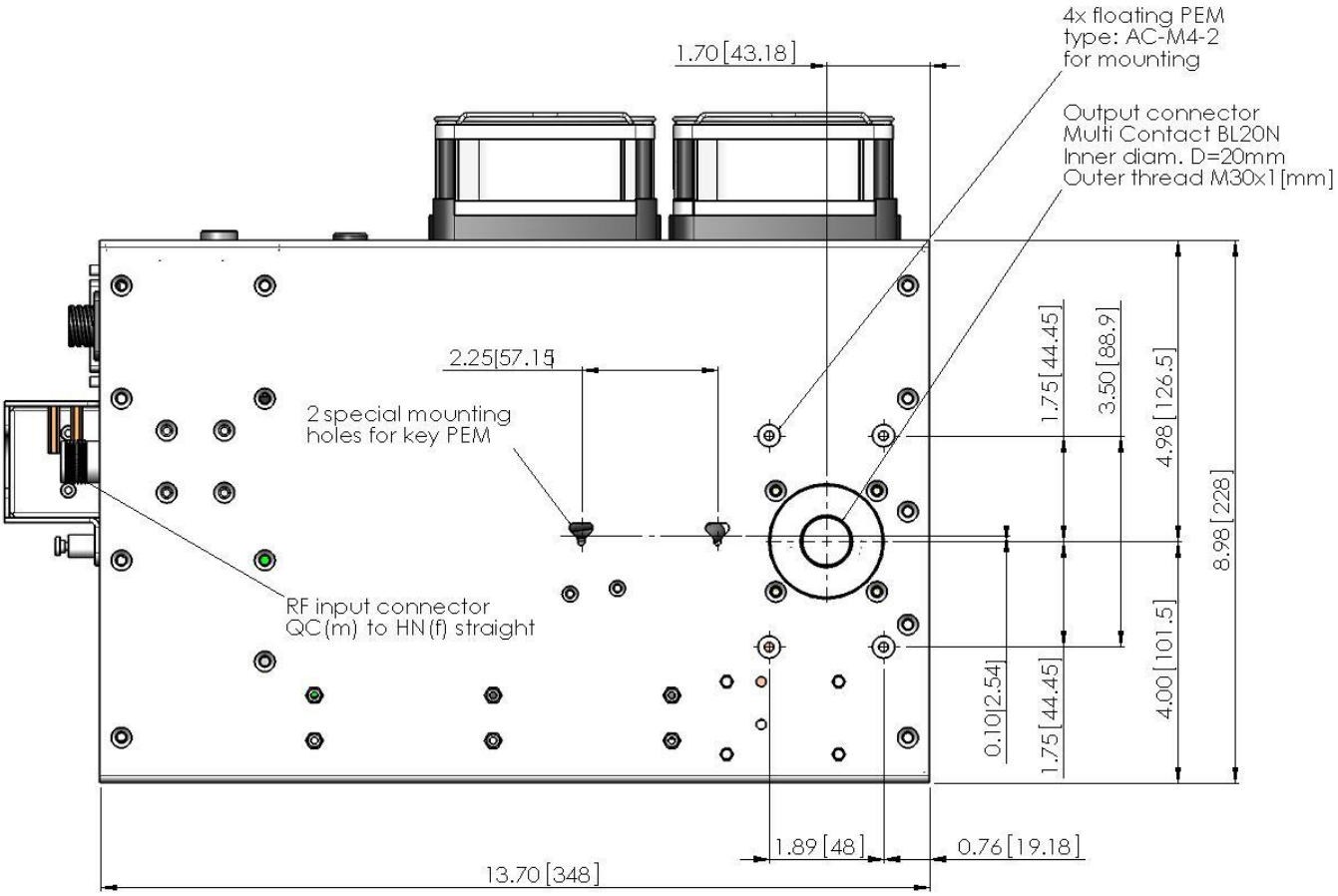
Front side view



Rear side view

3.5.2 Mounting details and RF output connector location

Bottom side view



3.5.3 Weight of the match

The matching network weight is 13.2 ± 1lb (6.0 ± 0.5kg).

3.5.4 Direction of air flow

The cooling fans are oriented to exhaust air from the matching network cabinet. This will blow air down and away from the chamber into free air.

3.5.5 Connectors

The DC input power is a 9 pin CPC **M**ale (Tyco).

The RF input connector is a type straight “HN” **F**emale with a QC base.

The RF output connector is a 20mm **F**emale socket (Multi-Contact BL-20N) set into a PEEK insulator.

The analog interface connector is a panel mounted 25 pin DSUB **F**emale

The serial communication port is a panel mounted 9 pin DSUB **F**emale

The USB port is a PCB (internally) mounted type B socket.

3.5.6 Silver plating

Per customer request, the inductor, the RF tune section interconnects and the output strap of the matching network are plated with a thick silver coating which is specified to have between 50.8 and 88.9 µm thickness.

3.6 Interfaces

The matching network has three communication interfaces (analog, RS232, and USB). The connectors are described in section 3.5.5.

The primary interfaces are an analog interface and an RS232 port for communication with the customer's system control.

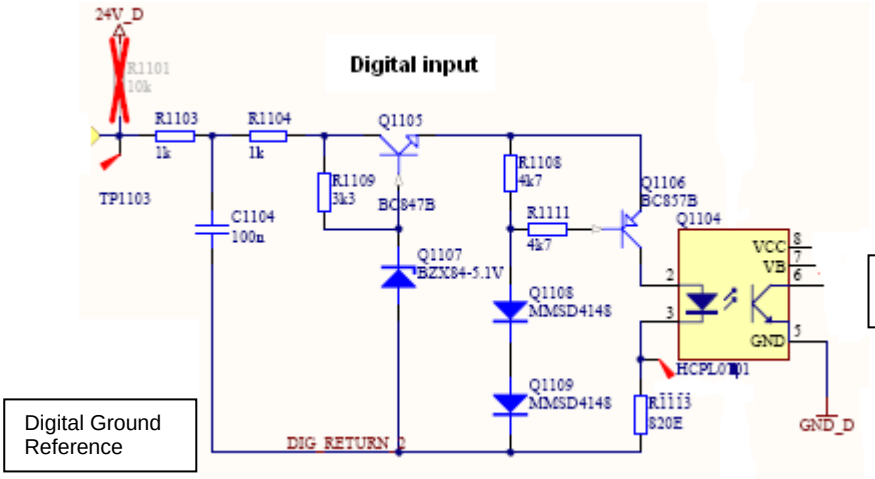
Additionally, there is a USB port provided for service purposes.

3.6.1 Analog interface

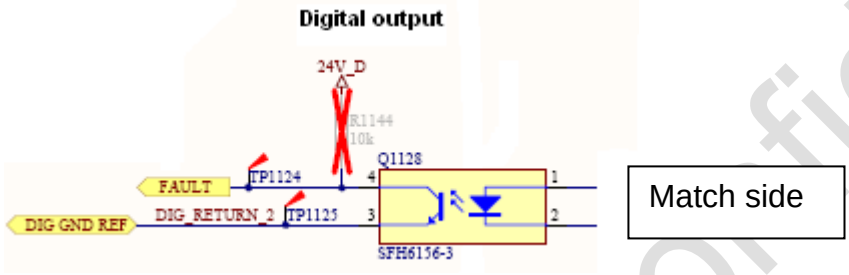
3.6.1.1 Analog interface pin-out

Pin #	Description	I/O Type
1	Interlock	Passive
2	Interlock	Passive
3	(C1) Load capacitor position (0-10Vdc)	AOUT
4	(C1) Load capacitor position (Rtn)	AOUT
5	Local/Remote Preset Select (N/C or Gnd = Local, +24Vdc = Remote)	DIN
6	Ground (Chassis)	Passive
7	(C2) Tune capacitor position (0-10Vdc)	AOUT
8	(C2) Tune capacitor position (Rtn)	AOUT
9	Auto/Manual (N/C or Gnd = Auto, +24Vdc = Manual)	DIN
10	Remote (C1) Load capacitor preset (Rtn)	AIN
11	N/C	
12	N/C	
13	+24Vdc output (user voltage for digital pull-up)	
14	N/C	
15	RF Voltage peak-to-peak signal (0-10Vdc = 0 – 2500 Vp-p)	AOUT
16	RF Voltage peak-to-peak signal (Rtn)	AOUT
17	Analog ground (reference for pins 18 & 19)	AOUT
18	Remote (C2) Tune capacitor preset (0-10Vdc)	AIN
19	Remote (C1) Load capacitor preset (0-10Vdc)	AIN
20	Digital ground for Local/Remote preset select pin 5 / pin 9	DREF
21	Remote (C2) Tune capacitor preset (Rtn)	AIN
22	Auxiliary Analog Output #2 (Rtn)	AOUT
23	Auxiliary Analog Output #2 (0-10Vdc)	AOUT
24	Fault – digital output, high / +24VDC during initialization or when software fault is detected; low / grounded during normal operation. Pull-up resistor required on PCB or system side.	DOUT
25	N/C	

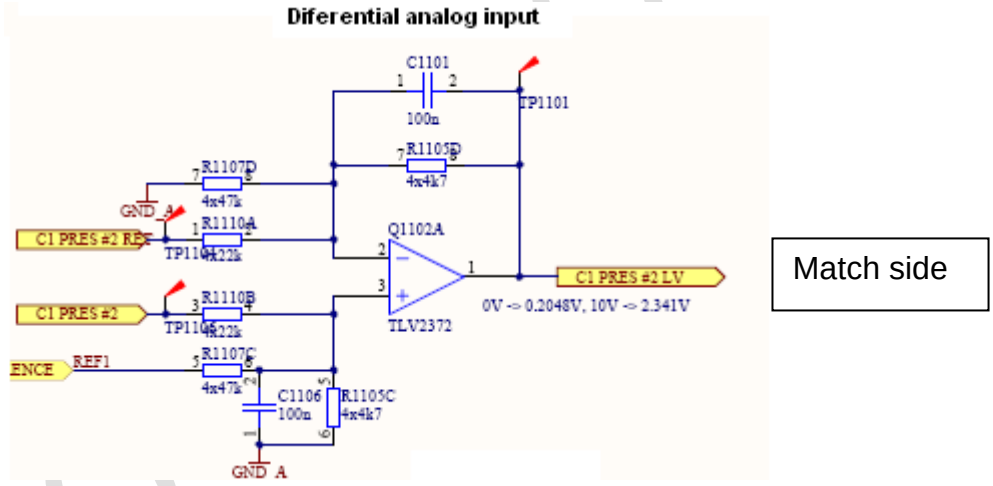
3.6.1.2 Typical digital input



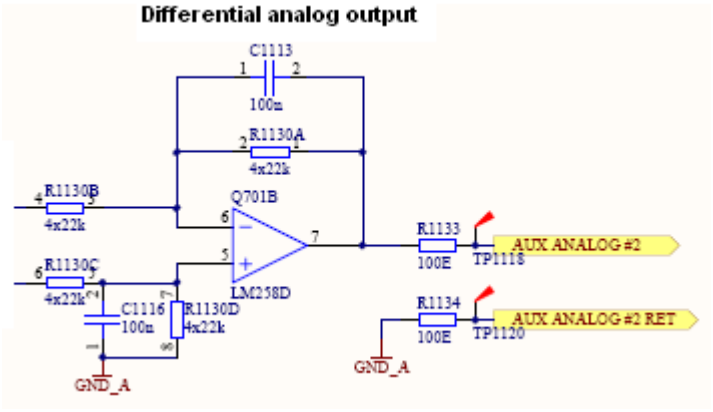
3.6.1.3 Typical digital output



3.6.1.4 Typical differential analog input

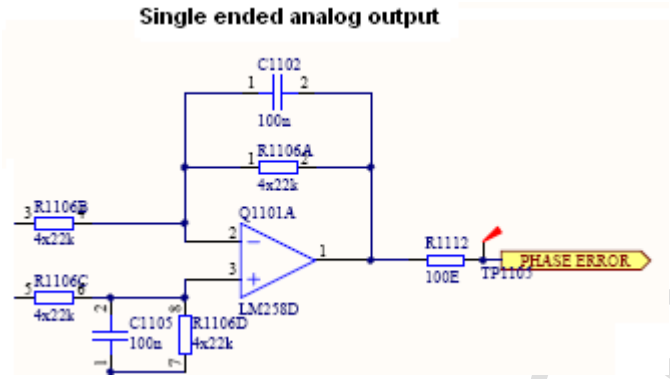


3.6.1.5 Typical differential analog output



Match side

3.6.1.6 Typical single ended analog output



Match side

3.6.2 Serial communication port

3.6.2.1 RS-232 port pin-out

Pin #	Description
1	N/C
2	TXD.D, RS-232 Transmit Data (to the Host)
3	RXD.D, RS-232 Receive Data (from the Host)
4	N/C
5	COM.D, Data Common
6	N/C
7	N/C
8	N/C
9	N/C

3.6.2.2 RS-232 communication protocol

Signals on the RS-232 port comply with EIA RS-232 standards.

The following settings apply for RS232 transmissions:

- Baud Rate: 9600
- Data Bits: 8
- Stop Bits: 1
- Parity: None
- Flow Control: None

The Carriage Return character (Hex code 0xD) is the indication for the “end of command string. Any query to the match requires a <CR> termination.

For each command received by the RF match unit, the match unit will reply with an “Acknowledge” message, or a “NAK” in case of an error.

Acknowledge prompt will be ‘>’, <LF>, <CR>

Any error prompt will be ‘N’ ‘A’ ‘K’ <LF> <CR>

Returned data to COMET standard query commands will be terminated by <LF><CR>.

3.6.2.3 Serial command set

The following serial commands are supported by the firmware of the match:

Command	Function	Syntax
Load	Set load capacitor (C1) position	Load##.#<CR> where ##.# is 00.0 to 99.9 %
Tune	Set tune capacitor (C2) position	Tune##.#<CR> where ##.# is 00.0 to 99.9%
QP	Query capacitor positions	QP##<CR> The answer string is ##.#, ##.# for C1 and C2 positions
Vers	Report firmware version	Vers<CR>
Unit	Report match serial number	Unit <CR>
Rest	Restart PCB	Rest<CR> Command is only accepted when RF is off wait at least 15 s before issuing the next serial command
Lube	Redistribute the grease on the lead screws of the capacitors	Lube<CR> Command is only accepted when RF is off wait at least 15 s before issuing the next serial command
Zload	Report load impedance	Zload<CR>
ASCoff	Returns control from serial command mode to GUI or analog input	ASCoff<CR>

Command	Function	Syntax
SP	Save current capacitor positions as preset n (n = 1....15)	SPn<CR> where n is 0...9 or A...F
G	Goto preset position n (n = 1...15)	Gn<CR> Where n is 0...9 or A...F
QPn	Query preset position n (n = 1...15)	QPn<CR> Where n is 0...9 or A...F
CQP	Constantly query capacitor positions in 0.1 s interval	CQP<CR>
SQP	Stop querying capacitor positions	SQP<CR>

These commands are explained in detail in [3].

Important note: All above commands are case-sensitive.