BTM Series Pulsed RF Power Amplifier Modules

Application Note

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Amplifier Safety Precautions

EXTREMELY IMPORTANT

The amplifier is designed to generate large amounts of RF power, and can generate high RF voltages. It is therefore capable of causing very serious injury unless the proper safety precautions are carefully observed. To minimise the risk, all personnel involved with operating or maintaining the amplifier must be thoroughly familiar with the following safety precautions:

- Tomco linear amplifiers are capable of producing much more than their rated output power. The amplifiers are designed such that an RF drive level of *not more than* 0dBm is required for full output power at any frequency. Applying more than 0dBm of RF drive can result in more RF output power, as the amplifier enters compression. It is safe to operate the amplifier in compression, provided that the RF drive level does not exceed +10dBm.

- The manufacturer has taken extensive precautions to ensure that unintentional contact with hazardous voltages within the radar equipment is minimised. However, all personnel involved in the operation of the amplifier must be aware that dangerous voltages are present within the equipment, and on any load, probe or antenna connected to its outputs.
- When the amplifier is operating, the RF field strength at various points in the near field of the RF load, probe or antenna may exceed the safe continuous exposure level specified in international standards. Personnel engaged in the operation or maintenance of this equipment should be aware of, and avoid, extended exposure to RF radiation.
- This is a high gain high power amplifier. As such, small amounts of unintentional feedback or small unintentional inputs can result in large RF output levels. These transient RF outputs are not only extremely dangerous, but may also cause extensive damage to any load, probe or antenna connected to the amplifier's output. Also, take care to use only high quality well shielded 50 ohm coaxial cable for the RF Drive and RF output connections.
- Do not permit unauthorised or untrained personnel to adjust, modify or tamper with any of the amplifier controls and connections.
- The amplifier produces high RF power levels at its outputs: contact with these points can cause, in the least case, penetrating RF burns to the skin. While the design of the equipment is such that unintentional contact is highly unlikely, all personnel should be aware of the hazard and exercise extreme caution when working on or near the amplifier or its load.
- If repairs or maintenance are to be performed to the amplifier's load, RF probe or antenna, the amplifier should be switched off at the prime power supply, and clearly labeled "Equipment Under Service - Do Not Switch On", before proceeding.
- Do not operate the equipment in any manner that is not described in this manual.

Hazardous Materials Warning:

- The RF power transistors used throughout the amplifier contain a Beryllium Oxide substrate. This substance is known to be highly toxic. Personnel involved in maintenance or disposal of the equipment should be made aware of the hazard and follow local authority regulations regarding handling and disposal.
- Teflon (PTFE) insulated coaxial cables have been used within the amplifier unit. In a fire situation where this material may be exposed to extremely high temperatures, it may give off toxic fumes. Appropriate measures, including the provision of nearby carbon-dioxide based fire extinguishers should be taken to prevent the amplifier from being exposed to fire.

Safety Symbols used in this Manual and on the Equipment

	This symbol is used throughout the manual when important safety information is included.
	Dangerous voltages are present. Use extreme care.
CAUTION	The caution symbol indicates a potential hazard. Attention must be given to the statement to prevent damage, destruction or harm.

General description:
The Tomco BT series pulsed RF amplifier modules are available in a variety of power levels, gains and frequency ranges. For operation they require an external DC power supply and a suitable heatsink (preferably including forced air cooling). External VSWR protection is also generally recommended.

Protection:
The modules include the following inbuilt protection

- Over-temperature shutdown. This is self-resetting. Typically, the shutdown circuit activates at a module case temperature of 100 degrees, and resets at approximately 70 degrees.
- DC supply reverse polarity protection. This is diode / fuse protection, so a reverse polarity connection from a high current source will result in the fuse blowing. The fuse is accessible by removing the module top cover.
- RF gate duty-cycle and pulse width protection. If the maximum RF gate duty-cycle or pulse width rating (generally 20% and 100 milliseconds respectively) is exceeded, the gate is inhibited. This protection is self-resetting when the RF gate is brought within specifications.

Note 1: Many of Tomco's amplifier modules are capable of both CW and pulsed operation. In those modules, the duty-cycle and pulse width limiter is disabled when the supply voltage is less than approximately half that recommended for full-power pulse-mode operation.

Note 2: The modules do not include output VSWR protection. The modules are designed to be very rugged, and will withstand severe mismatches without damage. However, if prolonged operation is anticipated with poor loads and high power levels, an external reflected power detector should be fitted to the output of the amplifier, to inhibit the RF gate signal or reduce the RF drive level in the event of a mismatch greater than 4:1 at full power.

Input signals

- RF drive: Standard connector type is SMA, 50 ohms. The nominal drive level for full output power depends on the model number. The RF drive signal can be either pre-gated or CW (pre-gated will give less RF feedthrough between pulses). To ensure the best possible performance, take the following precautions:

    1) Use only high quality well shielded 50 ohm coaxial cable to connect to the RF drive input.
    2) Keep the RF drive cable as short as practically possible.
    3) Route the RF drive cable carefully and keep it well away from the RF output cable, the RF load, and any other possible sources of noise or pickup.

- RF gate: Connect to Pin 1 on DB9 interface connector. The RF gate input is compatible with both CMOS and TTL voltage levels. Low (0 volts nominal) switches off the RF gate and the output stage bias. High (5 volts nominal) switches on the RF gate and the output stage bias. The nominal input impedance is 1k ohm.
  A "blanking delay" is specified for each type of module. The blanking delay is effectively the transition time between the blanked and unblanked states. When the RF gate is taken high, the gain of the module begins to rise towards its nominal value. The blanking delay is the time taken for the module to reach its full gain value. The converse applies on the falling edge of the RF gate.
  Thus, if the fastest possible RF pulse rise and fall times are required, the RF gate should be taken high at least one blanking delay before the RF drive pulse is applied.

Otherwise, the rise time of the RF output pulse will be approximately equal to the specified blanking delay.

Output signals

- RF output: Standard connector type is SMA, 50 ohms. Nominal load impedance is 50 ohms resistive. The RF OUT connector should be connected to a suitably rated RF load at all times when the amplifier is switched on.

Dangerous voltages are present on this connector when the amplifier is operating, and it should be considered a hazardous point whenever the amplifier is switched on.

DC supply

The positive DC supply is connected via a feedthrough capacitor with a solderable pin. The zero volts DC connection is made via a solder lug and bolt.
In general, only one DC supply voltage is required, usually +28V or +50V.

D9 interface connector

Status monitoring and control functions are available on a D9 connector. The pinout is as follows:

PIN #	FUNCTION	COMMENT
1	GATE input	Logic-level control input. 0V = blank +5V = unblank
2	PTT input	Logic-level control input. Open = blank Pull down to 0V = unblank
3	DC input current monitor	Analogue status output. Current in amps = 3.33 x pin 3 voltage
4	Temperature monitor	Analogue status output. Temp in degrees C = 45.5 x (V-1.47)
5	Overtemp status	Logic-level status output. 0V = OK +5V = Overtemp
6	Standby (low-current mode)	Logic-level control input. Open = Standard operation Pull down to 0V = Low-current mode, reduces current consumption when the amplifier is blanked, but may increase blank/unblank switching transients.
7	Gain control	Analogue control input, varies RF gain over approximately 7dB range. 0V = Maximum gain +5V = minimum gain.
8	Duty limit	Logic-level status output. 0V = duty-cycle is within limits. +5V = Duty-cycle limit is exceeded.
9	GND	0V reference for status and control functions.

Determining the DC power supply requirements

The minimum average current rating required for the DC power supply when operating the module at a particular input voltage and duty-cycle can be estimated as follows:

First estimate the maximum RF output power for the operating DC supply voltage:

$$P_{MAX} \sim P_{RATED} * (V_{DC} / V_{RATED})^2$$

Then calculate the required current rating:

$$I_{DC} = (P_{MAX} / V_{DC}) \times Duty \times 2.5 + 0.7$$

Where:

P_{RATED} = Amplifier peak power rating in watts (eg 250W)
V_{RATED} = Amplifier voltage rating for peak power in volts (eg 50V)

V_{DC} = Operating DC power supply voltage in volts
P_{MAX} = An estimation of the peak output power at V_{DC}

I_{DC} = Required DC power supply current rating in amps
Duty = Amplifier operating duty-cycle

For example, for a 250W amplifier running on 50V at a maximum duty-cycle of 20%, the DC power supply must have a current rating of at least:
$P_{MAX} \sim 250 \times (50/50)^2 = 250W$
$I_{DC} = (250/ 50) \times 0.2 \times 2.5 + 0.7 = 3.2A$

CAUTION

For safety reasons, it is advisable to avoid using a power supply that has a current capability much greater than the amount calculated using the above procedure. If the power supply has a variable current limit, set this to a point just above the level required for normal operation.

CAUTION

Note: Many Tomco amplifier modules are capable of both pulsed and CW operation. For CW operation it is necessary to reduce the power supply voltage, typically to half of that used for pulsed operation. See the “CW Operation” paragraph.

Determining the external cooling requirements

The amplifier module must be attached to a heatsink of sufficiently low thermal resistance to maintain a case temperature below approximately 70 degrees. The maximum power dissipation of the module can be estimated from:

$$P = (I_{DC} \times V_{DC}) – (P_{MAX} \times Duty)$$

Where:

P = amplifier maximum power dissipation in watts
V_{DC} = amplifier rated maximum duty-cycle
P_{MAX} = amplifier RF output power in watts
Duty = amplifier operating duty-cycle

For example, a module with a rated output power of 250W and a maximum duty-cycle of 20% will dissipate up to:

P = (3.3 x 50) – (250 x 0.2) = 115 watts

Note that the power dissipation does not scale with RF output power as the efficiency of the amplifier decreases rapidly with lower power – in other words, this estimate is valid only when the amplifier is operating at P_{MAX}.

To maintain a temperature below 70 degrees, the module must be fitted to a heatsink with a thermal resistance of no greater than:

$R_t = (75 – T_a) / P$

Where:

Rt = maximum permissible thermal resistance of the heatsink (including the thermal resistance of the module / heatsink interface), in degrees per watt
T_a = maximum ambient temperature in degrees C
P = maximum power dissipation as calculated above

So, for the amplifier in the above example, and a maximum ambient of 25C, the heatsink must have a thermal resistance of ***no more than***:

R_t = (75 – 25) / 100 = 0.5 degrees per watt

Note that this figure includes the thermal resistance of the module / heatsink interface. To keep the thermal resistance of this interface small, ensure that the mating surface of the heatsink is clean and flat, and smear the base of the module with silicone heatsink grease before bolting it down.

Note that when heatsink manufacturers quote the free-air thermal resistance of a particular heatsink, they refer to the ideal case in terms of air flow, fin orientation, and other factors. In practice, it is often not possible to achieve the quoted thermal performance, so use a very conservative approach when making a selection.

Forced air cooling (using a fan to blow air through the heatsink fins) dramatically reduces the thermal resistance of a heatsink. For power dissipation levels above about 30 watts, forced air cooling is strongly recommended.

CW Operation

Many Tomco amplifier modules are capable of both pulsed and CW (or high pulsed duty-cycle) operation. The power output rating for CW mode is typically one quarter of the PEP rating for pulsed mode. For example, a module specified for 200W PEP pulsed might be specified for 50W maximum in CW mode.

CAUTION

The following note must be observed when using these dual-mode modules:

- When operating in CW mode, the DC power supply voltage must be reduced to approximately half of the value specified for full-power pulsed operation. Above that level, the pulse width and duty-cycle limiter becomes active, preventing CW operation. For example, a module may be specified to operate on 50V DC in pulsed mode and 28V DC in CW or high duty-cycle mode.

Failure to observe these precautions may result in overheating or internal damage to the module. In particular, operation in CW mode for extended periods at high supply voltage must be avoided.

Examples of Measured Supply Current and Power Dissipation for a BTM00250-AlphaS Module

Vsupply	**Duty**	**Freq.**	**Pout RF (peak)**	**Isupply avg.**	**Pdiss**
50	0	-	-	0.72A	36W
50	20	30M	250W	3.14A	107W
50	20	30M	100W	2.28A	94W
50	20	30M	50W	1.84A	82W
50	20	30M	10W	1.3A	63W
28	0	-	-	0.7A	20W
28	20	30M	100W	2.26A	43W
28	20	30M	50W	1.82A	41W
28	20	30M	10W	1.2A	32W
28	CW	30M	50W	6.2A	124W
28	CW	30M	10W	3.55A	89W
16	CW	30M	10W	3.1A	40W

Determining the external storage capacitor requirements

For pulsed operation, external storage capacitors are required. During a pulse, the amplifier draws current from the storage capacitors. Between pulses, the power supply re-charges the capacitors ready for the next pulse.
During the pulse, the current drawn by the amplifier can be assumed to be constant, and therefore, the voltage across the storage capacitor can be assumed to drop linearly with time. The minimum required storage capacitor can be estimated from:

$C = 2.5 \times P_{MAX} \times PW_{MAX} / (V_{dc} \times (V_{dc} – (V_{dc} \times droop)))$

Where:

C = minimum storage capacitance required in farads
P_{MAX} = amplifier rated maximum pulsed power output in watts
PW_{MAX} = amplifier maximum rated pulse width in seconds
V_{dc} = amplifier rated DC power supply voltage in volts
Droop = acceptable RF output voltage at the end of the longest pulse, relative to the voltage at the start of the pulse, at full power

For example, for a 250W amplifier running on 50V DC, with a maximum pulse width of 10 milliseconds and an acceptable pulse droop of 5%, the required external storage capacitance is:

$C = 2.5 \times 250 \times 0.01 / (50 \times (50 - (50 \times 0.95))) = 0.05F = 50{,}000\mu F$

The capacitor must be rated for at least V_{dc}. For 50V operation, we recommend using at least a 63V rated capacitors. For 28V operation, we recommend using at least 35V rated capacitors.
Fit the capacitors as close as possible to the DC power connection on the amplifier module.
The capacitors should have a bleed resistor fitted across them, so that they discharge to a safe level in a reasonable length of time. For 50V we recommend a 1k-ohm 5W resistor. For 28V, a 270 ohm 5W resistor is recommended.

CAUTION

For safety reasons, it is advisable to avoid using a storage capacitor that is significantly larger than necessary.