DC – coupled power amplifier

1 Introduction

The TBDCA1 is a DC-coupled power amplifier with low output impedance. It delivers up to 150W_{RMS}, has a 3dB bandwidth from DC to 3 MHz, an output voltage range of up to 55 V_{pp}, a maximum continuous output current of 10 A_{RMS} and a usable frequency range from DC to 10 MHz.

Applications:

- General purpose output amplifier for arbitrary waveform generators
- Stress testing according to ISO 16750-2 and ISO 7637-2
- Power supply input impedance measurement
- Structure current injection for MIL-STD-461H, CS109
- Voltage ripple injection for MIL-STD-461H, CS101 or RTCA/DO-160 Section 18
- Immunity testing according to ISO 11452-10, SAE J1113-2 and various automotive manufacturer specific standards
- RF power amplifier to drive Helmholtz coils or loop antennas

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2 Specification

General specification

3 dB bandwidth:	DC – 3 MHz, useable up to 10 MHz
Output power:	150 W, depending on load impedance
Voltage gain:	switchable; 0 dB, 10 dB, 20 dB, 30 dB, 40 dB
Operating temperature range:	-20°C to +40°C
Dimensions:	W 300 mm x H 150 mm x L 420 mm;
Weight:	10 kg

Output specification

Nominal output power:	150 W @ RLOAD ≤ 2 Ω
	80 W @ RLOAD = 4 Ω
	30 W @ RLOAD = 12 Ω
Max. output voltage:	$56V_{PP}$
Max. continuous output current:	10 A_{RMS}
Max. output current:	20 A_{RMS} for 30 seconds
Min. output impedance:	0.5 Ω
Output offset voltage:	adjustable; ± 25 V
Output connector:	4 mm posts
Voltage monitor output:	voltage division ratio: 1:20 @ 50 Ω; 1:10 @ High Z; BNC-female
Current monitor output:	trans-impedance: 0.1 V/A @ 50 Ω; 0.2 V/A @ High Z; BNC-female
Current Limit:	adjustable, 0 … ±12 A
Rise time:	typ. ≥ 20 ns; ringing depending on load inductance and cable length

Input specification

Input coupling:	AC / DC; switchable
Input impedance:	50 Ω / High Z; switchable
Input voltage range:	± 3V ($6V_{pp}$) for maximum output power at 0 dB gain
Max. input voltage rating:	± 5V @ 50 Ohm input impedance; ± 30V @ High Z
Input connector:	BNC – female

Supply specification

Operating Voltage:	90 V – 260 V; 50 Hz / 60 Hz
Max. current consumption:	9 A @ 115 VAC; 4.5 A @ 230 VAC
Connector:	EN 60320, C14

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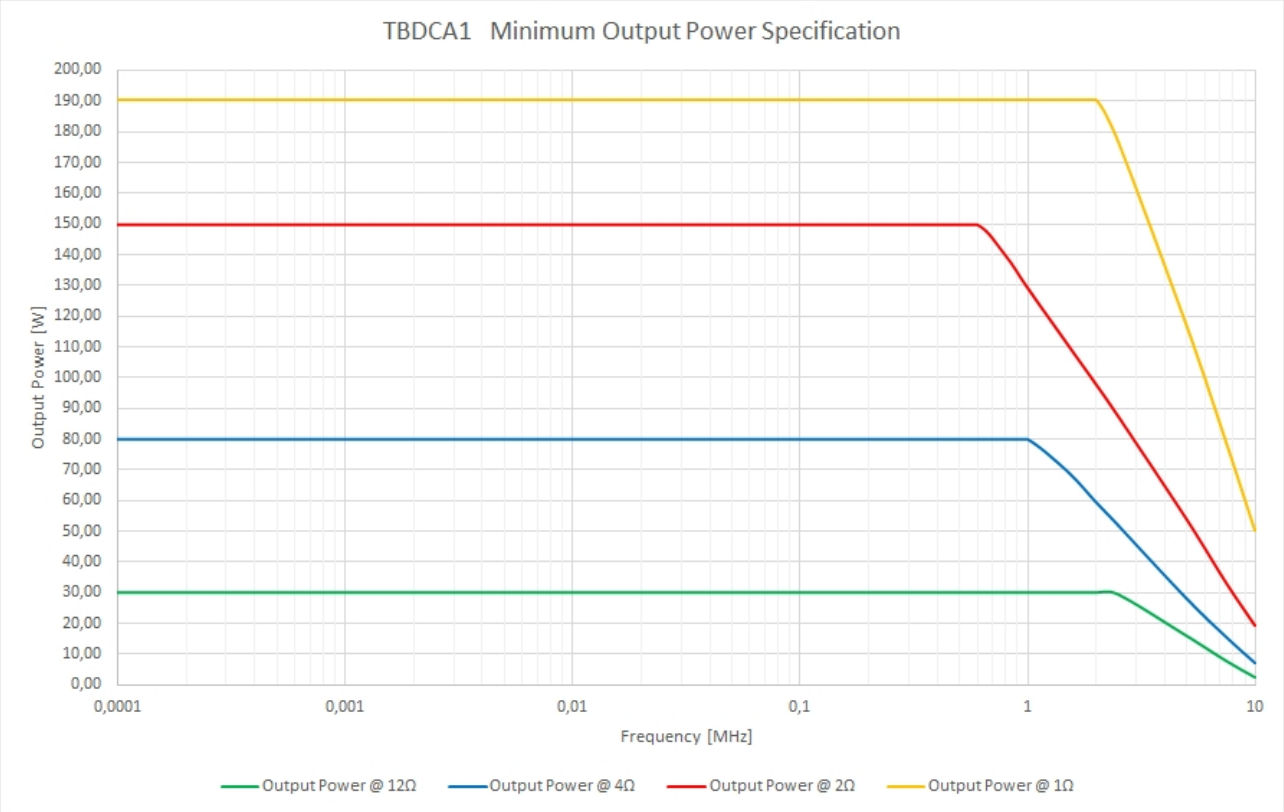
3 Output power bandwidth



4 Safety

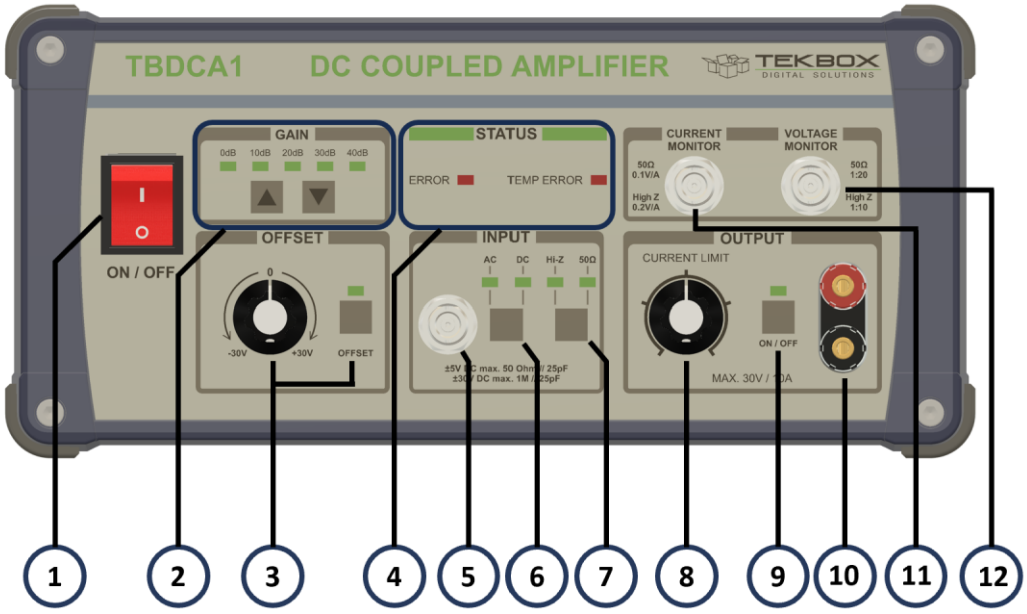
During operation, high voltages may be present at the output terminals of the TBDCA1.

Warning: Electrical Shock Hazard

- **The TBDCA1 must be used by trained laboratory technicians (electricians) only. There is a risk of death or serious injury, as the amplifier may produce AC or DC ouput voltages > 60 V.**
- **Unless you are absolutely certain that the amplifier is disconnected from mains, do not touch the output terminals.**
- **Ensure that the amplifier is physically and electrically separated from mains, before connecting any cables or components to the output terminals.**
- **Do not use the amplifier if you have an electronic medical device such as a pacemaker. Electronic medical devices may malfunction or fail, potentially resulting in death or serious injury.**

5 Operation

5.1 User Interface



1) Mains Power Switch
2) Voltage Gain; 0 dB after power-up; use the up/down buttons to set the desired voltage gain
3) Adjustable DC-Offset; max. ± 25V; OFF after power-up; press the button to turn the offset ON/OFF
4) Status LEDs
   - Thermal Error: indicates over-temperature of the output stage
   - Function Error:
     1 Pulse – I2C error
     2 Pulses - ± 15V supply, voltage out of range
     3 Pulses - ± 36V supply, voltage out of range
     4 Pulses - ± 36V supply, over-current
     5 Pulses - over-temperature error
     6 Pulses - ± 15V supply, over-current

   Restore a safe load condition and press the output button for 5 seconds to reset the amplifier.
5) Signal input; BNC-female
6) Input coupling selector; DC-coupling after power-up; press the button to toggle between AC - and DC – coupling
7) Input impedance selector; High Z after power-up; press the button to toggle between 50 Ω and High Impedance
8) Output current limit potentiometer; maximum current limit: ± 12 A
9) Amplifier output switch; OFF after power-up; press the button to enable the output; note that the output terminals are not physically connected / disconnected; the switch disables the signal path
10) Amplifier output terminals
11) Current monitor output; BNC-female; trans-impedance: 0.1 V/A @ 50 Ω; 0.2 V/A @ High Z
12) Voltage monitor output; BNC-female; voltage division ratio: 1 : 20 @ 50 Ω; 1 : 10 @ High Z

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5.2 Output Power

The maximum output voltage and maximum output current for DC applications employing the TBDCA1 as a voltage-controlled power supply are ± 28 V and ± 10 A, respectively. As a result, the maximum output power is 280 Watt.

In AC applications, assuming a sinusoidal output signal, the maximum output voltage is ($56V_{pp}/2.42$) = 19.9 V_{RMS}. Assuming a 10 A_{RMS} output current, the maximum output power is around 200 W_{RMS}. However, the voltage drop across the load could exceed the maximum output voltage even at lower currents, limiting the output power at lower values. The graphic in Chapter 3 depicts the highest possible output power based on load impedance.

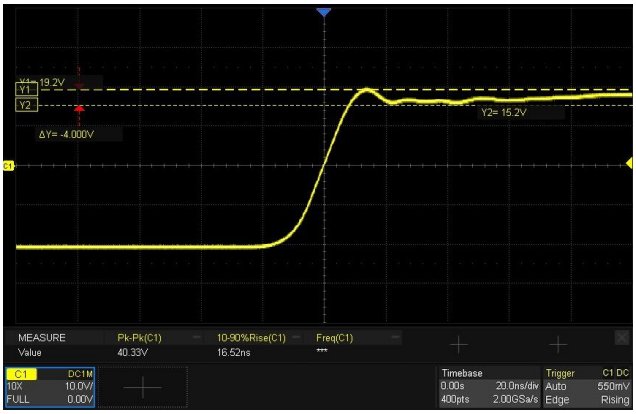
Although the amplifier can deliver a pulse power of up to 300 W for load impedances of ≤ 1 Ω, we strongly recommend against exceeding 150 W in continuous operation. Because of its small form factor, the amplifier's cooling capacity is constrained.

The power bandwidth for AC/RF input signals depends on the load impedance and on the output power. Higher load impedances and lower output power enable higher bandwidths. The amplifier´s 3 dB bandwidth is at least 3 MHz for any load impedance. Reducing the output power enables linear operation up to 10 MHz and above.

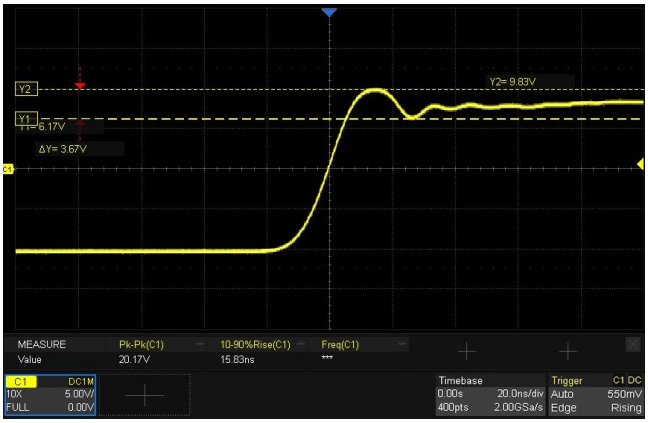
Note that operation at very low frequencies and high output power may cause mains flicker.

5.3 Rise time

Example waveforms:



R_{Load} = 2 Ohm; V_{OUT} = 40V pp; rise time: 17 ns; ringing: 10%



R_{Load} = 1 Ohm; V_{OUT} = 20V pp; rise time: 16 ns; ringing: 18%

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6 Applications

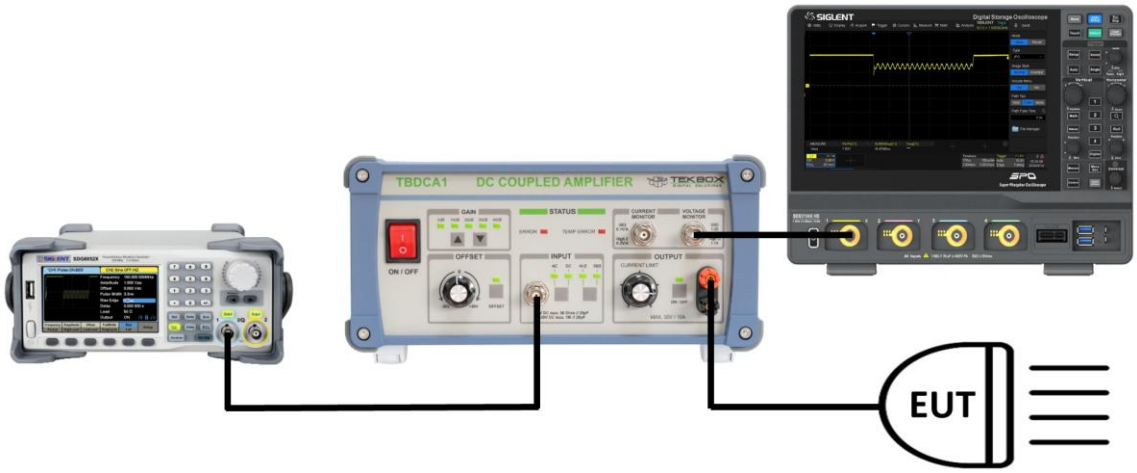
- **General purpose output amplifier for arbitrary waveform generators**

Most AWG output stages are limited to a maximum amplitude of 12 V (High Z) and 6 V (50 Ω). The TBDCA1 significantly extends the usability of AWGs to drive low impedance loads.

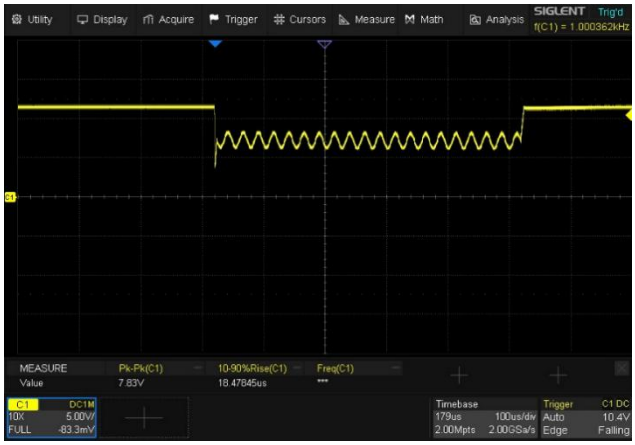
- **Stress testing according to ISO 16750-2 and ISO 7637-2**

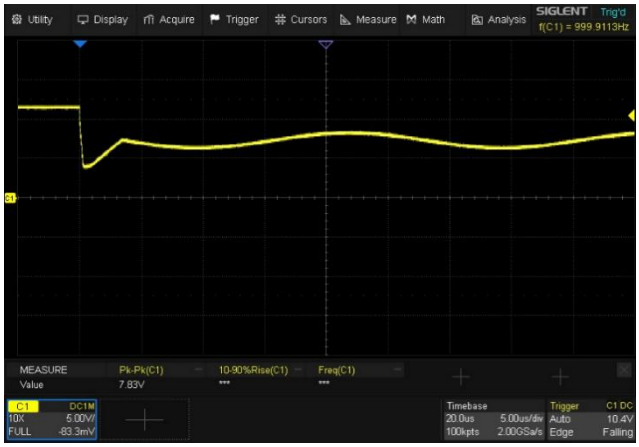
ISO 16750-2 and ISO 7637-2 specify supply waveforms for stress testing of automotive electronics. Certain waveforms require rise times that are challenging to produce using arbitrary programmable power supplies.

Setup:



Example: Starting profile





cranking voltage measured across the EUT supply line

For more details, read our application note *Creation of ISO 16750-2 waveforms with Siglent AWG and Tekbox TBDCA1.pdf*

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- **Power supply input impedance measurement**

Measuring the input impedance of power supplies requires the capability to modulate the supply voltage with a swept AC signal. The impedance is calculated from the measured AC voltage amplitude and the amplitude of the resulting supply current ripple.

For DC/DC converters with input voltages of up to ± 24 V and current consumption of less than 10A, the TBDCA1 can directly provide the modulated supply voltage. The DC level can be set with the offset potentiometer and the swept signal can be AC coupled into the amplifier. Furthermore, the amplifier provides a current monitoring output.

For DC/DC converters with input voltages > ± 24 V or for AC power supplies, the swept AC signal can be injected with a transformer such as the TBJT04 or similar in series to the supply line. The setup is similar as for the CS101 test described further down in this chapter. Moreover, Tekbox provides a power line ripple detector, model TBPRD-CS101-240V for voltage measurement and a range of current monitoring probes to measure the supply current ripple.

- **Structure current injector for MIL-STD-461G, CS109**

MIL-STD-461G CS109 tests the ability of equipment and subsystems to withstand electrical currents conducted directly onto their enclosure or chassis. It ensures that low-frequency structure currents, specifically from 60 Hz to 100 kHz, do not cause malfunctions, performance degradation, or deviations in sensitivity, particularly for sensitive Navy equipment.
Current is injected into the metal enclosure of the Equipment Under Test, with the connection points at diagonal extremes across all surfaces of the equipment, whereas the ground of the EUT and measurement equipment is connected to a single-point ground.

MIL-STD-461G, CS109 specifies following setup:

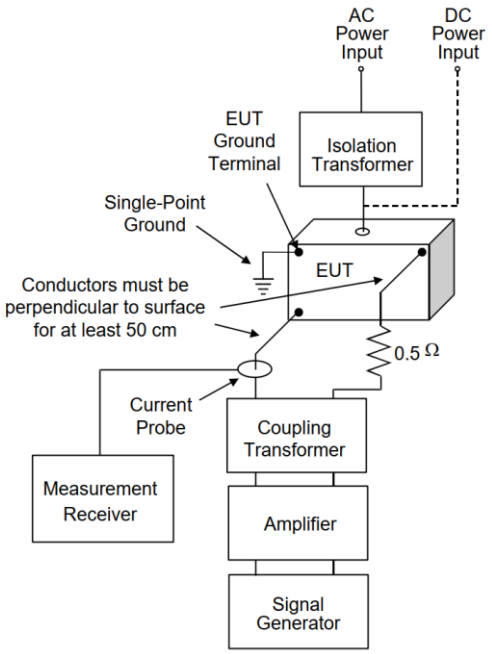

Figure 11: CS109 test configuration; from MIL-STD-461H

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Typically, amplifiers with low output impedances are utilized. It is not possible to short the amplifier output, though. A 2 Ω to 0.5 Ω coupling transformer and a 0.5 Ω resistor are used as a workaround.

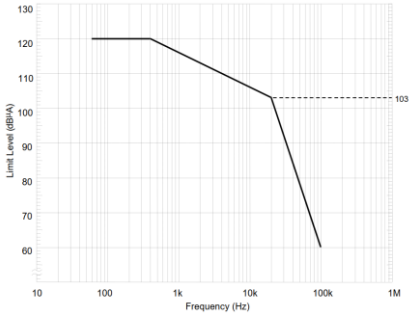


Figure 12: CS109 limit

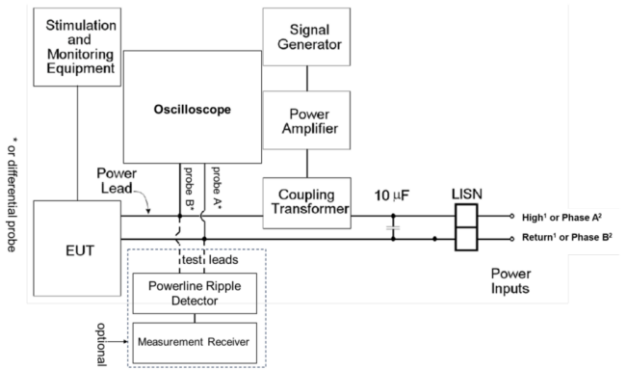
The required current is 120 dBµA (1 A_{RMS}) at 60 Hz, decreasing to 60 dBµA (1 mA_{RMS}) at 100 kHz.

Tekbox supplies all necessary components for a CS109 setup:

- Measurement receiver: TBMR-110M
- Amplifier: TBDCA1
- Coupling transformer: TBJT04
- 0.5 Ohm resistor: TBR-CS101
- Current probe: e.g. TBPCP3-20H70
- Signal Generator: e.g. tracking generator of TBMR-110M and CS109 application in receiver SW

- **Voltage ripple injection for MIL-STD-461H, CS101 or RTCA/DO-160 Section 18**

CS101 injects signals from 30 Hz to 150 kHz into power supply leads and checks, if the EUT exhibits any malfunction, performance degradation or any other deviation from specified performance. The signal is coupled via a transformer and has a power of up to 80 W. The CS101 procedure requires a calibration before testing the EUT. A test setup for DC or single-phase supplied EUTs is shown below:



Tekbox supplies all necessary components for a CS101 setup:

- Measurement receiver: TBMR-110M
- Amplifier: TBDCA1
- Coupling transformer: TBJT04
- 0.5 Ohm resistor: TBR-CS101
- Powerline Ripple Detector: TBPRD-CS101-240V
- Signal Generator: e.g. tracking generator of TBMR-110M and CS101 application in receiver SW

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Amplifier protection:

CS101 setups require several considerations to prevent damaging the power amplifier. When testing DC supplied EUTs, on initial turn on, DC to DC power switching converters can create large voltages on the primary side of the injection transformer that can damage the power amplifier. A precaution is to place a 5-ohm resistor across the primary and to disconnect the transformer during initial turn on. After turning on the EUT, disconnect the 5-ohm resistor across the primary and connect the amplifier output instead. It is also good practice to disconnect the amplifier, before turning off the EUT.
AC supplied EUTs with high supply current, can create large currents on the primary of the coupling transformer. This currents at line frequency have to be absorbed by the output stage of the power amplifier and may cause significant additional dissipation and consequently an over-temperature shut down of the amplifier. MIL STD-461H proposes following setup using two coupling transformers to cancel line currents and prevent them from reaching the amplifiers output terminals:

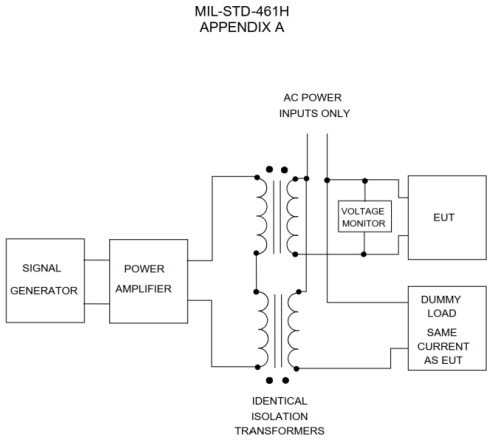

FIGURE A- 12. CS101 power amplifier protection.

Carefully study Appendix A.5.7 of MIL-STD-461-H to avoid damaging the TBDCA1.

7 Ordering Information

Part Number	Description
TBCDA1	DC – coupled amplifier

8 History

Version	Date	Author	Changes
V1.0	12.9.2026	Mayerhofer	Creation of the document