Texas Components Corporation

USA Manufacturer of Precision Resistors featuring Bulk Metal® Foil*

TX2352

'Naked' Bulk Metal® Foil Resistor
for Audio Applications

[The TX2352 was originally introduced by Texas Components in 1997, and is available in all values from 1Ω to 10Ω and 100kΩ to 250kΩ]

Ultra High Precision; Ultra Low Noise and Distortion; Ultra High Linearity

Tight Tolerance, Low Temperature Coefficient of Resistance (TCR), and Low Voltage Coefficient of Resistance (VCR)

Resistors made with Bulk Metal® Foil are known for their unique combination of unmatched performance in all 10 major technical areas:

Temperature Coefficient of Resistance (TCR)	**Tolerance**
Power Coefficient of Resistance (PCR)	**Thermal Stabilization**
Voltage Coefficient of Resistance (VCR)	**Load Life Stability**
Thermal Electromotive Force (EMF)	**Response Time**
Electrostatic Discharge (ESD)	**Noise**

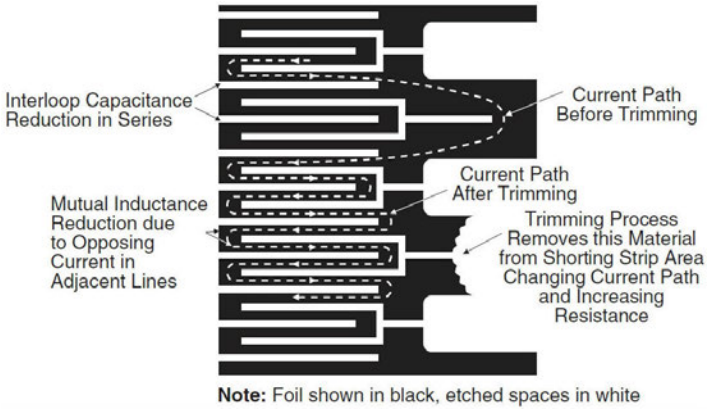
The TX2352 is made using Bulk Metal® Foil technology, providing improved sound quality and featuring a combination of low noise and low inductance/capacitance that makes it optimally suited for applications requiring quiet, distortion-free performance. Bulk Metal® Foil resistors like the TX2352, originally introduced to the market by Texas Components in 1997, **are already widely acknowledged as the leading resistors for audio applications**, and **the special 'naked' design** (without encapsulation) **aids in reducing signal distortion and increasing both precision and clarity in signal processing**. For non-standard technical requirements and special applications, our sales staff and applications engineers are available to advise you and make recommendations.

Characteristics of Different Types of Resistors

Technology	Temperature Coefficient of Resistance (TCR) -55ºC to +125ºC, +25ºC ref.	Initial Tolerance	End of Life Tolerance	Load Life Stability at +70ºC, Rated Power at 2000 Hours and then at 10,000 Hours	ESD (V)	Thermal Stabilization	Noise (dB)
Bulk Metal® (C/K) Foil	±2 ppm/°C; ±1 ppm/°C	From 0.001%	< 0.05%	0.005% (50 ppm) 0.01% (100 ppm)	25,000V	< 1 second	**-42db**
Thin Film	±5 ppm/ °C	From 0.05%	< 0.4%	0.05% (500 ppm) 0.15% (1500 ppm)	2,500V	> minutes	-20db
Thick Film	±50 ppm/ °C	From 0.5%	< 5%	0.5% (5000 ppm) 2% (20,000 ppm)	2,000V	> minutes	+20db
Wirewound	±3 ppm/ °C	From 0.005%	< 0.5%	0.05% (500 ppm) 0.15% (1500 ppm)	25,000V	> minutes	-35db

TRIMMING TO SPECIFIC VALUES

(a conceptual illustration of Bulk Metal® Foil)



Note: Foil shown in black, etched spaces in white

To achieve a precise resistance value, the Bulk Metal® Foil chip is **adjusted by selectively removing built-in "shorting bars"**. To increase the resistance in known increments, marked areas are cut, producing progressively smaller increases in resistance. **This method reduces** the effect of **"hot spots"** and **improves the long term stability of the resistor**.

TX2352 FEATURES & SPECIFICATIONS

- **Temperature coefficient of resistance (TCR):** ± 1 ppm/°C typical 10Ω to 100kΩ and ± 2 ppm/°C typical 100kΩ to 250kΩ (-55 °C to +125 °C, +25 °C ref)
- **Power coefficient of resistance:** ± 5 ppm at rated power
- **Rated power:** For 1Ω to <100kΩ, to 0.267 W rms (0.4 W peak) at +70 °C
  For 100kΩ to 250kΩ, to 0.133 W rms (0.2 W peak) at +70 °C
- **Resistance tolerance:** to ± 0.01 % (0.005 % is possible by special request)
- **Exceptional load life stability:** ± 0.005 % at +70 °C, 2000 h at rated power
- **Resistance range:** 10Ω to 250kΩ (not restricted to any standard values)
- **Bulk Metal® Foil resistors are not restricted to standard values**; specific custom values can be supplied at no extra cost (e.g. 1K2345 vs 1K)
- **'Naked' foil resistor** design, without molding or encapsulation, aids in reducing signal distortion and increasing clarity in signal processing paths
- **Electrostatic discharge (ESD)**: at least to 25 kV
- **Capacitance:** 0.5 pF typical; 1.0 pF max (non-capacitive design)
- **Rise time:** 1.0 ns, effectively no ringing
- **Current noise:** 0.010 µV (rms)/Volt of Applied Voltage (< -40 dB)
- **Thermal EMF:** 0.05 µV/°C typical (0.10 µV/°C max)
- **Voltage coefficient:** < 0.1 ppm/V
- **Thermal stabilization time:** < 1 s (nominal value achieved within 10 ppm of steady state value)
- **Inductance:** < 0.08 µH typical; 0.1 µH max; (non-inductive design)
- **Terminal Finish:** tin/lead alloy std; Pb free (RoHS-compliant) is available
- **Fast delivery of custom made units:** Typical lead time is 2-4 weeks, but expedited delivery in less than 1 week is possible even for custom values.

*Bulk Metal® Foil is a registered trademark of Vishay Precision Group (VPG)

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CHALLENGES IN AUDIO APPLICATIONS

Precision electronic equipment, including high-end audio equipment, will often suffer from noise effects due to tolerance stacking, circuit drift, and other instabilities. Constant adjustments, troubleshooting, and even **costly compensation circuitry can prove ineffective in addressing these problems** because **the source of such noise and instabilities can often be traced to simple "fixed" resistors** whose resistance values, in actual use, do not remain fixed. In addition, resistors can be direct sources of noise as well, depending on combinations of signal frequency, resistance value, current, temperature, applied voltage, and resistor type. **Many experiments have been done to show why some resistors are "noisier" than others**, but electronics experts and audiophiles agree that **what really matters is the true level of fidelity experienced by the user** when different resistor technologies are applied within audio system circuitry.

High-end audio applications require low intrinsic noise, highly linear amplification, and minimal dynamic distortion. The typical audio amplifier consists of a voltage preamplifier (preamp) and a power amplifier (final driver). The voltage **preamplifier deals with low-level signals, so its intrinsic noise level is critical**, while the **power amplifier must have a high linearity of amplification with minimal dynamic distortion**.

NOISE

Resistors can be one of the principal noise sources found in both preamplifiers and amplifiers. Several types of noise are found in and/or caused by resistors.

Thermal noise is **caused by thermal agitation of the discrete charge carriers (electrons) within the resistive material**. Thermal noise gets worse as resistance and temperature increase. Thermal noise is uniformly distributed throughout the audible frequency spectrum (as "white" noise).

Shot noise is **caused by fluctuations in the flow or density of discrete charges carriers (electrons) along the circuit**. Shot noise increases at high frequencies and as current and temperature decrease. Shot noise is uniformly distributed throughout the audible frequency spectrum (as "white" noise).

Flicker (aka current) noise is **caused by fluctuations in resistance along the signal path**, which is then transformed into voltage and/or current fluctuations - so it is highly dependent on the resistive material. Flicker noise increases as frequency decreases and current increases. **The use of resistors with a higher power rating than is otherwise needed can help to reduce flicker noise**. Flicker noise has a 1/f type spectral density of voltage (aka "pink" noise).

LINEARITY

In addition to noise, **every resistor possesses a certain nonlinearity of its electrical resistance** and, therefore, a nonlinearity in voltage and current characteristics. **The degree of nonlinearity depends on**, among other factors, **the internal microstructure of the resistive material**, the **quality and characteristics of calibration technique**, and **the quality of the contact between the resistive element and the terminals**.

Regarding the microstructure of the resistive material, **the most linear materials are pure metals and metal alloys in bulk, such as the foil in Bulk Metal® Foil resistors**. **Bulk Metal® Foil resistors are characterized by the exceptionally high intrinsic linearity** of their resistive element. **Bulk Metal® Foil resistors** owe their **high linearity**, and **ultra low current noise**, to the type of material they're made of (which is a cold-rolled metal foil several microns thick). When the same materials are deposited in the form of very **Thin (nanometer range) Films**, they **are less linear**. And **even less linear** than Thin Film resistors **are** the composite materials, like resistive cermets, used in **Thick Film** resistors, **and** the carbon compositions used in **Carbon Composition** resistors.

Regarding the other factors affecting linearity, **the trimming of Bulk Metal® Foil resistors** consists of cutting shorting bars/jumpers (which **do not damage the remaining current carrying portions of the resistive element**) and **the terminals in Bulk Metal® Foil resistors are an integral part of the foil resistive element** (**insuring a high-quality contact between resistive element and terminals**).

CONCLUSION

In summary, the **factors that cause noise and nonlinearity in other types of resistors are either minimized or not even relevant to Bulk Metal® Foil based resistors**. **Carbon Composition resistors are the noisiest resistive device type, followed by Thick Film** and **then Thin Film resistors**. The **least noisy are bulk metals and metal alloys (Bulk Metal® Foil and Wirewound)**. But, among other problems, **Wirewound resistors suffer from inherent inductance/capacitance** that **Bulk Metal® Foil resistors do not have - so the possibility, even probability, of self-excitation or "ringing" of the amplification circuit is reduced or eliminated when Bulk Metal® Foil resistors are used**. Both **noise and non-linearities are minimized by the inherent design and use of Bulk Metal® Foil resistors**.

For high-end audio equipment, **the careful selection of resistors is one of the best ways to avoid or minimize unwanted noise and distortion in the signal path,** and **Bulk Metal® Foil resistors, particularly the 'naked' versions** (without encapsulation)**, are by far the best possible choice for low-noise, high-fidelity applications.**

TABLE 1 – TCR BY RESISTANCE RANGE

RESISTANCE VALUE (Ω)	TYPICAL TCR (& MAX SPREAD)
100kΩ-250kΩ*	± 2.0 (± 2.5) (ppm/°C)
80Ω-100kΩ	± 1.0 (± 2.5) (ppm/°C)
50Ω-80Ω	± 1.0 (± 3.5) (ppm/°C)
10Ω-50Ω	± 1.0 (± 4.5) (ppm/°C)
1Ω-10Ω	± 2.2 (± 6.0) (ppm/°C)

* Resistance values greater than 150kΩ are available only by special request
** Values less than 2Ω are recommended at ±0.5%.

TABLE 2 – AVAILABLE TOLERANCES BY RESISTANCE RANGE

RESISTANCE VALUE (Ω)	AVAILABLE TOLERANCES (%)	CODE
50Ω-250kΩ	±0.005%	V
25Ω-250kΩ	±0.01%	T
12Ω-250kΩ	±0.02%	Q
5Ω-250kΩ	±0.05%	A
2Ω-250kΩ	±0.1% (recommended)**	B
2Ω-250kΩ	±0.25%	C
1Ω-250kΩ	±0.5%	D
1Ω-250kΩ	±1.0%	F

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FIGURE 2 – STANDARD DIMENSIONS

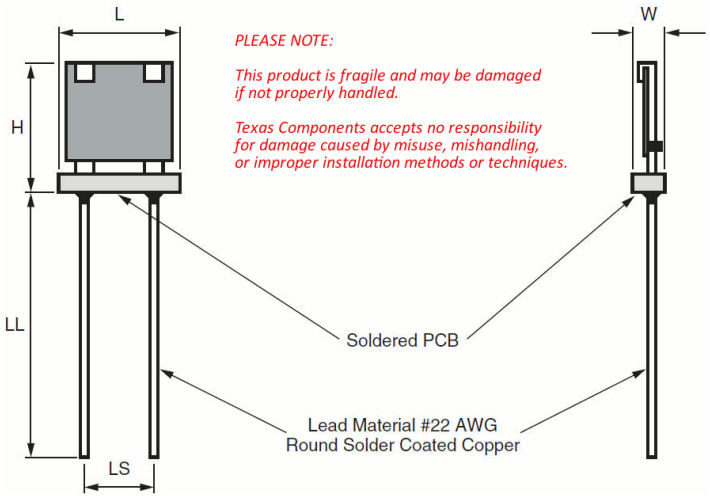

FIGURE 3 – POWER DERATING CURVE

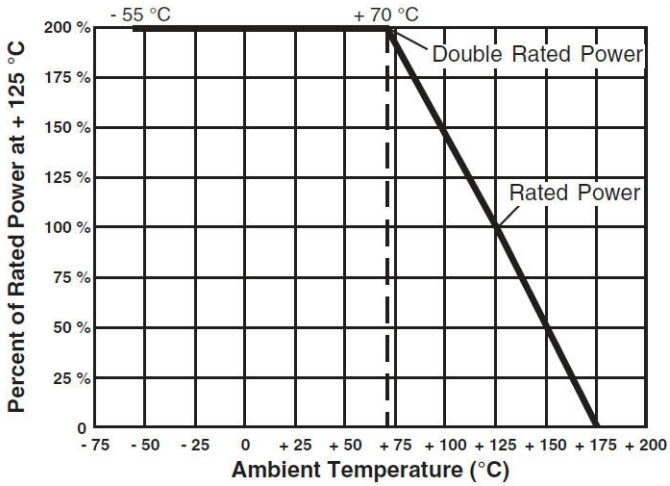

TABLE 3 - SPECIFICATIONS

RESISTANCE RANGE (Ω)	MAX WORKING VOLTAGE	AMBIENT POWER RATING			DIMENSIONS		Packaging
		Ω	at + 70 °C	at + 125 °C	inches	mm	
1Ω to 250kΩ*	200 V (rms) (300 V peak)	1Ω up to 100kΩ	0.4 W rms (0.6 W peak)	0.2 W rms (0.3 W peak)	W: 0.080 max L: 0.250 max H: 0.310 max LL: 1.000 ± 0.125 LS**: 0.150 ± 0.005	W: 2.03 max L: 6.35 max H: 7.87 max LL: 25.4 ± 3.18 LS**: 3.81 ± 0.13	All TX2352 values are provided in Bulk Pack (Code = B)
		100kΩ to 250kΩ	0.267 W rms (0.4 W peak)	0.133 W rms (0.2 W peak)			
		(If you need higher power ratings, ask about our multi-chip models TX2352-2,3,4, etc.)					

* Single chip values above 150kΩ (up to 250kΩ) are available only by special request. For values above 250kΩ, ask about our multi-chip models.
** By special order, a lead space option of 0.200" (5.08 mm) is also available.

TABLE 4 – HOW TO ORDER THE CORRECT PART NUMBER

MODEL	TERMINATIONS (FINISH)	RESISTANCE VALUE	TOLERANCE
TX2352	TIN/LEAD (Std) = Blank	1Ω to 250kΩ (R = Ω and K = kΩ) Always given as 6 characters	0.005% to 1.0%
	LEAD FREE = T		

A 20,001 ohm resistor with lead free terminations and a 0.01% tolerance would be ordered as: **TX2352 T 20K001 0.01%**

A 15.3 ohm resistor with standard terminations and a 0.5% tolerance would be ordered as: **TX2352 15R300 0.5%**

(Due to limited surface space, the TX2352 may be marked/printed as a T2352.)

[Note: The Vishay Precision Group (VPG) VAR (Vishay Audio Resistor) is a product application similar to the TX2352 that was developed and released to market by VPG based on the success of the TX2352 and, more recently, the TX2575. The VAR, made in Israel, can be obtained through Texas Components too through our distribution agreement with VPG - but the TX2352, TX2575, and other TX series audio resistors are manufactured by Texas Components at our facility in Texas and, therefore, are available with shorter lead times and with many more customized variations. Surface mount versions are also available from Texas Components.]

For more information about this subject or this product line, please contact us at resistorinfo@texascomponents.com. You can also "Follow" Texas Components and Bulk Metal® Foil Resistors on Twitter @TexasComponents and/or "Like" Texas Components on Facebook.