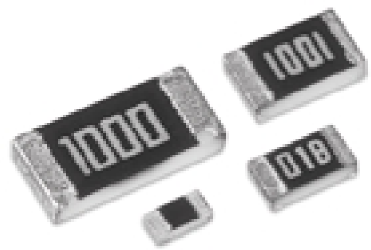
Application note

High-stability thin-film chip resistors



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High-stability thin-film chip resistors

Phycomp's new range of high-stability thin-film resistors has been introduced to meet growing market requirements for passive components with ever tighter specifications – especially in the digital and HF areas. In case sizes down to 0402, the range offers all the intrinsic benefits of thin-film technology including narrow tolerance, low, stable temperature coefficient and excellent high-frequency performance.

In contrast to the screenprinting process used for thick-film products, the new range is manufactured using an established thin-film process in which conductive films (usually of nickel-chromium) are deposited on a ceramic substrate by sputtering. This results in thin (~50 nm), highly homogeneous films, allowing the products to be manufactured with narrow tolerances down to 0.1% and with exceptionally low temperature coefficients down to 25 ppm/K (thanks to the low TCR of the NiCr films)*. This contrasts sharply with thick-film products in which the screen-printed paste (containing silver particles) limits temperature coefficient to 50 ppm/K or more.

What's more, the new range also exhibits low parasitics, low noise and superior high-frequency performance. All this makes the products attractive for a broad range of HF and digital applications, including telecommunications, EDP and digital consumer equipment, where they enable equipment manufacturers to realize the full potential of their modern circuit designs.

Compared with thick-film products, Phycomp's new thin-film resistor range also offers a much lower profile, greatly increasing the potential for miniaturization.

Thin-film chip specifications and mechanical details

Table 1 Thin-film resistor quick-reference specifications

Case sizes	1206, 0805, 0602, 0402
Resistance range*	
1206	10 Ω to 1 MΩ
0805	10 Ω to 1 MΩ
0603	10 Ω to 330 kΩ
0402	10 Ω to 100 kΩ
Tolerance	±1%, ±0.5%, ±0.25%, ±0.1%
Noise figure	Typically 0.1 µV/V (see Fig.3)
Temperature coefficient	±50 ppm/K, ±25 ppm/K (Fig.2)

* E96 series standard, E192 series on request

* Note: narrower tolerances and lower TCR values can be supplied on request

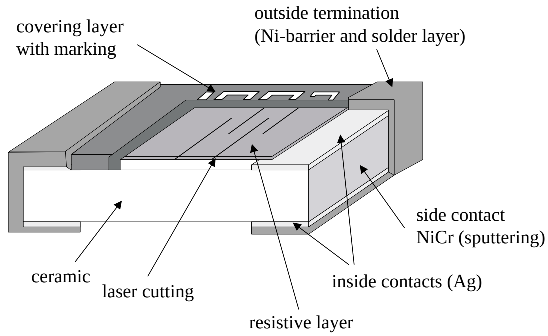


Fig.1 Thin-film chip resistors

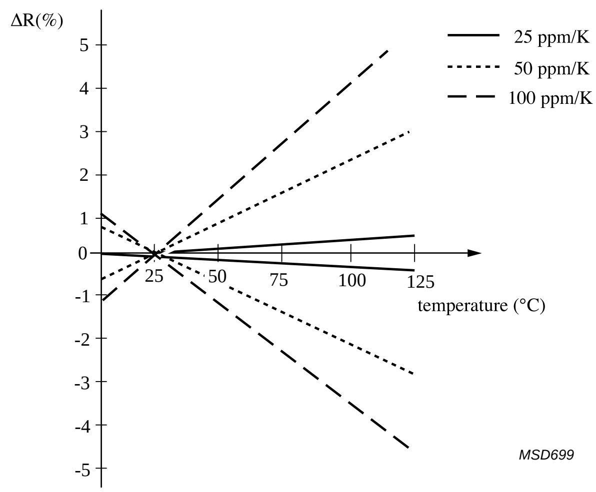


Fig.2 A typical thin-film resistor has a temperature coefficient of resistance (TCR) as low as 25 ppm/K, significantly less than the 50 ppm/K attainable in thick-film technology

Benefits of thin-film technology

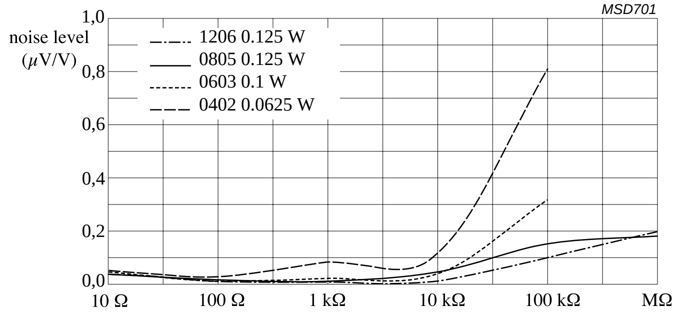
As Tables 2 and 3 show, thin-film chip resistors offer significant advantages over thick-film resistors. Figure 3 compares the noise figure as a function of resistance for thin-film and thick-film resistors. Whereas for both technologies, the noise remains relatively constant up to around 10 kΩ, the noise exhibited by the thin-film products is only around 1/50th to 1/100th that of the thick-film products. This has important consequences particularly in signal-processing circuitry.

Table 2 General comparison of thin- and thick-film technologies

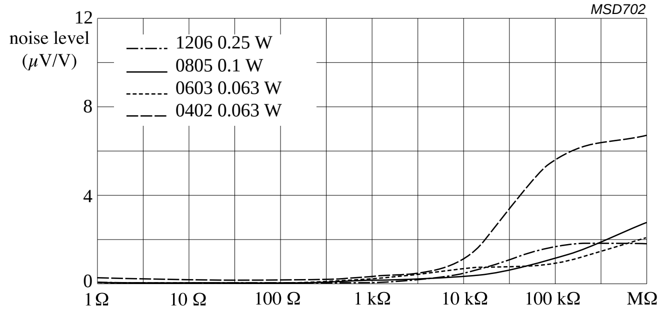
Thin-film resistors	Thick-film resistors
• Sputtering layer	• Screen printing
• Homogeneous films	• Grain containing pastes
• Low loss and highly stable materials	• Materials with standard performance
• Low parasitics	• High parasitics
• HF stable, low noise	• Parallel resonances
• Low profile	• Higher profile than thin-film
• Narrow tolerance	• Standard tolerance
• High integration potential	• Limited possibilities for integration

Table 3 Comparison of specifications and characteristics – thin- versus thick-film chips resistors

	Thin film	Thick film
Standard precision	±0.1%, ±0.5%	±1%, ±5%
Temperature coefficient	±25 ppm/K	±100 ~ 250 ppm/K
Stability	Excellent	Fair
High-frequency characteristics	Excellent	good
Current noise	Excellent (see Fig.3)	Fair
3rd harmonic stress (non-linearity)	Excellent	good
Life drift	0.1%	0.5%
Temperature drift	0.1%	0.2%
Stability after:		
-endurance 1000 hrs	±(0.5% + 0.05 Ω)	±(0.5% + 0.1 Ω)
-short-time overload	±(0.5% + 0.05 Ω)	±(0.5% + 0.05 Ω)
-rapid change of temperature	±(0.5% + 0.05 Ω)	±(0.5% + 0.05 Ω)
-damp heat	±(0.5% + 0.05 Ω)	±(1.0 + 0.05 Ω)
-thermal shock	±(0.5% + 0.05 Ω)	±(0.5% + 0.05 Ω)
Insulation resistance	10^4 MΩ	10^3 MΩ
Moisture resistance	±(0.5% + 0.05 Ω)	±(2% + 0.1 Ω)



(a)



(b)

Fig.3 Typical noise figure as a function of rated resistance (a) thin-film resistors (b) thick-film resistors

Applications

The superior characteristics of thin-film resistors make them ideal for a host of modern application demanding precision and excellent high-frequency behaviour. Applications include:

- **EDP**
  - Printers
  - Motherboards
  - Servers
  - HDD servos
  - Scanners
- **General Industrial**
  - DC-DC power converters
  - Test & measuring equipment
- **Telecom**
  - Base stations
  - Switching
  - Access systems
- **Automotive**
  - ABS
  - Airbag
  - Fuel injection
- **Consumer**
  - Audio amplifiers
  - Tuner
  - Liquid crystal display panels

Fig.4 With their superior characteristics, thin-film resistors are suitable for a host of modern applications including T&M equipment, mobile computing, airbag sensors and engine-management systems

Thin-film resistors in microprocessor supply circuits

Application notes of microprocessor manufacturers such as Intel give recommendations on how to design a PC power supply in order to prevent or limit computer crashes. Intel also advises on the use of two types of voltage regulator: *switching* and *linear*.

Most PCs have a power supply unit that converts the net voltage down to 5 V or lower for use in the system. These voltages, moreover, must meet demanding stability requirements. To meet these requirements, a voltage regulator close to the processor is recommended to prevent losses, noise and inaccuracies caused by the length of the feed line (see Fig.5).

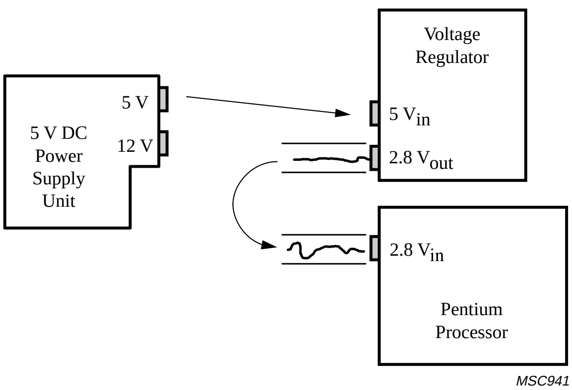


Fig.5 The voltage regulator should be as close as possible to the processor

Linear regulators are usually chosen for this application in preference to switching regulators because, although they are less efficient and dissipate more power, they react faster to changes in load, use fewer external components and are cheaper.

Both types of regulator, however, meet the stability requirements at the necessary low voltage levels provided their outputs are stabilised with precision feedback resistors. As we shall show below, Phycomp's new thin-film resistor range is ideal for this application.

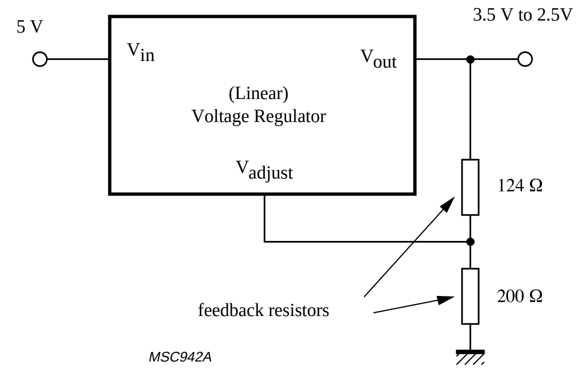


Fig.6 Typical example of a voltage regulator circuit

For the latest Pentium chips, Intel specifies a 3 V supply with maximum variation of 3%. The static power supply voltage specifications (such as line regulation, temperature drift, and the initial set point) must be held to 1% if any transients are to be permitted. The transients themselves induced by changes in environment and load can easily reach 50 mV or 1.7%. To remain within the accuracy of ±3% specified by Intel, therefore, the two feedback resistors must have a total permitted drift including tolerance of no more than ±0.3%.

Table 4 summarizes the relative performance of thin-film and thick-film resistors both as single chip and in the voltage divider circuit, and shows conclusively that the thin-film resistors are the obvious choice for this application.

Table 4 Thin-film and thick-film resistors compared in a voltage regulator for the supply of a Pentium processor

	Thin Film		Thick Film	
Specification	Single chip	In voltage divider	Single chip	In voltage divider
Tolerance	0.1%	0.2%	0.5%	1%
Life drift	0.1%	0.05%	0.5%	1%
Temp.drift (TC)	0.1%	0.05%	0.2%	0.4%
Total	**0.3%**	**0.3%**	**1.2%**	**2.4%**

The use of matching feedback resistors is also highly recommended for this application since with resistors of the same technology, ageing effects are likely to be similar and hence will not contribute to the initial set point tolerance of the voltage regulator. Although thick-film resistors from the same series offer similar behaviour, differences in drift and especially temperature coefficient between the two resistors (even from the same batch) are far greater than with thin-film resistors such as those from Phycomp's new range with their exceptionally low temperature coefficient.

Signal processing circuitry

With their low noise, Phycomp's thin-film resistor range is also ideal for use in operational amplifier feedback networks used, for example, in signal-processing circuitry.

A typical amplifier/signal-processing circuit provides a load-independent output voltage, protecting the integrity of the input signal. Low noise is a prime requirement of the operational amplifier since this determines the quality of the output voltage V_{out} (Fig.7).

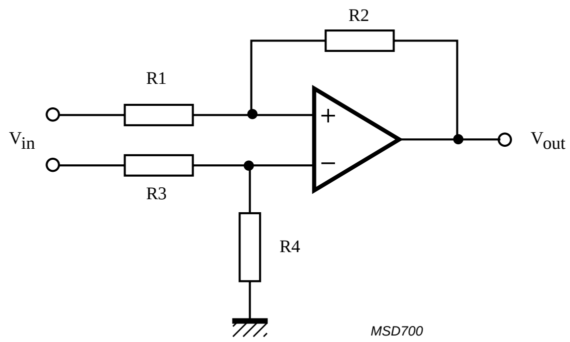


Fig.7 Operational amplifier feedback network

The noise generated at the output is determined not only by the quality of the opamp itself, but also by the surrounding resistors. The noise figure of a typical thin-film resistor is around only 1/100th of that exhibited by a thick-film resistor (Fig.3) and this has important consequences on the opamp output signal. With a typical input voltage of say 2 V, and a noise figure of around say 10 µV/V for a thick-film resistor, the noise at the opamp output will be 2 mV. Contrast that with a similar circuit using thin-film resistors. Here with the same input voltage, a typical noise figure of around 0.1 µV/V will generate a noise at the output of no more than 0.02 mV.

Application overview

Table 5 Application matrix highlighting the benefits of Phycomp's thin-film resistors

Application area	Application detail	High stability over time	Low TCR	Low noise	High pulse load	Narrow tolerance
EDP	• voltage regulation in power supply	x	x			x
General Industrial	• DC-DC power conversion	x	x			x
	• test & measuring	x	x	x	x	x
Telecom	• base stations	x		x	x	
	• switching	x			x	
	• power supply	x	x		x	x
Automotive	• airbag, ABS	x	x		x	x
Consumer	• audio	x	x	x		x
	• displays		x	x	x	
	• amplifier	x	x	x		x
	• power supply	x	x		x	x

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