

Will you invest extra power part #2

Concept Overview

In this second installment of our series on power investment in cooling technologies, I want to dive into the fascinating world of the thermoelectric effect and how it's harnessed for cooling applications. This phenomenon, discovered nearly two centuries ago by Thomas Johann Seebeck and Jean Charles Athanase Peltier, enables direct energy conversion between heat and electricity. The thermoelectric effect can be exploited both ways: to generate electricity from a temperature difference or to create a temperature difference by applying electrical power.

For cooling, think of it as investing electrical energy to pull heat away from a source, effectively creating a cold side and a hot side. But as any engineer who's played with thermoelectric coolers (TECs) knows, the devil is in the details — especially when it comes to power consumption and heat dissipation.



Figure 1: Illustration of the Seebeck and Peltier effects, foundational phenomena behind thermoelectric devices.

Thought Process

Let's cut to the chase and examine two typical TEC devices to understand their performance trade-offs. The first, TEC-30-40-127, is rated at an ambient temperature of 27°C to handle a maximum heat load of 33.4 W (Q_{max}) with a maximum temperature difference (ΔT) of 68°C. At a higher ambient of 50°C, it can handle 39 W with a ΔT of 75°C. It has a self-resistance around 3.2–3.6 Ω .

However, these extreme ratings don't align perfectly on the performance graphs, which is typical for TECs. The higher the ΔT you want to achieve, the more current you have to push through the device. For example, at 25°C ambient temperature, to maintain a ΔT of 15°C and cool a 28 W heat source, the TEC demands about 4.2 A at 13.5 VDC — that's an electrical power investment of roughly 56.7 W!

Remember from Part #1 that the hot side heatsink must dissipate not only the 28 W from the heat source but also the

extra 56.7 W of electrical power converted into heat. That sums up to 84.7 W, which is a significant thermal management challenge requiring a heatsink with low thermal resistance to maintain system stability.

Hot Side Temperature(°C)	27 °C	50 °C
Qmax (Watts)	33.4	39
Delta Tmax(°C)	68	75
I _{max} (Amps)	4.0	4.0
V _{max} (Volts)	15.4	16.4
Module Resistance(Ohms)	3.22	3.63

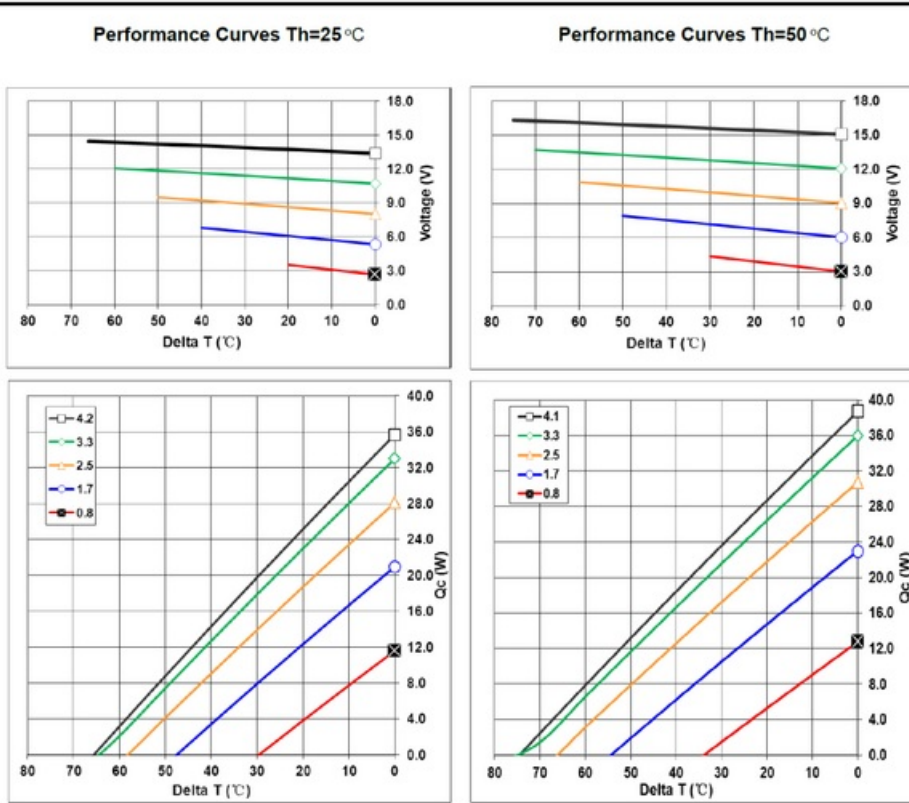


Figure 2: TEC-30-40-127 thermoelectric cooler with performance specs illustrating power and temperature delta trade-offs.

Now, consider the second device, TEC-30-33-71. It's rated for a slightly higher maximum heat load — 38 W at 27°C ambient with a ΔT of 68°C, and 46 W at 50°C ambient with a ΔT of 75°C. Its self-resistance is much lower, around 0.86–0.96 Ω .

At 25°C ambient, for the same 15°C ΔT and 28 W heat source, it requires a higher current of 6.9 A but at a much lower voltage of 4 VDC. This means the electrical power consumed is about 27.6 W — less than half the power investment compared to the first TEC.

Consequently, the hot side heatsink must handle 28 W plus 27.6 W, totaling 55.6 W, which is more manageable but still a considerable thermal load to evacuate.

Hot Side Temperature(°C)	27 °C	50 °C
Qmax (Watts)	38.5	46
Delta Tmax(°C)	68	75
I _{max} (Amps)	8.5	8.5
V _{max} (Volts)	8.6	9.6
ModuleResistance(Ohms)	0.86	0.97

**Tolerances for thermal and electrical parameters ± 10%.

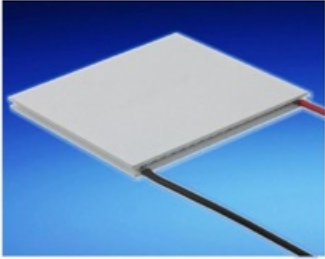
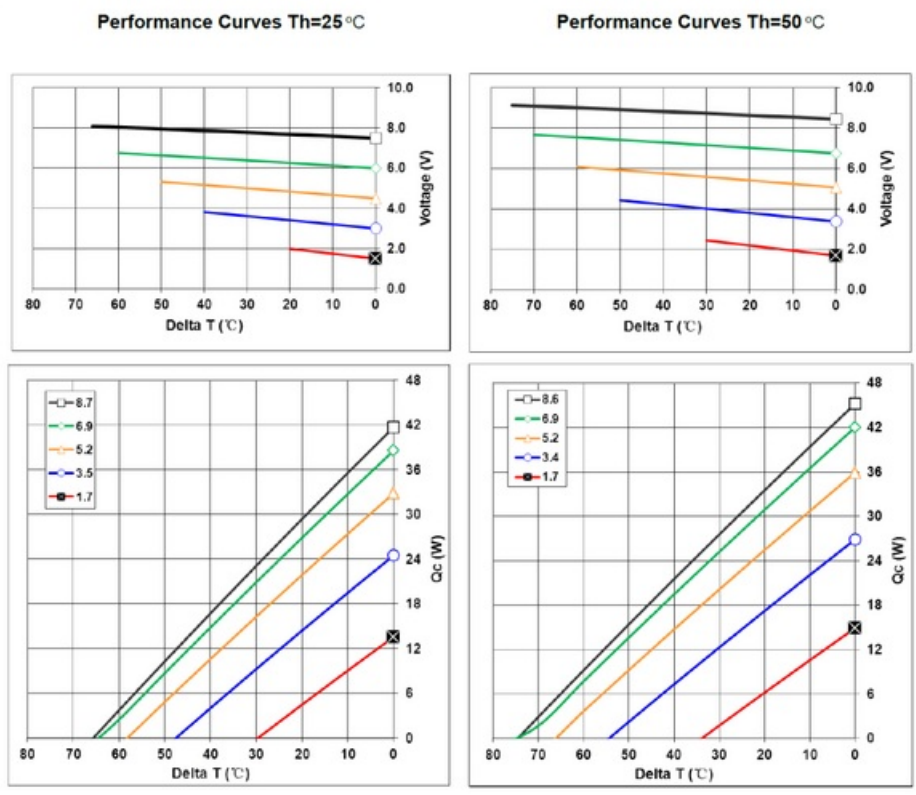



Figure 3: TEC-30-33-71 thermoelectric cooler with specifications showing improved electrical power efficiency.

What’s clear from this comparison is that cooling with TECs often requires more than double the electrical power of the heat being removed. This “extra power” is the price paid to create the temperature gradient. It’s a classic engineering trade-off: you gain solid-state cooling with no moving parts, the ability to reach below ambient temperature, and potentially very stable temperature control — but you pay in electrical power and heat dissipation complexity.

Potential Applications

Despite the seemingly inefficient power usage, TECs have carved out important niches. Their lack of moving parts means high reliability and silent operation — ideal for sensitive electronics, scientific instruments, and even consumer products where vibration or noise is a concern. The ability to cool below ambient temperature without compressors or refrigerants is a big plus in compact or environmentally sensitive designs.

Typical applications include laser diode cooling, CCD sensors in cameras, portable coolers, and thermal management in aerospace or defense electronics. At TrigoPi, we’ve seen firsthand how these coolers enable designs that would be impossible with conventional refrigeration methods. It’s the kind of challenge that keeps our engineers awake at night—in a good way.

Challenges & Next Steps

The main challenge with TECs remains their power inefficiency and the thermal management burden on the hot side. The hot side heatsink must be carefully designed to handle the combined heat load of the source plus the electrical power converted to heat. This often means bigger, heavier heatsinks or active cooling on the hot side, which can offset the simplicity gained on the cold side.

In Part #3 of this series, we'll explore which applications can truly benefit from these "inefficient" coolers — where their unique advantages outweigh the power trade-offs. We'll also discuss strategies to optimize system design and how to balance power consumption, heat dissipation, and cooling performance effectively.

Key Insights

- Cooling with thermoelectric coolers sometimes requires more than twice the electrical power of the heat being removed.
- The hot side heatsink must handle both the heat from the source and the additional heat generated by the TEC's power consumption.
- TECs offer unique advantages: no moving parts, silent operation, ability to cool below ambient temperature, and stable temperature control.
- Careful system design is essential to manage the thermal load and optimize efficiency.

At TrigoPi, we love testing the edges of thermal management technologies like TECs. It's a fascinating blend of physics, materials science, and practical engineering — and it's where innovation often happens.

Stay tuned for Part #3, where we'll dive deeper into real-world applications and design strategies for thermoelectric cooling.

For more information, call us at info@trigopi.com or visit www.trigopi.com.