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Development of TEC System for Commercial Cooling Applications

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Abstract

This paper represents the possibility of using the TEC-Thermo Electric Coolers in cooling applications. Such application with small area away connected is possible with the use solar energy as power source. Factors affecting the performance of TE will discussed also. The effect of Heat Sink Extender (HSE) for TEC assembling will be considered. TEC performance is tested for different modules. The assembling for best performance of TEC and the supply requirements using PV as a power source is presented for potential commercialization.

Keywords: TEC, Cooling, TE performance, Heat Sink Extender, Photovoltaic

1. Introduction

A thermoelectric (TE) cooler, is a semiconductor-based electronic component that functions as a small heat pump. By applying a low-voltage DC power source to a TE module, heat will be moved through the module from one side to the other. One module face will be cooled while the opposite face simultaneously is heated. Thermoelectric modules as shown in Figure 1 are solid-state heat pumps that operate on the Peltier effect.

The widely availability of Thermoelectric cooling (TEC) modules, making them a potential equipments to be apply for the thermal run away in electronics circuits. The TEC modules, which have a maximum rated operating temperature of 200 °C makes thermoelectric cooling a possible option in the thermal management of high temperature electronic packaging.

1.1 Advantages of a thermoelectric unit over a compressor

Thermoelectric modules have no moving parts and do not require the use of chlorofluorocarbons. Therefore they are inherently reliable and are virtually maintenance free. They can be operated in any orientation and are ideal for cooling devices that may be sensitive to mechanical vibration. Their compact size also makes them ideal for applications that are size or weight limited where even the smallest compressor would have excess capacity. Their ability to heat and cool lends them to applications where both heating and cooling is necessary or where precise temperature control is critical.

1.2 TEC Operation

Electrons can travel freely in the copper conductors but not so freely in the semiconductor. As the electrons leave the copper and enter the hot-side of the p-type, they must fill a "hole" in order to move through the p-type. When the electrons fill a hole, they drop down to a lower energy level and release heat in the process. Essentially the holes in the p-type are moving from the cold side to the hot side. Then, as the electrons move from the p-type into the copper conductor on the cold side, the electrons are bumped back to a higher energy level and absorb heat in the process. Next, the electrons move freely through the copper until they reach the cold side of the n-type semiconductor. The electrons bump up an energy level when they move into the n-type in order to move through the semiconductor then heat is absorbed, then the electrons leave the hot-side of the n-type and move freely in the copper and drop down to a lower energy level and release heat in the process.

1.3 TEC reliability

Thermoelectric systems are highly reliable provided they are installed and used in an appropriate manner. The specific reliability of thermoelectric coolers tends to be difficult to define because failure rates are highly dependent upon the particular application. Thermoelectric modules that are at steady state (constant power, heat load, temperature, etc.) can have mean time between failures (MTBFs) in excess of 200,000 hours.

1.4 Cool by nature

Environmental friendly cooling could be obtained by the use of TEC because there is no chlorofluorocarbons (CFCs) and also no need for refills. Once the thermoelectric cooling is implemented then there will be no worries that the cooling system has a negative impact on the environment as compared to the traditional cooling system.

1.5 TEC Installation

The two wires attached at the side of TEC is known as hot side if the red/black wire is connected to positive voltage/ground respectively. Usually, the red wire is positive and the black wire is ground. The hot side and cold side of TEC can be swapped if the red/black wire polarity is swapped.

2. TEC Cooling Design

2.1 TEC Proper *fit consideration*

The proper fit between the heat side of TEC and the heat sink affect the performance of TEC, good thermal conduction will lead to better performance, although good thermal isolation between heat and cold side will give better performance. Figure 2 shows a single TEC module with the heat side attached to a heat sink and the cool side is free to air. Figure 3 shows the temperature measured direct form TEC cold side. This shows two states of measurements ie. the data measured good thermal conduction of heat sink and hot side of TEC and the other one with bad thermal conduction. The proper fit of TEC will improve its performance, especially when heat sink compound is added.

2.2 Thermal isolation

Selecting a proper heat sink is very important when a thermoelectric cooling system is designed. Usually, temperature of a heat sink rises 10ºC above the ambient temperature after TEC is applied with a proper voltage and the cold side of TEC is without any heat load. The different TEC has a different operating voltage. Heat pump power is proportional to voltage power. The bigger the heat sink on hot side of TEC the better the performance of TEC.

For the best performance to be achieved for the TEC module, a good thermal isolation between hot and cold side is important since the distance between the two sides is so critical. To overcome such problem the extension of heat sink could be used for several purposes. One is to increase the distance from the heat sink plate to the cold sink plate. This allows for thicker insulation and longer assembly bolts. As a result, heat conducting from the heat sink plate back to the cold sink plate is reduced. Another purpose involves temperature control. In certain control schemes, the TE system operates until a thermostat trips off.

With a Heat Sink Extender in use, there will be a larger thermal resistance exist between the heated and cold sink. As a result, the cold space does not heat back up as quickly as compared with a systems that do not employ HSEs. Figure 4 shows the TEC module attached to a heat sink with extender. Probably the most important use of an extender is when the extender serves as a thermal junction. In many applications, a TE system is used to cool an insulated box. The cold sink and heat sink are separated by the thickness of the box's insulation. The extender, therefore, is used to thermally join the TE module to either the cold sink or the heat sink.

Table 1 shows the data taken using single module with HSE. A comparison with the above test without HSE shows that the temperature at cold side it higher; i.e. less cool but still convenient. On the other hand less heat at the hot side of the TEC module that attached to HSE. As shown in Table 1 the temperature at cold side is higher compared to without HSE. But the temperature at the cooled side also is lower referring to tests without HSE.

3. Cooling Applications

The precious section shows that the effect of good heat isolation is quite sensitive to the TEC performance. The small size and simplicity make TE the best choice to be applied for cooling application. One of the main application that can be considered is the cooling of away connected electronics, such as in the telecommunication cabinets. This cooling arrangement can be easily supplied from a PV panel with a DC-DC converter. The input power to the DC-DC converter will be supplied from an input solar panel of 72W power rating. The use of PV as a power source for the converter make it reliable for outdoor cooling applications.

Figure 5 shows a developed prototype for TEC cooling. This prototype uses 4 TECs of 15x15x3 mm size that attached to the four sides of the cooling box. This prototype is tested using the developed converter and draw a current of 2 to 5 amps. And the measured outlet temperature is 17 to 15 °C referring to ambient temperature of around 23 to 21 °C.

Figure 6 shows the TEC modules attached to heat sink (30x17x4 cm), then the spaces have to be filled by Teflon thin sheets. The cold side of TEC modules are attached to an aluminum sheet. Then the sheet is attached to testing a cabinet. The experiment is conducted to test the TEC function as shown in Figure 7. The TEC was connected in parallel combination and it's required about 12A current , which provided by a DC converter.

A sample of solar fridge prototype unit is developed using four TEC as shown in Figure 8. The prototype with a 12 in x 8 in x 6 dimension capable to function in both cooling and heating operation. The unit takes about 30 minutes to reach

the minimum temperature of 18 °C within the compartment. This invention uses sunlight which is captured by an array of solar panel of 70W. The coling is being preseved by a quality insulation, thus food and drinks cooled quickly even at high outside temperature.

The operation is controlled manually by switch which is located at the back of the unit.

Conclusion

The TEC cooling technique is found to be free of some problems attached to traditional cooling techniques such as noise, size and vibration. In addition it has no side effect on the environment with zero emission of CO_2 gas. The paper had discussed the use of the TEC-Thermo Electric Coolers in the off-grid mode where solar energy is used as power source. The TE performance found to be affected by many factors such as the usage of HSE and TEC proper fit assembling. The prototype TEC fridge has the potential for commercialization.

References

C. Lertsatitthanakorn (2003), Cooling Performance of Thermoelectric Water Cooler, *Naresuan University Journal*: 11(2), pp: 1-9.

Jianzhong, Z., Tiemin, W., Xueming, L., Guanghui, T. (1998), Application of the thermoelectric cooler in the seventeenth Chinese retrievable satellite, Proceedings of the 5th International Conference on Solid-State and Integrated Circuit Technology, pp: 865 - 868.

MAGALAND TECHNOLOGY, INC., (2007). Thermoelectric Cooling Modules Application Note. Available: www.magaland.com (August, 2007).

Moores, K.A., Joshi, Y.K., Miller, G.. (1999). Performance assessment of thermoelectric coolers for use in high temperature electronics applications, Eighteenth International Conference on Thermoelectrics, pp:31 – 34.

Optimizing TEC Drive Current Application Note (2006). Available: www.ilxlightwave.com.

Optimizing TEC Drive Current Application Note (2006). Available: www.ilxlightwave.com.

Paul G. Lau, Todd M. Ritzer and Richard J. Buist, (2005). Thermodynamic Optimization of Heat/Cold Sink Extenders in Thermoelectric Cooling Assemblies. TE Technology, Inc., Michigan 49686 USA.

Supercool AB (2005). Available: www.supercool.com.

Supercool AB. (2007). Available: www.supercool.com (Nov., 2007).

TE Technology Inc, (2007). Available: www.tetech.com/techinfo (June, 2007).

Thermoelectric Handbook (2006). Available: www.melcor.com (May, 2006).

Table 1. TEC with HSE

Amps	Cold side	Hot side (HSE)
0	23	23
0.5	20	24
1	18	25
1.5	15	25
2	12	26
2.5	6	27
3	1	28
3.5	-3	30

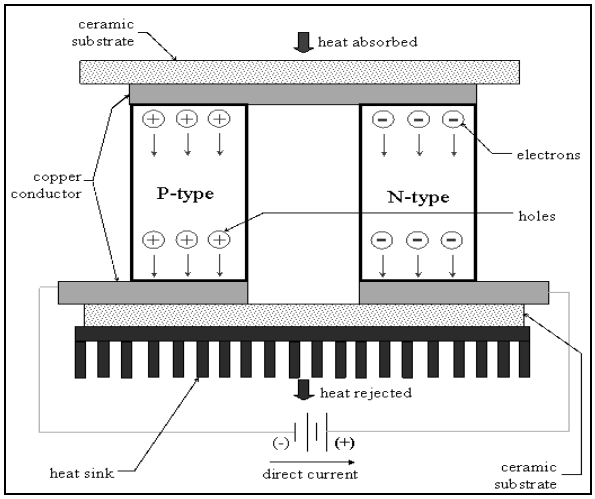

Figure 1. TEC Module

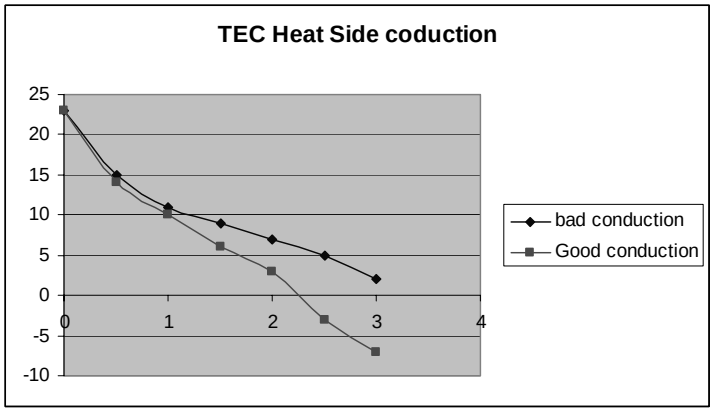

Figure 2. TEC direct measured temperature at cold side

Figure 3. TEC module with the heat sink

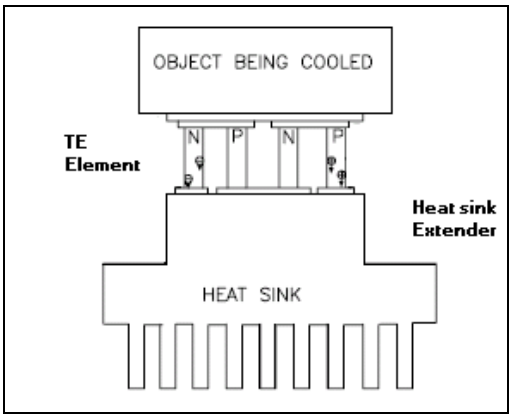

Figure 4. Heat sink with extender

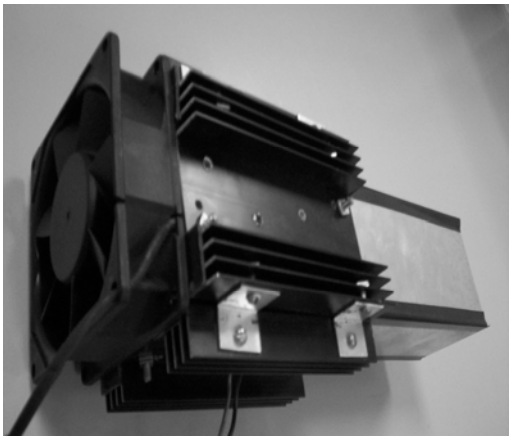

Figure 5. A developed TEC cooling prototype

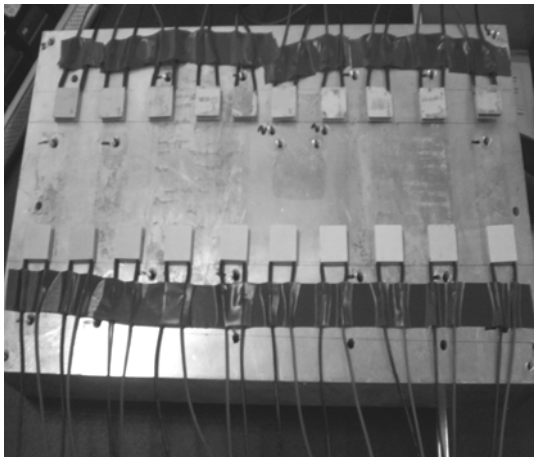

Figure 6. TEC modules attached to heat sink

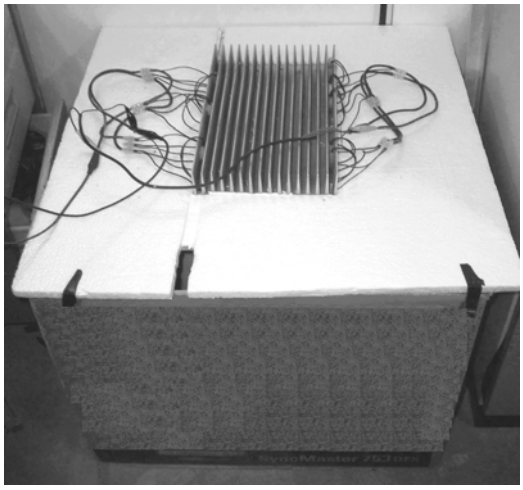

Figure 7. TEC modules attached to test cabinet

Figure 8. Mini solar and heater