Figure 1. Top View of TEC18V10AD

Figure 2. Bottom View of TEC18V10AD

FEATURES

- **The World's First TEC Controller Module Features Auto PID Compensation Network**
- **Power Supply Voltage: 5.5V ~ 18V**
- **Max. Driving Current: ±10A@VPS = 5.5V ~ 18V**
- **Rail-to-Rail Output Voltage: 0 ~ ±VPS**
- **High Efficiency: > 90%**
  @VPS = 18V & VTEC = 9V & ITEC = 10A
- **High Temperature Stability: <±0.001°C**
- **Thermal Pads underneath for Better Heat Sinking**
- **Programmable Output Current and Voltage Limits**
- **PWM Smoothed Continuous Output Current**
- **Accept Multiple Types of Temperature Sensors: thermistor, RTD, and temperature sensor IC**
- **High Reliability and Zero EMI**
- **Compact Size: 1.42 × 1.42 × 0.32 (inch)**
  36 × 36 × 8.2 (mm)
- **100 % lead (Pb)-free and RoHS compliant**

APPLICATIONS

Controlling high power TEC modules to achieve high temperature stability at high efficiency.

DESCRIPTION

A Thermo-Electric Cooler (TEC) is a solid-state semiconductor device capable of cooling or heating a thermal load. By adjusting the magnitude and polarity of the electrical current flowing through the TEC, the device can either absorb heat from the load (cooling) or deliver heat to it (heating).

Our TEC controller is designed to accomplish this task by supplying a precisely regulated current to the TEC, ensuring stable, accurate, and responsive temperature control of the target thermal load.

The TEC18V10AD controller is specifically designed to manage the operation of a TEC, maintaining the target object's temperature within a precise range around a set value. This high level of temperature control is achieved by adjusting both the direction and magnitude of the current supplied to the TEC. The controller operates with a DC input voltage between 5.5V and 18V, and is capable of delivering up to 10A of current without requiring an additional heat sink. Figure 1 shows the TEC18V10A controller.

It's easy to use this controller. Figure 3 is a simplified schematic for using this TEC controller. it is consisted of a power supply, a temperature setting potentiometer, TEC assembliy, a few passive components if using external compensation network, and the controller. Figure 4 shows the procedure for using the controller.

INTERFACING WITH DIGITAL PERIFERALS

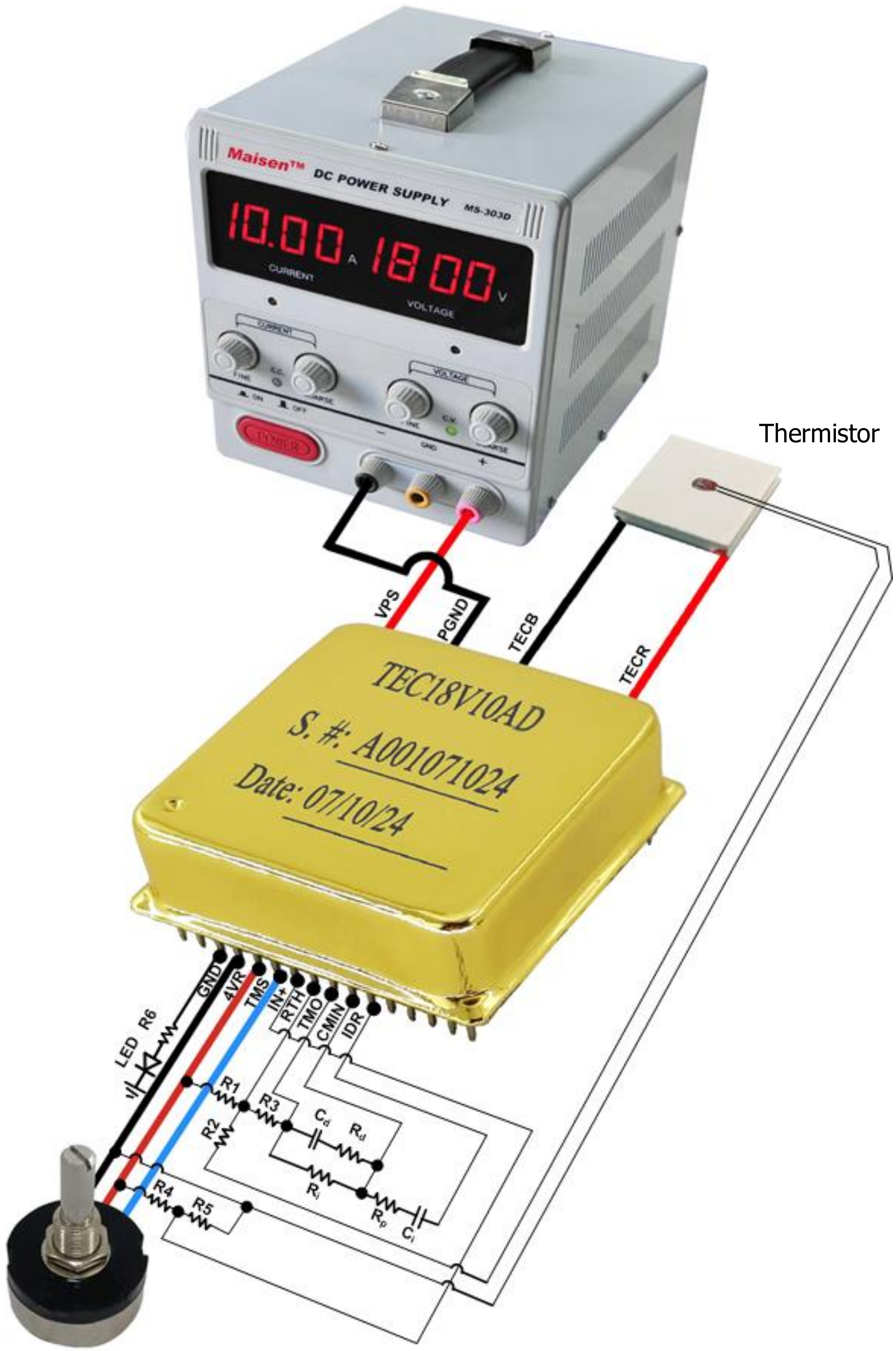


Figure 3. A 3-D Schematic Drawing for Using TEC18V10AD TEC Controller

OPERATION STEPS

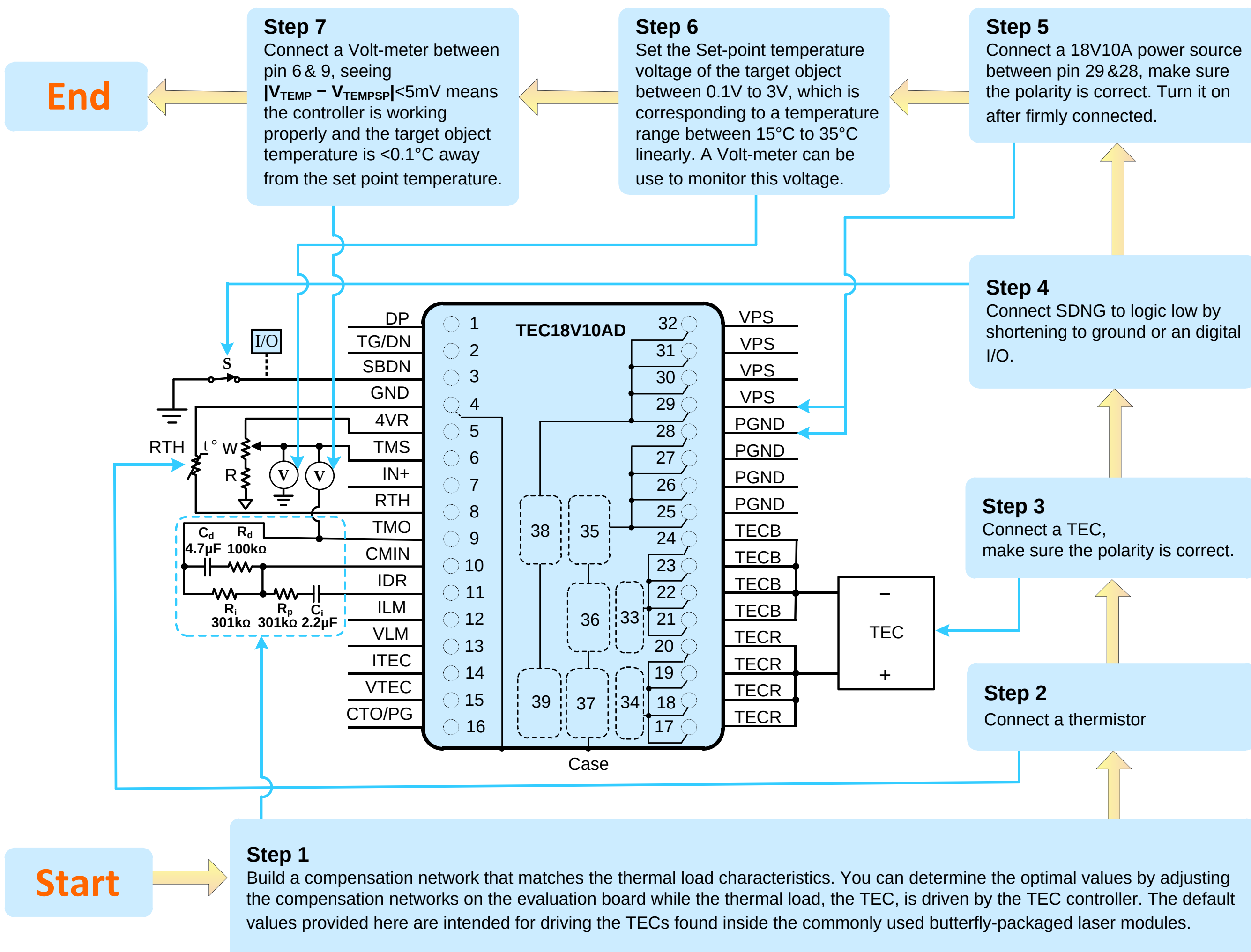


Figure 4. Operation Steps

BLOCK DIAGRAM

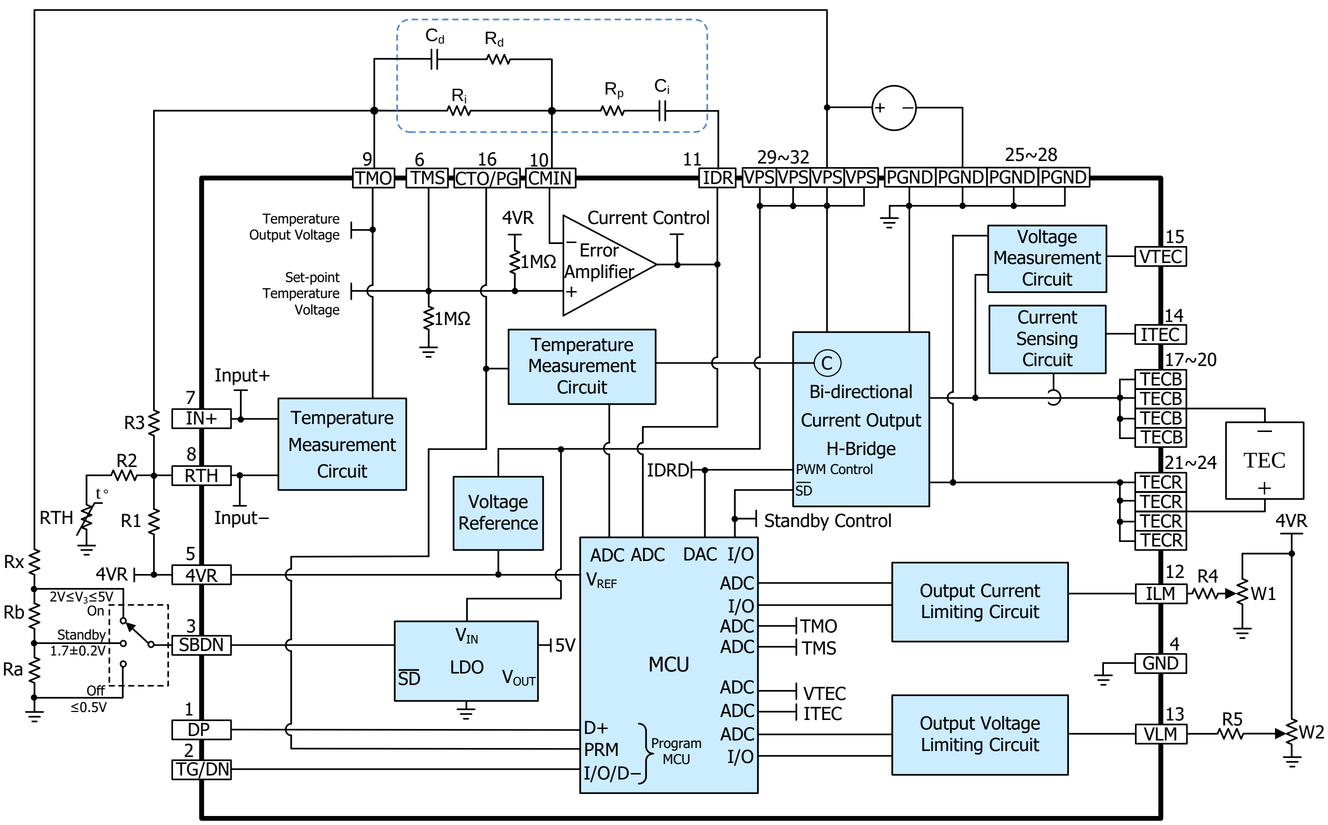


Figure 5. Block Diagram

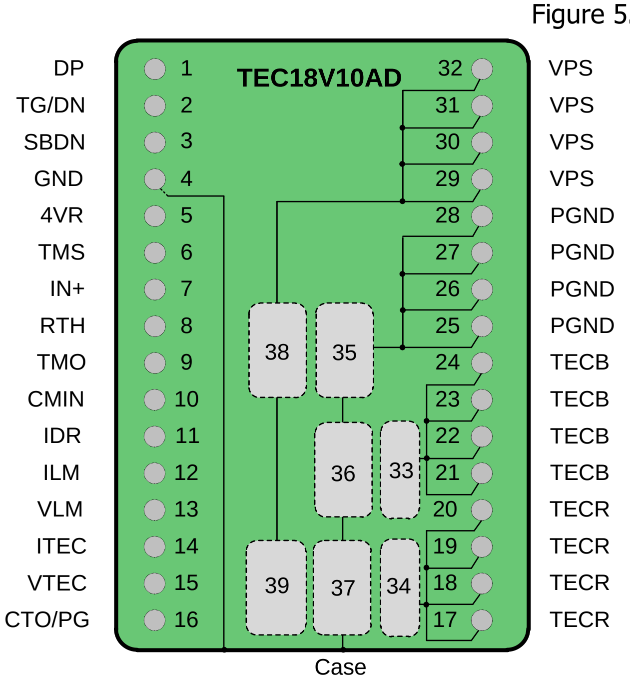


Figure 6. Pin Names and Locations

Figure 5 is its block diagram. The essentral part of the controller is consisted by 3 control loops: thermal loop, current loop, and voltage loop respectively. Before reaching or hitting the limits, the TEC is constrolled by the temperature loop in which the actual target object's temperature follows a pre-set or time variing value representing the set-point temperaturee. The TEC controller TEC18V10AD allows setting the set-point temperature for the target object, maximum output currents and voltages for cooling and heating separately. These three settings are the input parameters for the three control loops: constant temperature, constant current, and constant voltage. Before hitting the output voltage or the output current limit, the temperature loop is in control. When hitting the voltage or current limit, the controller will be outputting a constant voltage or current to the TEC respectively and override the constant temperature loop. In addition to the pre-set limit value, the maximum output voltage magnitude is also limited by the power supply voltage and the maximum

Figure 6 shows the pin names of the controller, allowable output current magnitude is 10A.

This controller can accommodate the commonly used 3 types of temperature sensors for sensing the target object's temperature: thermistor, RTD or temperature sensor IC, within them the thermistor is the mostly used type due to its high sensitivity, small size, and low cost. When using a thermistor, the set-point temperature range is determined by an external temperature network formed by 3 resistors.

One advanced feature of this TEC controller is that it comes with a smart auto PID controller implented by a micro-processor which senses and compensates for the thermal load characteristics automatically at real time, without needing external components to form a compensation network, nor requiring to fine tune the network with load tediously. The TEC controller with auto PID has a part number: TEC18V10ADAPID for the DIP package.

Conservative users can still choose using the conventional analog compensation network. The same as in the past, it requires a one-time pre-tuning the network to match the thermal load, but provides reliable and high accuracy control. For fixed thermal load applications, conventional analog compensation might be a good choice, while for applications with variable or numerous types of thermal loads, the automatic PID control is more suitable.

Figure 6 is the top view of the controller, showing the pin names and the locations. There are a total of 32 pins in 2mm pitch. All the pins on the left are for either control input or indication output signals; all the right pins are power input or output.

The pin function details are given in Table 2.

At the thermistor input, there is a linearization circuit for the thermistor, to make the temperature output voltage be more linearly proportional to the actual thermistor temperature. There is a voltage inverter circuit, and it makes the temperature output voltage be positively proportional to the temperature, since the thermistor has a negative temperature coefficient. These 2 circuits together are called temperature measurement circuit. See Figure 4.

The set-point temperature voltage and the voltage representing the actual temperature are sent to an error amplifier. There is a compensation network inserted in the loop, to stop the oscillation of the controller caused by phase delay effects of the thermal load. Therefore, the compensation network must match the need for driving a particular thermal load. To simplify the tuning, a tunable compensation network is provided by the evaluation board for this TEC controller. A detailed guidance about how to tune the compensation network with a thermal load is given in the evaluation board application note.

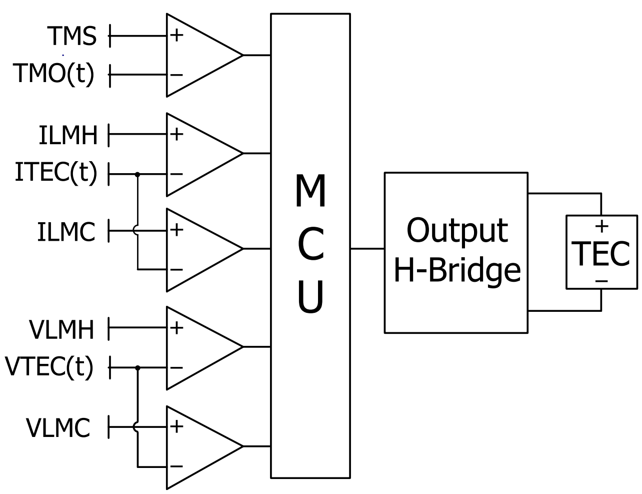


Figure 7. Key Control Loops of TEC18V10A

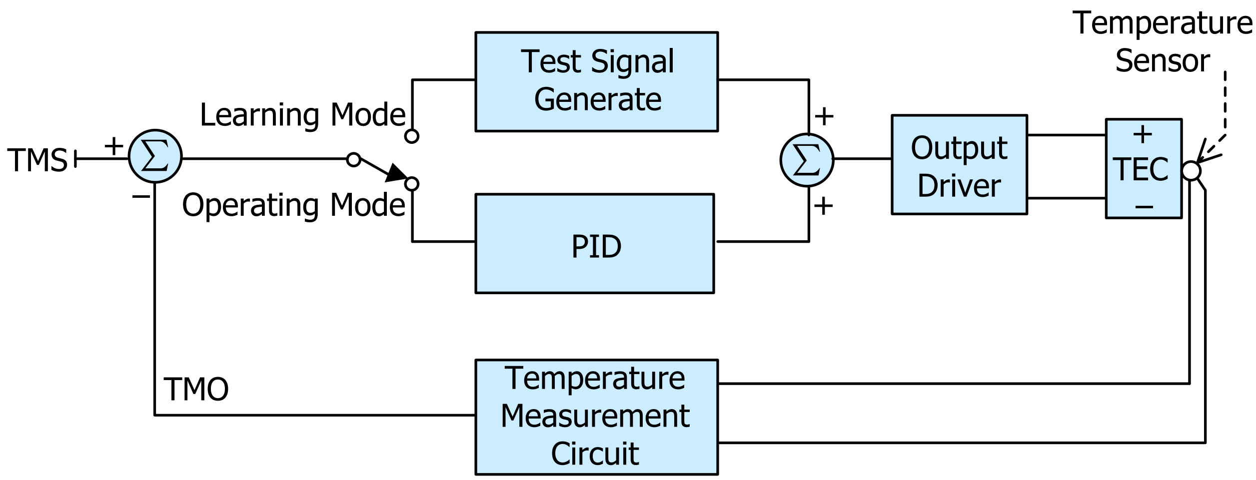


Figure 8. Auto PID Block Diagram

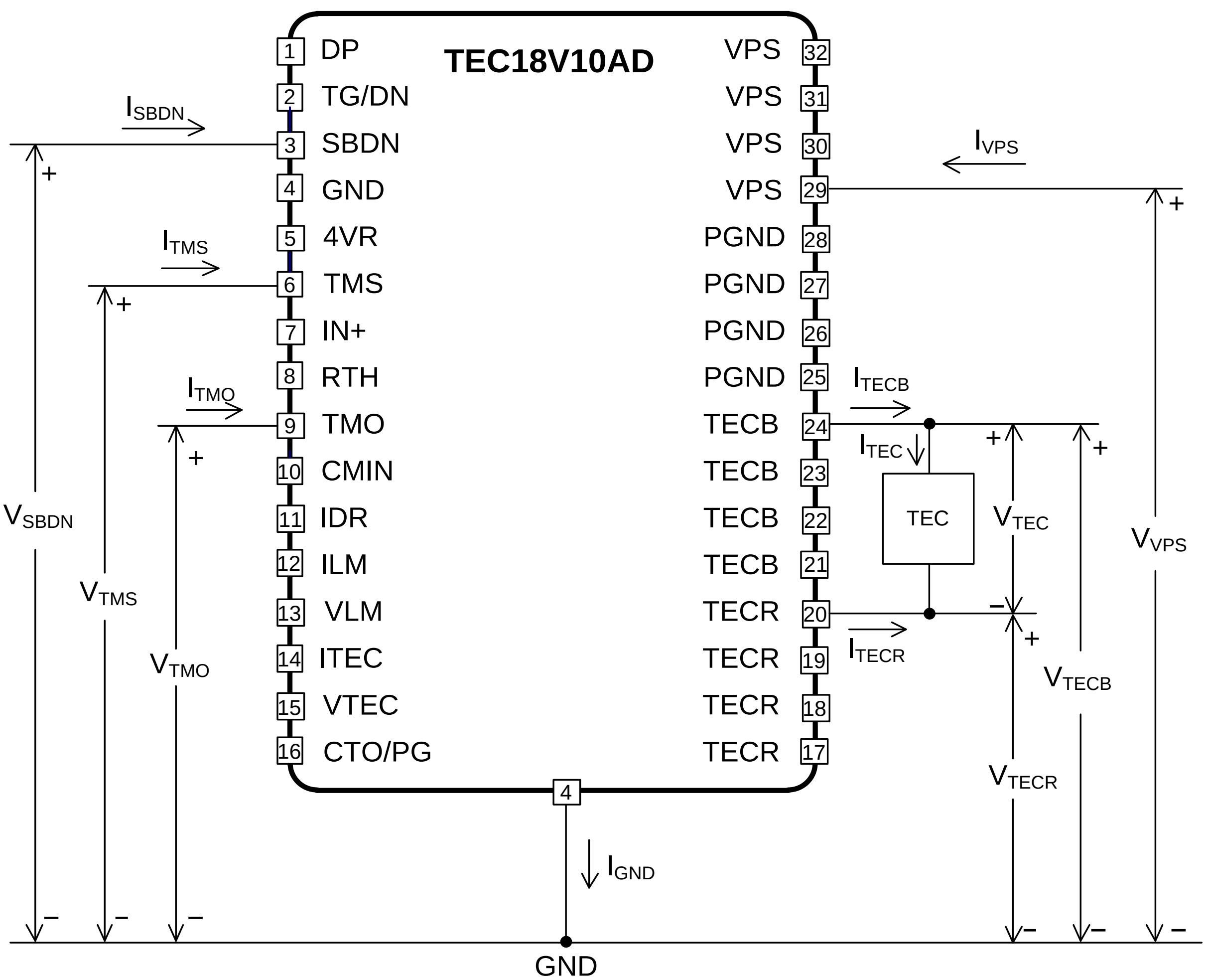


Figure 9. Parameter Variable Conventions

SPECIFICATIONS

Table 1. Pin Function Descriptions

Pin #	Name	Note	Description
1*	**DP**	Digital output	DP is the positive differential signal line used for data transmission in a USB interface. During data transmission, the signal on the DP line is complementary to that on the DN line, enabling efficient and reliable high-speed data communication through differential signaling.
2	**TG**	Digital output	Temperature good indication. Logic high indicates when actual target object temperature is within ±0.001°C away from the set-point temperature.
	DN	Digital output	DN is the negative differential signal line used for data transmission in a USB interface. During data transmission, the signal on the DN line is complementary to the signal on the DP line, enabling reliable data communication through differential signaling.
3	**SBDN**	Analog /Digital input	It sets the controller to be on Operation, Standby or shut down mode. This SBDN pin high input impedance. See page 15 for details.
4	**GND**	Ground	Signal ground. Connect this pin to the signal ground of ADCs, DACs, and the signal sources. It can also be used as analog output pin ground.
5	**4VR**	Analog output	Reference voltage output, 4.096V. It can be used as the voltage reference by the potentiometers or DACs for setting the analog ports, such as TMS, ILM, VLM, etc. It can also be used by ADCs for sensing the analog output ports: TMO, CTMO, ITEC and VTEC. The initial accuracy is 0.1%, and the temperature coefficient is <50ppm/°C max.
6	**TMS**	Analog input	Analog Input port for setting the set-point temperature for the target object. It is internally tied a 1MΩ resistor to the half value of the reference voltage, 2V. The open circuit voltage of this pin is thus 2V, corresponding to a set-point temperature of 25°C by using the default temperature network (with the set-point temperature range being from 15°C to 35°C). It is highly recommended to set this pin's voltage by using the controller's 4V voltage reference. This pin can be set by using a POT or DAC. When the set-point temperature needs to be at 25°C, leave this pin unconnected but by-passed by a 1μF capacitor to the ground. Note: The absolute max. voltage range of TMS pin is 0V ~ 4V. It's recommended to set the voltage between 0.2V ~ 3.8V, to prevent entering the saturation region.
7	**IN+**	Analog input	Receive external temperature signal (thermistor and temperature sensor, etc.)
8	**RTH**	Analog input	Thermistor connection port. Connect to the thermistor which is mounted on the target object for sensing its temperature. By using the default internal temperature network, a 10kΩ @ 25°C thermistor can be used. Other type of thermistors or temperature sensors can also be used, see the application section for details.
9	**TMO**	Analog output	Actual target object temperature indication. It swings from 0V to 4V. By using a default internal temperature network, it represents 15°C to 35°C when this pin's voltage swings 0.1V to 3.9V linearly, provided a standard 10kΩ thermistor is used as the temperature sensor device.
10	**CMIN**	Analog input	Compensation input pin for the thermal control loop.

Pin #	Name	Note	Description
11	**IDR**	Analog input and output	This voltage is derived from the temperature error detection circuit and used as the input control signal of the current loop for the TEC. Its internal impedance is 10kΩ and can be over-driven by an external analog signal which is able to over-ride the 10kΩ resistor. The voltage range is from 0V to 4V, corresponding to –10A to +10A output current. Setting this pin voltage to 2V forces the output current to zero.
12	**ILM**	Analog input	This pin sets the TEC Current Limit. The maximum limit current is 10A. Setting this pin's voltage from 0V to 4V corresponds to setting the current magnitude limit from 0A to 10A.
13	**VLM**	Analog input	This pin sets the TEC voltage Limit. The maximum limit voltage is 30V. Setting this pin's voltage from 0V to 4V corresponds to the TEC voltage magnitude limit being from 0 to 30V: $V_{VLM} = \frac{\lvert V_{TEC+} - V_{TEC-} \rvert_{MAX}}{7.5}$
14	**ITEC**	Analog output	TEC current indication. ITEC is an analog voltage output pin with a voltage proportional to the actual current through the TEC. ITEC's center voltage is 2V, corresponding to zero current through the TEC. $V_{ITEC} = \frac{I_{OUT}(A)}{7.5} + 2V$, where I_{OUT} is the actual output current of the controller, flowing out from TEC+ port and flowing in to TEC– pin.
15	**VTEC**	Analog output	TEC voltage indication. VTEC is an analog voltage output pin with a voltage proportional to the actual voltage across the TEC. It swings from 0V to 4V to indicate the output voltage being from –30V to 30V, so the center voltage is 2V. $V_{VTEC} = \frac{V_{TEC+} - V_{TEC-}}{15} + 2V$
16	**CTMO**	Analog output	The controller internal temperature indication output. It can be used for sensing the actual temperature of the controller, to avoid over-heating. 0V to 4V sets the internal temperature from −55°C to 125°C linearly. **For the controller with PID function:** When there is a new load and the PID coefficient needs to be re-identified, the voltage of the pin is 4V.
17, 18, 19, 20	**TECR**	Analog power output	This pin is for connecting to the positive terminal of the TEC module, all 4 pins are internally connected for increasing the current capability.
21, 22, 23, 24	**TECB**	Analog power output	This pin is for connecting to the negative terminal of the TEC module, all 4 pins are internally connected.
25, 26, 27, 28	**PGND**	Power ground	Power ground for connecting to the power supply 0V return node, all 4 pins are internally connected.
29, 30, 31, 32	**VPS**	Power input	Power supply voltage positive node. The normal operating voltage range is 5.5V to 18V, the maximum value is 18V. All 4 pins are internally connected.

Table 2. Electrical characteristics.

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Units
Temperature Good Indication: TMGD pin, pin 2						
Voltage Range (Open circuit)	$V_{TMGDOUT}$	Open circuit voltage = 4V	0		4	V
Voltage Range (with load)	$V_{TMGDOUT}$	Open circuit voltage = 4V	0		4	V
Maximum Sourcing Current	I_{TMGDSC}	Open circuit voltage = 4V	1		15	mA
Maximum Sourcing Voltage	V_{TMGDSC}	Open circuit voltage = 4V	3.7		4	V
Maximum Sinking Current	I_{TMGDSK}	Open circuit voltage = 4V	3		20	mA
Maximum Sinking Voltage	V_{TMGDSK}	Open circuit voltage = 4V	0		0.6	V
Standby Shutdown Control: SBDN pin, pin 3						
Input Current	I_{SBDNIN}	V_{SBDN} = 0V	0.1		0.3	μA
		V_{SBDN} = 4V	4.0		6.0	
		V_{SBDN} = 30V	30		50	
Input Voltage Range	V_{SBDNIN}	Open circuit voltage = 5V	0		18	V
Shutdown Logic Low	$V_{SBDNSDL}$	Open circuit voltage = 5V	0		0.5	V
Shutdown Logic High	$V_{SBDNSDH}$	Open circuit voltage = 5V	0		1.0	V
Standby Logic Low	$V_{SBDNSBL}$	Open circuit voltage = 5V	1.1		1.4	V
Standby Logic High	$V_{SBDNSBH}$	Open circuit voltage = 5V	1.5		1.9	V
Operation Logic Low	$V_{SBDNOPL}$	Open circuit voltage = 5V	2.0		2.5	V
Operation Logic High	$V_{SBDNOPH}$	Open circuit voltage = 5V	2.5		5.0	V
Reference Voltage Output: 4VR pin, pin 5						
Output Voltage Range	V_{4VROUT}	T_A = 25°C	4.0925	4.096	4.0995	V
Initial Error	V_E	T_A = 25°C		0.05		%
Temperature Coefficient	T_C	T_A = −40°C ~ 125°C		3	8	ppm/°C
Maximum Load Current	I_{4VRMAX}	T_A = 25°C	−20		+20	mA
Maximum Load Capacitance	C_{4VRMAX}		0.1		1	uF
Temperature Set: TMS pin, pin 6						
Input Impedance (See Figure 3)	Z_{TMSIN}			5		MΩ
Input Voltage Range	V_{TMSIN}		0		4	V
Open Circuit Voltage	V_{TMSOP}			2		V
Temperature Signal Input: IN+ pin, pin 7						
Input Voltage Range	V_{IN+}		0		4	V
Thermistor Connection Port: RTH pin, pin 8						
Input Voltage Range	V_{RTHIN}		0		4	V
Actual Target Object Temperature Indication: TMO pin, pin 9						
Output Voltage Range	V_{TMOOUT}	R_{LOAD} = 10kΩ to 2V −40°C≤ T_A≤ +125°C	0		4	V

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Units
Output Current	I_{TMOOUT}	V_{SS} = 0V T_A = 25°C	−12		12	mA
Compensation Input: CMIN pin, pin 10						
Input Voltage Range	V_{CMIN}	R_{LOAD} = 10kΩ to 2V −40°C≤ T_A≤ +125°C	0		4	V
Input Current	I_{CMIN}	−40°C≤ T_A≤ +125°C		90	200	pA
Compensation Output: IDR pin, pin 11						
Output Voltage Range	V_{IDROUT}	R_{LOAD} = 10kΩ to 2V −40°C≤ T_A≤ +125°C	0		4	V
TEC Current Limit: ILM pin, pin 12						
Input Impedance	Z_{ILM}			21		kΩ
Input Voltage Range	V_{ILMIN}		0		4	V
TEC Voltage Limit: VLM pin, pin 13						
Input Impedance (See Figure 5)	Z_{VLM}			10		kΩ
Input Voltage Range	V_{VLMIN}		0		4	V
TEC Current Indication: ITEC pin, pin 14 TEC Voltage Indication: VTEC pin, pin 15 Controller Temperature Indication: CTMO pin, pin 16						
Output Voltage Range	V_{CTMO}	T_A = 25°C	0		4	V
Maximum Load Current	$I_{CTMOOUT}$	T_A = 25°C	−12		12	mA
TECR/TECB pin, pin 17~20/pin 21~24						
Maximum Output Current	$\|I_{MAXTEC+}\|$ $\|I_{MAXTEC-}\|$	V_{VPS} = 5.5V~18V T_A = 25°C	0		15	A
Maximum Output Voltage	$\|V_{OUTMAX}\|$	V_{VPS} = 18V	0		14.4	V
Power Supply Input: VPS pin, pin 29~32						
Input Voltage Range	V_{VPS}		5.5		18	V
Input Current	I_{VPS}	Operation mode	0.05		16	A
	I_{VPSSB}	Standby mode	5		20	mA
	I_{VPSSD}	Shutdown mode			50	μA
Temperature Stability						
Temperature Error Voltage	$V_{TMO}-V_{TMS}$		−0.47	0.02	0.47	mV
Efficiency	η	V_{VPS} = 18V $\|V_{TEC+}- V_{TEC-}\|$ = 14V $\|I_{TEC+}- I_{TEC-}\|$ = 10A		≥92		%
Case Operating Temperature Range	T_{CS}		−40		110	°C

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Units
Ambient Operating Temperature Range	T_A		−40		65	°C
Storage Temp. Range	T_{STG}		−40		125	°C
Controller Case Thermal Resistance	R_{TH}			9		°C /W

This TEC controller can only drive the TECs having >1Ω impedance, which equals V_{MAX} / I_{MAX}.

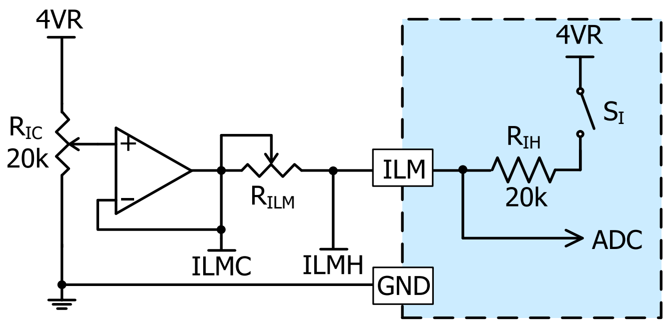


Figure 9. ILM Input Equivalent Circuit

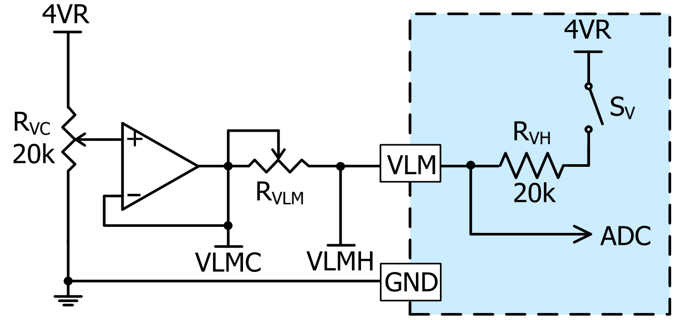


Figure 10. VLM Input Equivalent Circuit

Current limit for cooling:

$$I_{LMC} = \frac{ILMC}{4} \times 10(\mathrm{A}) = 2.5ILMC$$

Current limit for heating:

$$I_{LMH} = \frac{ILMH}{4} \times 10(\mathrm{A}) = 2.5ILMH$$

$$ILMH = ILMC + \frac{4 - ILMC}{20k + R_{ILM}} \times R_{ILM}$$

$$I_{LMH} = \left(\frac{ILMC}{4} + \frac{4 - ILMC}{4} \times \frac{R_{ILM}}{20k + R_{ILM}}\right) \times 10(A)$$

$$= \left[\frac{ILMC}{4} \times \left(1 - \frac{R_{ILM}}{20k + R_{ILM}}\right) + \frac{R_{ILM}}{20k + R_{ILM}}\right] \times 10(A)$$

$$= \left[\frac{ILMC}{4} \times \frac{20k}{20k + R_{ILM}} + \frac{R_{ILM}}{20k + R_{ILM}}\right] \times 10(A)$$

$$= \frac{1}{20k + R_{ILM}} \times \left[\frac{ILMC}{4} \times 20k + R_{ILM}\right] \times 10(A)$$

$$= \frac{5ILMC + R_{ILM}}{20k + R_{ILM}} \times 10(A)$$

$$R_{ILM} = \frac{20I_{LMH} - 50ILMC}{10 - I_{LMH}} = \frac{20I_{LMH} - 20I_{LMC}}{10 - I_{LMH}}$$

Voltage limit for cooling:

$$I_{VLMC} = \frac{VLMC}{4} \times 10(\mathrm{A}) = 2.5VLMC$$

Voltage limit for heating:

$$I_{VLMH} = \frac{VLMH}{4} \times 10(\mathrm{A}) = 2.5VLMH$$

$$VLMH = VLMC + \frac{4 - VLMC}{20k + R_{VLM}} \times R_{VLM}$$

$$I_{VLMH} = \left(\frac{VLMC}{4} + \frac{4 - VLMC}{4} \times \frac{R_{VLM}}{20k + R_{VLM}}\right) \times 10(A)$$

$$= \left[\frac{VLMC}{4} \times \left(1 - \frac{R_{VLM}}{20k + R_{VLM}}\right) + \frac{R_{VLM}}{20k + R_{VLM}}\right] \times 10(A)$$

$$= \left[\frac{VLMC}{4} \times \frac{20k}{20k + R_{VLM}} + \frac{R_{VLM}}{20k + R_{VLM}}\right] \times 10(A)$$

$$= \frac{1}{20k + R_{VLM}} \times \left[\frac{VLMC}{4} \times 20k + R_{VLM}\right] \times 10(A)$$

$$= \frac{5VLMC + R_{VLM}}{20k + R_{VLM}} \times 10(A)$$

$$R_{VLM} = \frac{20I_{VLMH} - 50VLMC}{10 - I_{VLMH}} = \frac{20I_{VLMH} - 20I_{VLMC}}{10 - I_{VLMH}}$$

APPLICATIONS

TEC controller connections are shown in Figure 11.

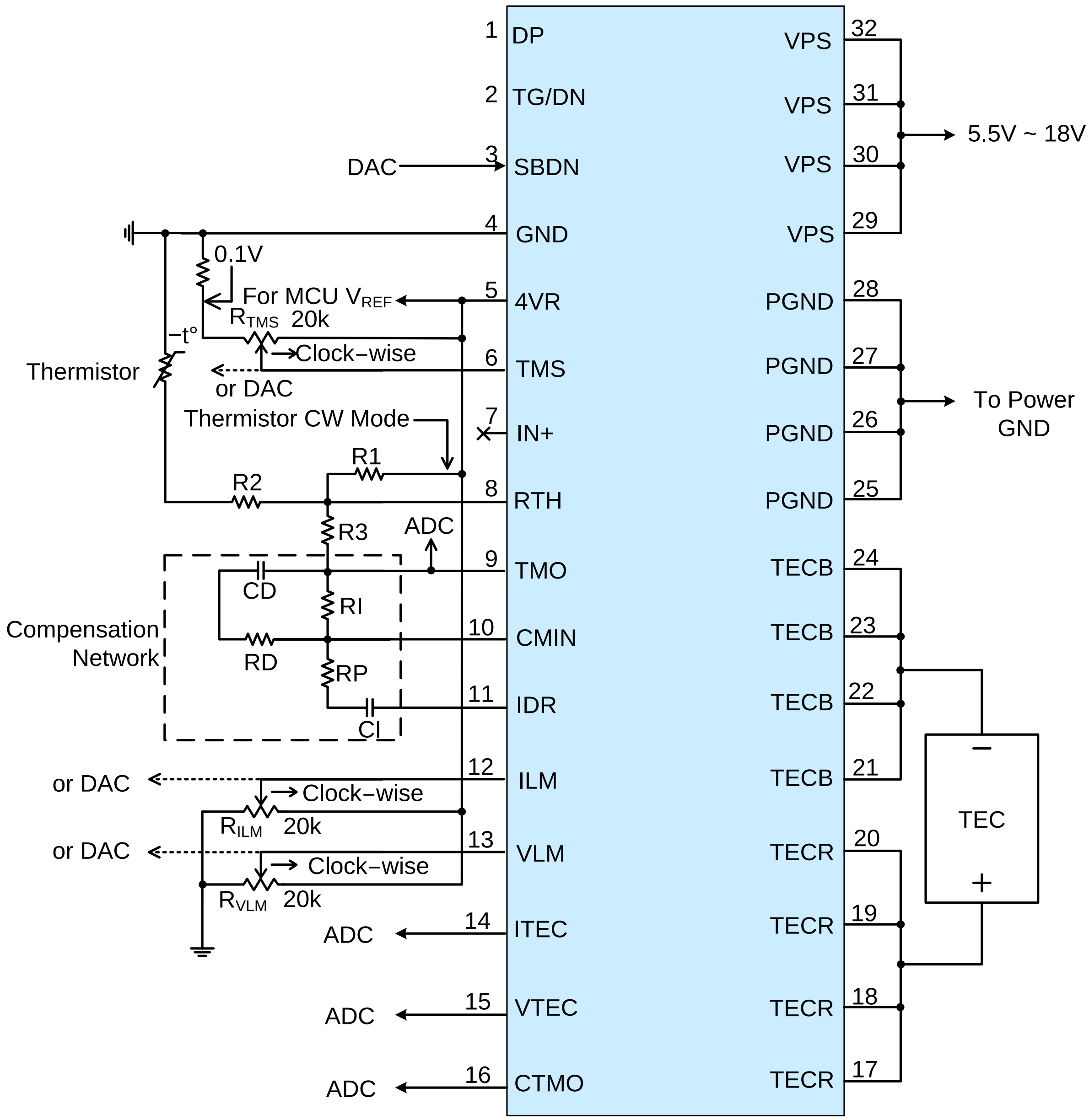


Figure 11.1. Using External Analog Compensation Network

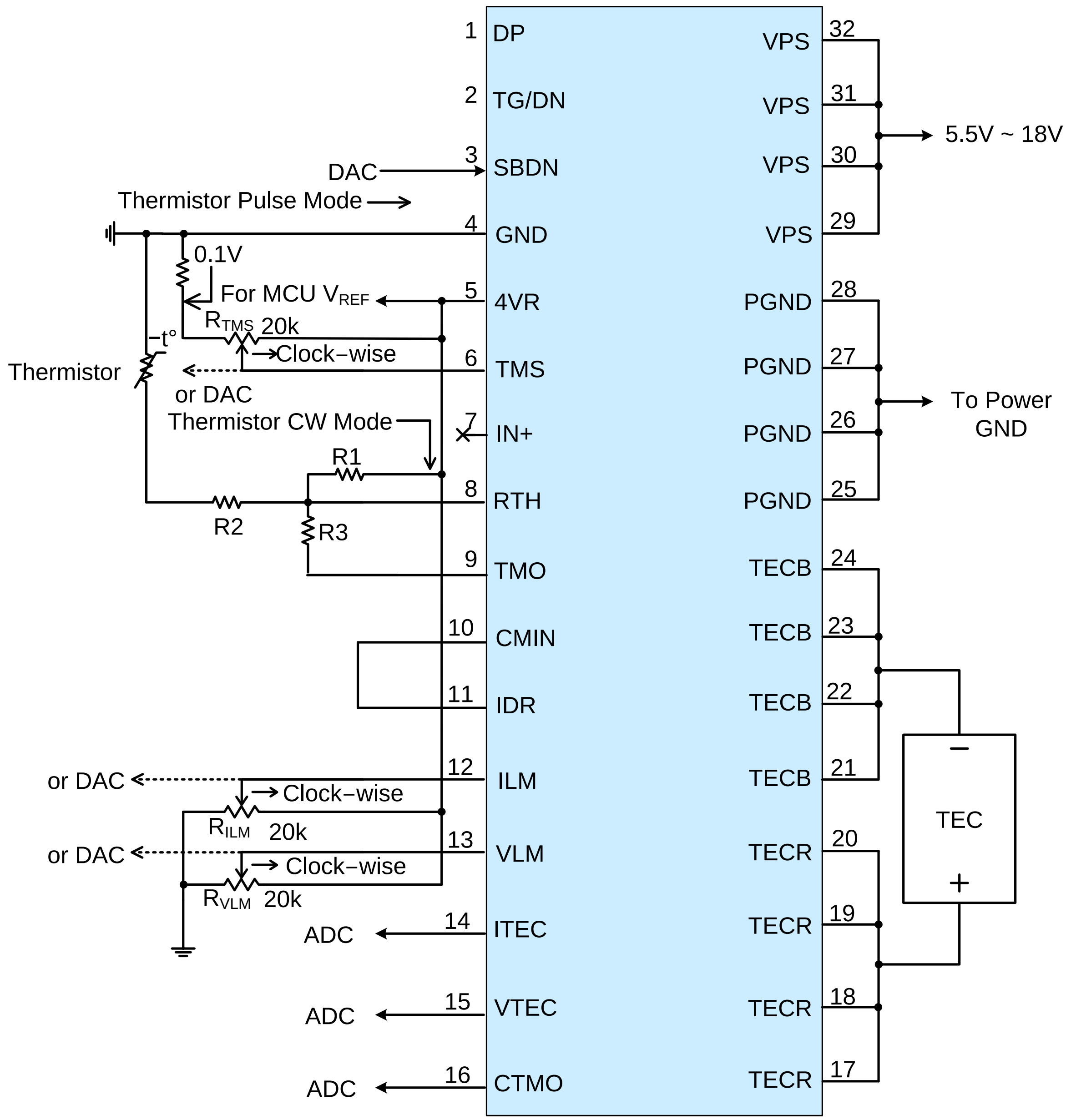


Figure 11.2. Using Auto PID

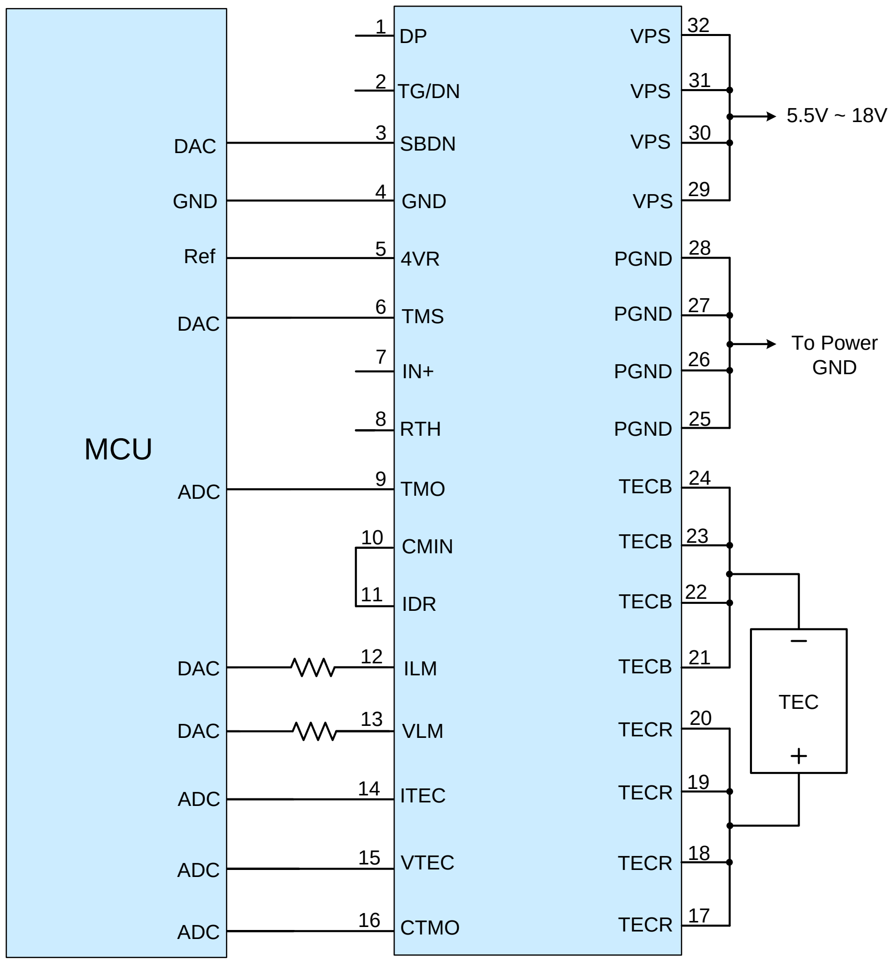


Figure 11.3. Using Auto PID with a Microcontroller

SBDN

Table 3. For Controllers without Auto PID (TEC18V10AD)

No.	Input	Voltage	Controller State	Temperature Sensor Type and Mode
1	SBDN	≤ 0.5V	Shut Down	-
2		1.7V ± 0.2V	Standby	-
3		2V ~ 5V	Working	Temperature Sensor IC, RTD and RTH

Table 4. For Controllers with Auto PID (TEC18V10ADAPID)

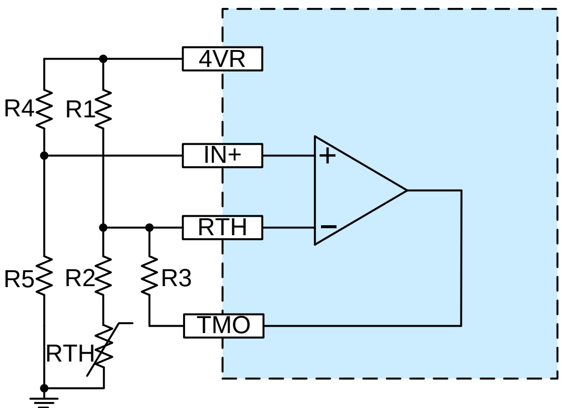
No.	Input	Voltage	Controller State	Temperatue Sensor Type and Mode	PID Type
1	SBDN	≤ 0.5V	Shut Down	-	-
2		1.3V ± 0.3V	Standby	-	-
3		2.5V ± 0.4V	Working	Temperature sensor IC or RTD	External Analog PID
4		3.5V ± 0.4V		Temperature sensor IC or RTD	Auto PID

Temperature Sensor Selections and Their Schematics

There are three types temperature sensors frequently used: thermistor, RTD (Resistance Temperature Device), and temperature sensor IC (Integrated Circuit).

A. Thermistor and Its Temperature-Network

TEC18V10AD reliles on an external temperature network setting the set-point temperature range.



Note: R4=R5

Figure 12. Schematic for Using A Thermistor

a. After determining the set-point temperature range, look up the R-T curve of the thermistor, get the values for R_U, the upper limit resistance; R_M, the middle limit resistance; and R_L, the lower limit resistance.

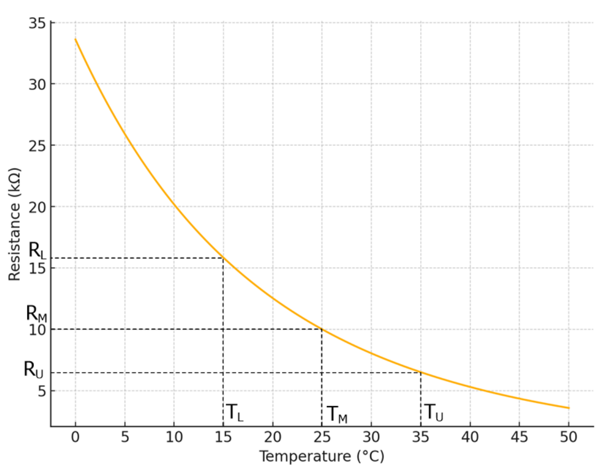


Figure 13.

b. Use the following formula to calculate R1, R2 and R3:

$$\mathrm{R1} = R_\mathrm{M} + \frac{R_\mathrm{M} \times (R_\mathrm{L} + R_\mathrm{H}) - 2 \times R_\mathrm{H} \times R_L}{R_\mathrm{H} + R_\mathrm{L} - 2 \times R_\mathrm{M}} \quad \text{-- (1)}$$

$$\mathrm{R2} = \mathrm{R1} - R_\mathrm{M} \quad \text{----- (2)}$$

$$\mathrm{R3} = \frac{\mathrm{R1} \times (\mathrm{R1} + R_\mathrm{L} - R_\mathrm{M})}{R_\mathrm{L} - R_\mathrm{M}} \quad \text{------- (3)}$$

For example, setting the high set-point temperature at 35°C and the low set-point temperature at 15°C results in a middle set-point temperature (35 + 15)/2 = 25°C. Use the R-T table of a thermistor.

R_H = 6.9kΩ, R_M = 10kΩ and R_L = 14.8kΩ

Note that Equation 1 to Equation 3 result in

R1 = 17.5kΩ, R2 = 7.5kΩ and R3 = 81.3kΩ

R4=R5, can be any value. The consideration: lower the value, smaller the noise, but higher the power consumption. We recommend choosing 10kΩ.

About Rth nominal resistance. The nonominal resistance of thermistors found in most off-the-shelf optical components, such as butterfly packadged laser modules, is 10kΩ. However, if your application requires minimizing the temperaturation sensing errors caused by self-heating effect, higher resistance value thermistors can be selected, such as 100kΩ@25°C.

B. RTD

RTD, standing for Resistance Temperature Detector, is anothe type of temperature sensor. Comparing with thermistors, it features high accuracy, high repeatibility, good linearity, and low drift, but larger size, higher cost, and lower sensibility —— It means it's hard to achieve 0.001°C temperature stability as what thermistor can. The most significant difference is that it has a positive temperature coefficient, as opposed to the negative temperature coefficient as that found in the thermistors, as shown in Figure a.

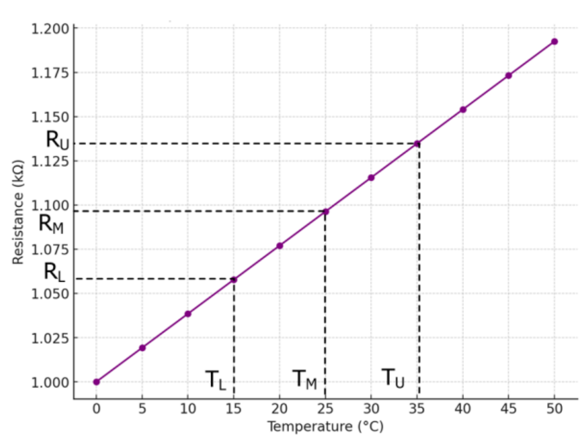


Figure 14.

There are a few ways to connect the RTD to the TEC controller.

Table 5. Schematics for Interfacing an RTD

Figure	Features	Feature List
15.1	①④	①. V_{TMO} almost proportional with T_{RTD}
15.2	②④	②. V_{TMO} inversely proportional to T_{RTD}
15.3	③	③. V_{TMO} absolutely proportional with T_{RTD} ④. One RTD end is grounded

A. Schematic in Figure 13.1 is connected to the positive input of the amplifier while its other end is grounded as shown in the application circuit given in Figure 8. However, the schematic in Figure 8 has one major drawback: it's linearity is not good, since the voltage across the RTD is not constant, it changes with temperature. To achieve ideal linearity, the schematic in Figure 13.2 can be used. It also has a drawback: the output voltage is not mono proportional to the RTD temperature.

It usually generates heat when the current flows through the RTD, which is called self-heating effect. This is due to the fact that the resistance of RTD is usually lower, such as 100 Ohm, maximum up to 1000 Ohm. At this low resistance, high current has to be injected to the RTD in order to generate enough voltage for the amplifier to sense the resistance change caused by the temperature. To avoid the self-heating effect, higher resistance RTD is recommended to use.

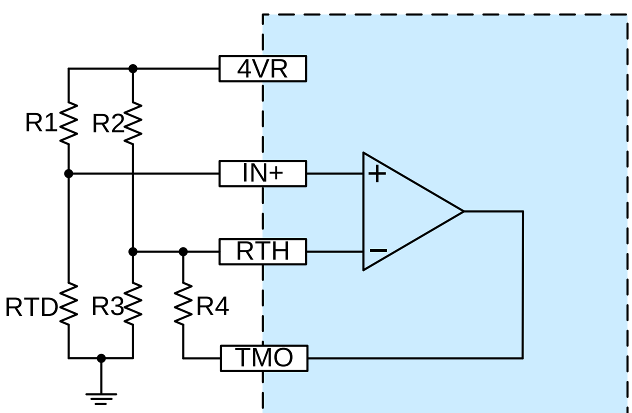


Figure 15.1. Schematic for Using an RTD

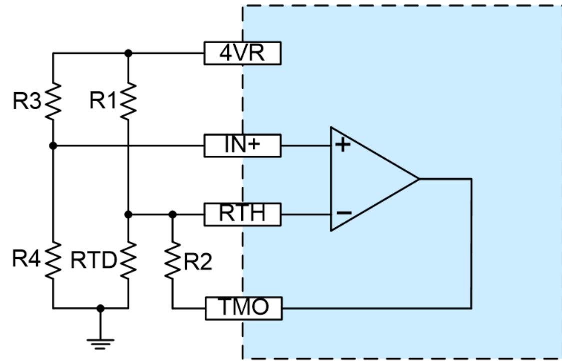


Figure 15.2.

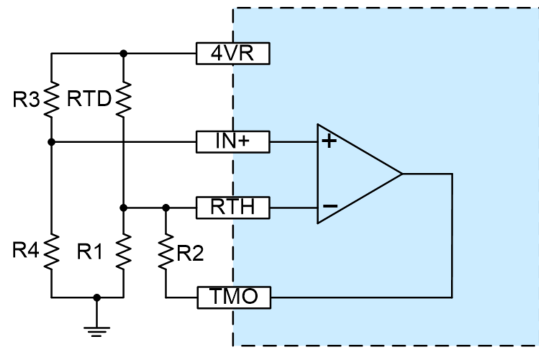


Figure 15.3.

Design steps:

a. On the R-T curve of the RTD, determin the RU and RL, where TU and TL are the upper and lower temperature limit respectively. In the RTD spec., its nominal resistance is rated at 0°C.

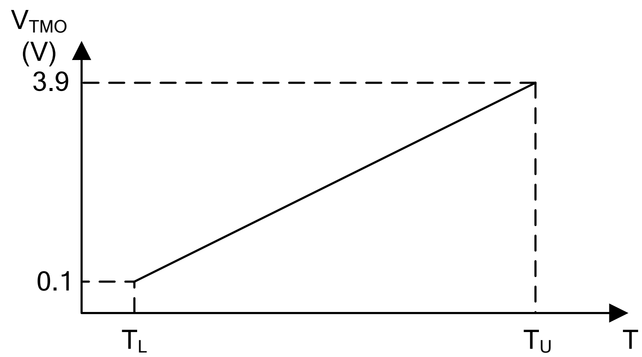


Figure 16. Linear Relationship between V_{TMO} and Temperature

$R_{TD} = R_0 \times (1+0.00385T)$

e.g. $R_0 = 1k\Omega$

When T = 10°C, $R_{TD}(10) = 1.0385k\Omega$

When T = 40°C, $R_{TD}(40) = 1.154k\Omega$

Choose R1

A. $P_{RTD} \leq 1mW$, $R_{TD} = 1000\Omega$

$P_{RTD} = (I_{RTD})^2 \times 1000\Omega = 0.001W$

$I_{RTD} = 1mA = \frac{4VR}{R1 + R_{TD}} = \frac{4}{R1 + 1k} \Rightarrow$ R1=3kΩ

B. $P_{RTD} \leq 1mW$, $R_{TD} = 100\Omega$

$P_{RTD} = (I_{RTD})^2 \times 100\Omega = 0.001W$

$I_{RTD} = 3.16mA = \frac{4VR}{R1 + R_{TD}} = \frac{4}{R1 + 0.1k} \Rightarrow$

R1=1.15kΩ

$$V_{TMO} = \frac{4 \times R_{TD}}{R1 + R_{TD}} \times \left[1 + \frac{R4 \times (R2 + R3)}{R2 \times R3}\right] - \frac{4 \times R4}{R2}$$

I. When T = 10°C, R1 = 3kΩ, $R_{TD}(T_L) = 1.0385k\Omega$,

$$0.93 = \frac{R4 \times (2.97R3 - 1.03R2)}{R2 \times R3}$$

When T = 40°C, R1 = 3kΩ, $R_{TD}(T_U) = 1.154k\Omega$,

$$2.79 = \frac{R4 \times (1.11R2 - 2.89R3)}{R2 \times R3}$$

II. When T = 10°C, R1 = 1.15kΩ, $R_{TD}(T_L) = 1.0385k\Omega$,

$$1.8 = \frac{R4 \times (2.1R3 - 1.9R2)}{R2 \times R3}$$

When T = 40°C, R1 = 1.15kΩ, $R_{TD}(T_U) = 1.154k\Omega$,

$$1.9 = \frac{2 \times R4 \times (R2 - R3)}{R2 \times R3}$$

To achieve the required V_{TMO} outputs at the three different setting point temperatures in the Temperature Network, use the equation:

When T = LOW, RTD = RTD_L, TMO = 0.1V, $V_1 = V_{1L}$

When T = HIGH, RTD = RTD_H, TMO = 4.0V, $V_1 = V_{1H}$

ΔTMO = 4V - 0.1V = 3.9V

$\Delta V1 = V_{1H} - V_{1L}$

$$G = \frac{\Delta TMO}{\Delta V1} = 1 + \frac{R4 \times (R2 + R3)}{R2 \times R3}$$

RTD = $R_0 \times (1+0.00385T)$

e.g. R_0 = 1kΩ

$$V1 = 4.096V \times \frac{RTD}{R1 + RTD}$$

$V_{1L} = 0.5V$

$$R1 = RTD_L \times \frac{4.096V}{V_{1L}} - RTD_L$$

R2 = R1, R3 = RTD_L

$$R4 = (G - 1) \times \frac{R2 \times R3}{R2 + R3}$$

For example, setting the high set-point temperature at 60°C and the low set-point temperature at 0°C.Use RTD = $R_0 \times (1+0.00385T)$, (e.g. R_0 = 1kΩ).

$RTD_L = R_{TD}(10°C) = 1.0k\Omega$

$RTD_H = R_{TD}(60°C) = 1.231k\Omega$

$R_1 = 7.192k\Omega$

$R_2 = R_1 = 7.192k\Omega$

$R_3 = RTD_L = 1.0k\Omega$

$R_4 = 32.308k\Omega$

3. IC

(1). Positive Coefficient

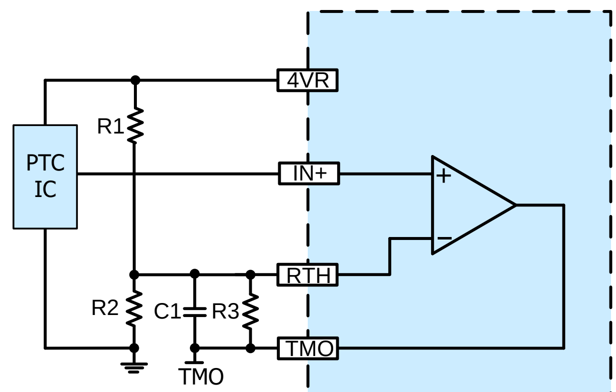


Figure 17.1. PTC IC temperature sensor

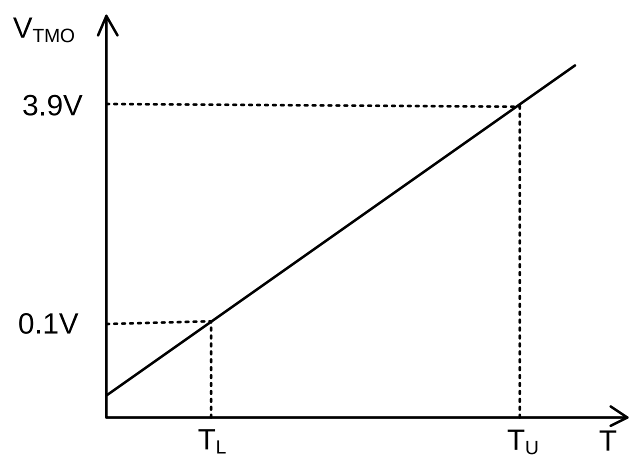


Figure 17.2. Objective

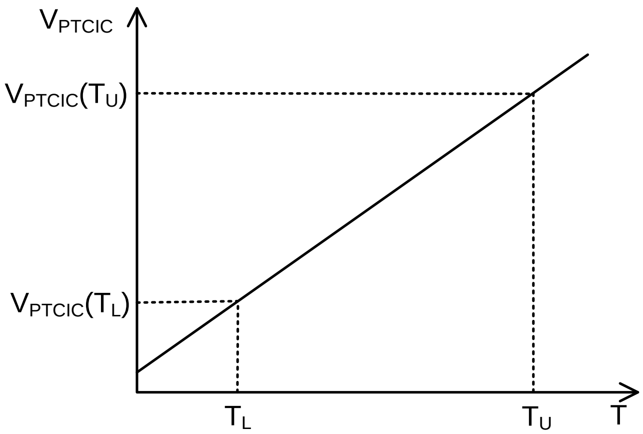


Figure 17.3. Temperature vs. V_{PTCIC}

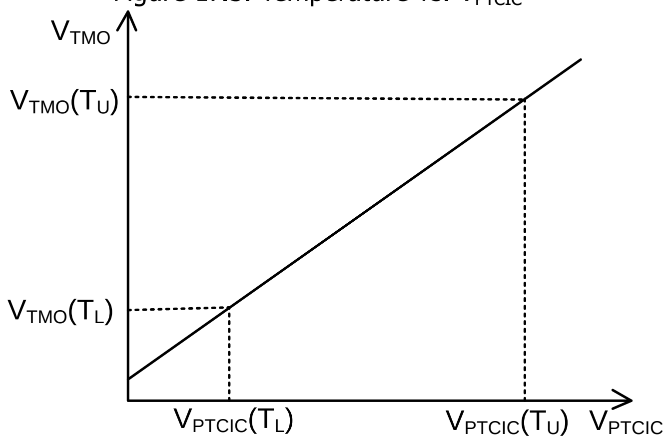


Figure 17.4. V_{PTCIC} vs. V_{TMO}

$V_{TMO}(T_L) = 0.1V$, $V_{TMO}(T_U) = 3.9V$

$$G = \frac{\Delta V_{TMO}}{\Delta V_{PTCIC}} = \frac{V_{TMO}(T_U) - V_{TMO}(T_L)}{V_{PTCIC}(T_U) - V_{PTCIC}(T_L)}$$

$$G = \frac{R3}{R1//R2} + 1$$

$$V_{PTCIC}(T_M) = \frac{V_{PTCIC}(T_U) + V_{PTCIC}(T_L)}{2}$$

$$V_{PTCIC} = V_{PTCIC}(T_M),\ V_{TMO} = \frac{3.9V + 0.1V}{2} = 2V$$

$$\frac{V_{PTCIC}(T_M)}{R2} = \frac{2V - V_{PTCIC}(T_M)}{R3} + \frac{4V - V_{PTCIC}(T_M)}{R1}$$

R3=20kΩ

$$R2 = \frac{R3}{[4V - V_{PTCIC}(T_M)] \times G - 2}$$

$$R1 = \frac{R2 \times R3}{R2 \times (G - 1) - R3}$$

2. Negative Coefficient

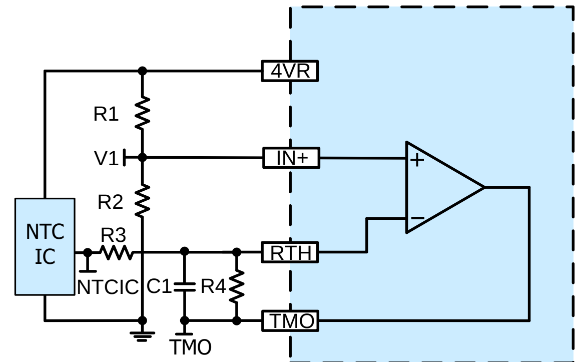


Figure 18.1. NTC IC Temperature Sensor

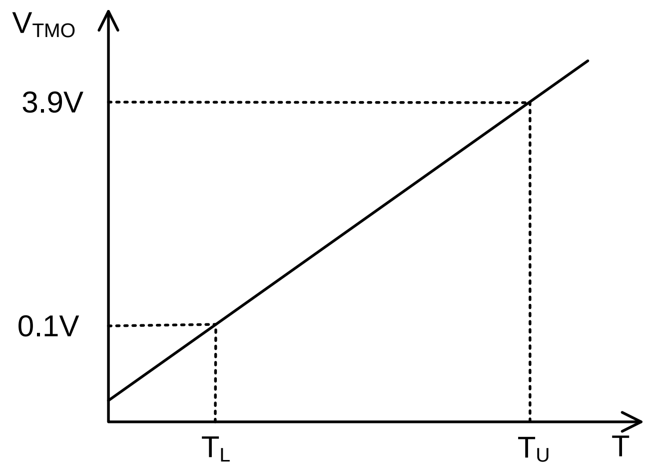


Figure 18.2. Objective

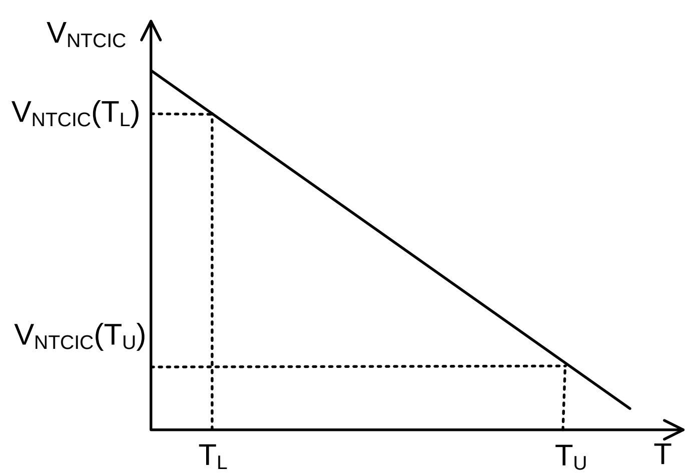


Figure 18.3. Temperature vs. V_{NTCIC}

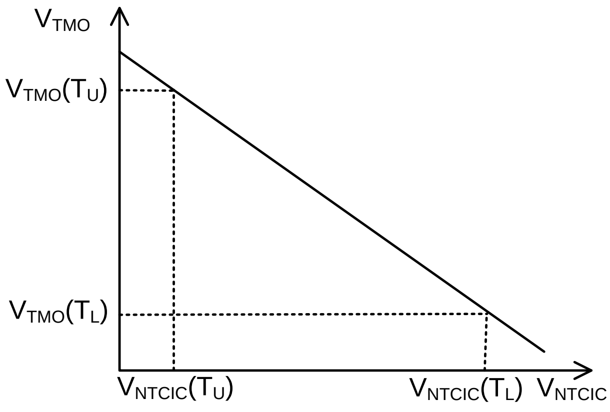


Figure 18.4. V_{PTCIC} vs. V_{TMO}

$V_{TMO}(T_L) = 0.1V$, $V_{TMO}(T_U) = 3.9V$

$$G = \frac{\Delta V_{TMO}}{\Delta V_{NTCIC}} = \frac{V_{TMO}(T_U) - V_{TMO}(T_L)}{V_{NTCIC}(T_U) - V_{NTCIC}(T_L)}$$

$$G = \frac{R4}{R3}$$

R4 =20kΩ ~ 200kΩ

$$R3 = \frac{R4}{G}$$

$$V_{NTCIC}(T_M) = \frac{V_{NTCIC}(T_U) + V_{NTCIC}(T_L)}{2}$$

$$\frac{[2V - V_{NTCIC}(T_M)] \times R3}{R3 + R4} + V_{NTCIC}(T_M) = \frac{4V \times R2}{R1 + R2}$$

R2=10k

$$R1 = \frac{40 \times (1 + G)}{2 - V_{NTCIC}(T_M)} - 10$$

$$\frac{1}{2\pi \times (R3//R4) \times C} = 200Hz$$

$$C = \frac{1}{2\pi \times (R3//R4) \times 200Hz} = \frac{1 + G}{400\pi \times R4}$$

Maximum sourcing current: $\frac{V_{NTCIC}(T_L) - V1}{R3} \leq I_{SOURCEMAX}$

Maximum sinking current: $\frac{V1 - V_{NTCIC}(T_L)}{R3} \leq I_{SOURCEMAX}$

SBDN

SBDN is suggested to be pulled up to VPS with a 10µA current and contains a 1.50V logic threshold. Drive this pin to a logic-high to enable the TEC18V10A. Drive to a logic-low to disable the TEC controller and enter micro-power shutdown mode.

ITEC and ILM

When the voltage of the ITEC is V_{ITEC} = 2V, the current of the TEC Controller I_{TEC}=0A. When V_{ITEC} = 0V, I_{TEC} has the maximum reverse current, −10A. When V_{ITEC} = 4V, I_{TEC} has the maximum forward current, 10A.

TEC controller is working on the cooling region, when it has forward current. On the opposite, it works on the heating region when reversing the current, as shown in Figure 12.

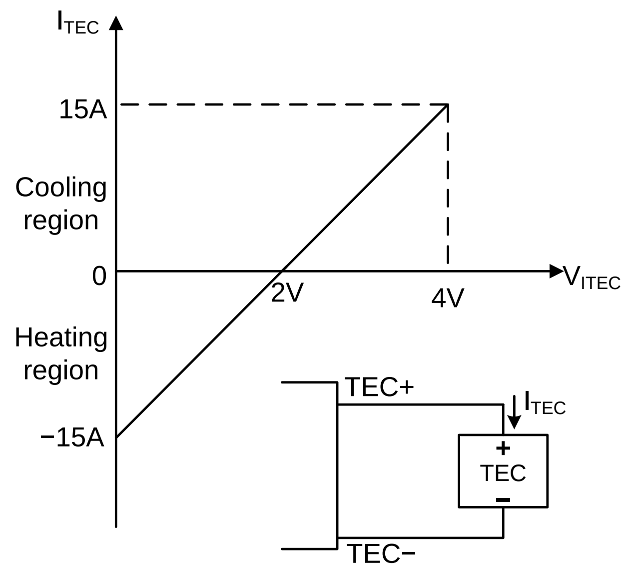


Figure 19. V_{ITEC} vs. I_{TEC}

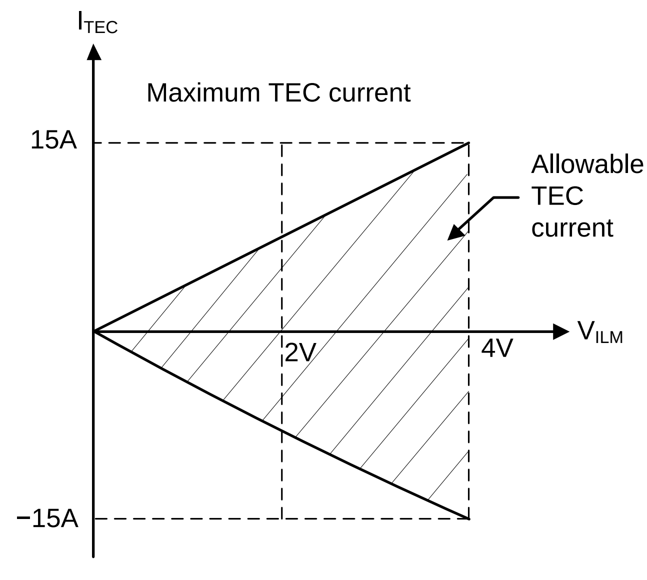


Figure 20. V_{ILM} vs. I_{TEC}

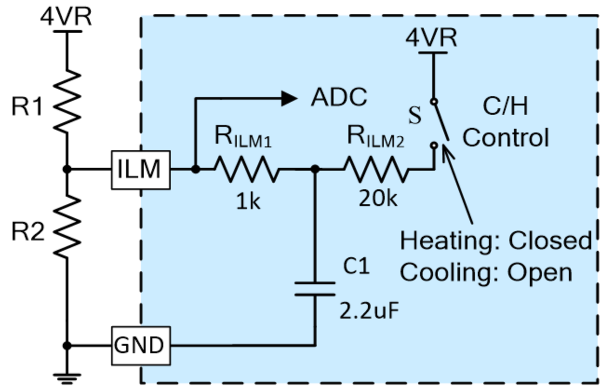


Figure 21. ILM vs. Cooling and Heating Control

Calculate the maximum current in cooling and heating region according to Figure 14.

1. Cooling region

$I_{TEC}\geq 0A$, $V_{ILM}\geq$ 2V, Cooling region => S1 = Open;

Maximum cooling current:

$$I_{TEC}\leq \frac{V_{ILM}}{4V}\times 15A = \frac{R2}{R1+R2}\times 15A$$

2. Heating region

$I_{TEC} < 0A$, $V_{ILM} < 2V$, Heating region => S1 = Close;

Maximum heating current:

$$|I_{TEC}|_{MAX}\leq \frac{V_{ILM}}{4V}\times 15A = \frac{R2//R_{ILM}}{R1+R2//R_{ILM}}\times 15A$$

3. After deciding the heating current shrinking ratio, we can determine the value for R1 & R2.

Calculate R1 & R2 ratio

$$I_{COOLMAX} = \frac{R1}{R1+R2}\times 15A \qquad \text{--------------(1)}$$

Calculate R1 & R2 value by deciding the heating current shrinking ratio:

KHC = maximum heating current / maximum cooling current

$$= \frac{I_{ITEC\,-(TH-MAX)}}{I_{ITEC\,-(CL-MAX)}} \qquad \text{--------------(2)}$$

$$= \frac{\dfrac{R2//R_{ILM}}{R1+R2//R_{ILM}}}{\dfrac{R2}{R1+R2}}$$

$$= \frac{200\times(R1+R2)}{R1\times R2 + 200\times(R1+R2)}$$

VTEC and VLM

VTEC = $V_{TEC}+ - V_{TEC}-$, as shown in Figure 16.

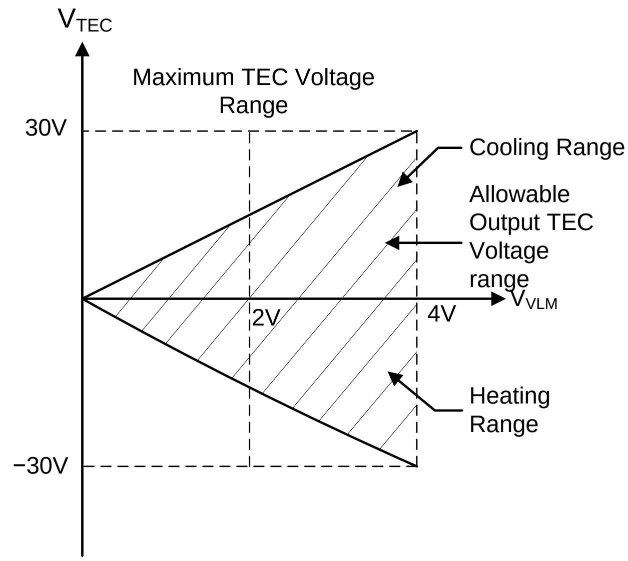


Figure 22. V_{TEC} vs. V_{VLM}

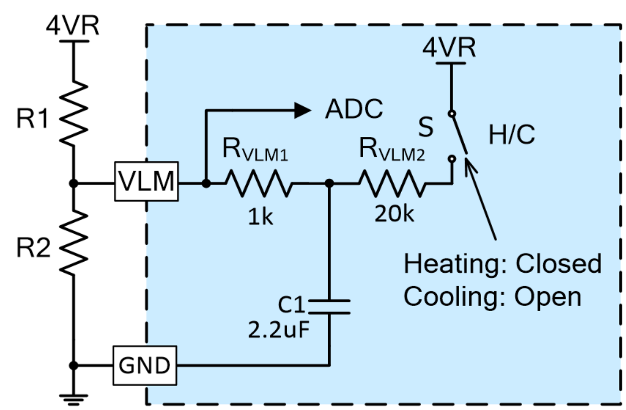


Figure 23. VLM vs. Cooling and Heating Control

VLM and ILM

If you want to use this TEC controller for other applications not discussed here, such as with wave locker controllers, consult with us. The same for other customizations, such as setting the ILM and VLM by using voltage source swings above 4V and/or VPS.

An external voltage connects the ILM pin through a resistor. This voltage can be used to adjust the voltage range of cooling or heating, and advice is 1.5V. The resistor can be used to adjust the difference of cooling and heating, and advice is 10kΩ. See Figure 18.

For example, the voltage midpoint of the ILM pin (V_m) is 2V. Adjust the external voltage, and make the voltage range 1V, but it is only with the center of 2V (V_m). If you adjust the resistor W2, you can move the limit of the cooling to be greater than the limit of the heating. It is shown in Figure 19 and Figure 20.

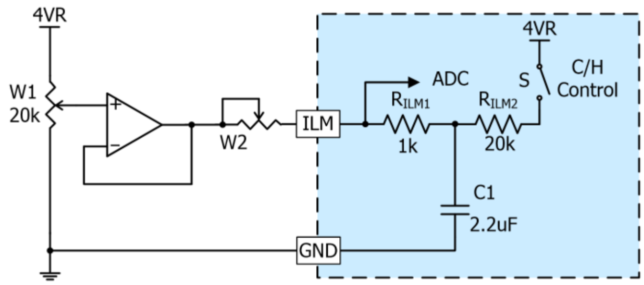


Figure 24. ILM vs. Cooling and Heating Control

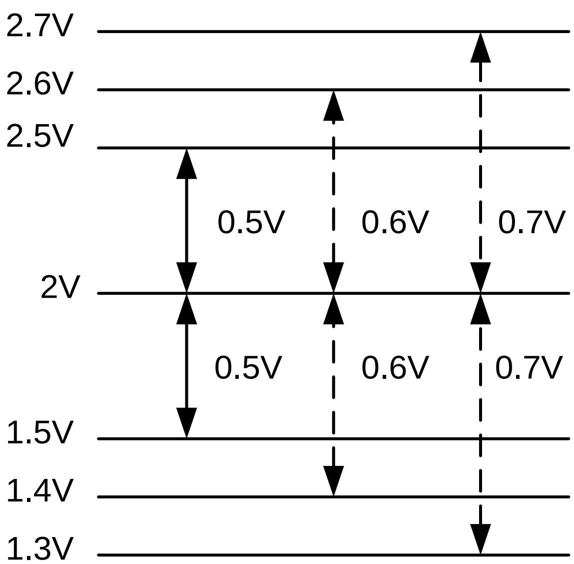


Figure 25. Adjust the External Voltage

We can tell the VLM or ILM voltage in cooling control or heating control through the waveforms on the VLM or ILM pin, see Figure 21 and Figure 22. The duty cycle in Figure 21 is 99% and 1% in Figure 22. We can also measure both voltages by a multimeter. When the controller is in the Standby State, the voltage measured by the multimeter is the VLM or ILM voltage in cooling control. When the controller is in Operation State, the voltage measured by the multimeter is the VLM or ILM voltage in heating control.

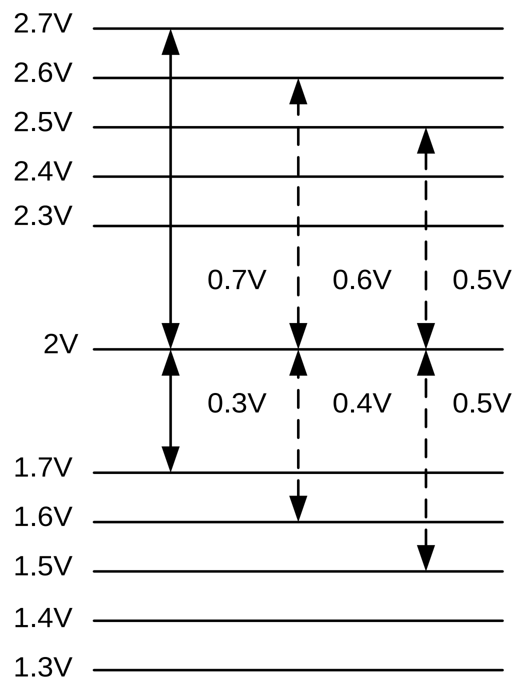


Figure 26. Adjust the Resistor

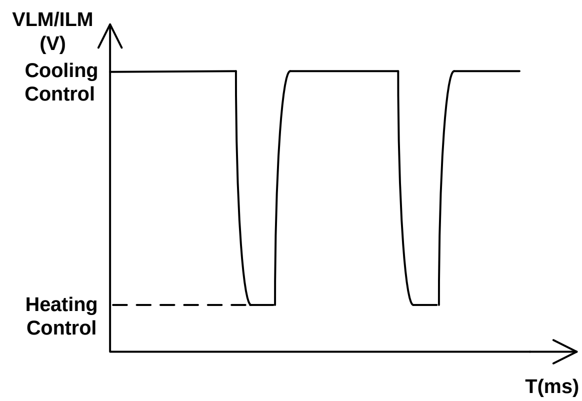


Figure 27. The Waveform on the VLM or ILM Pin @ SB State

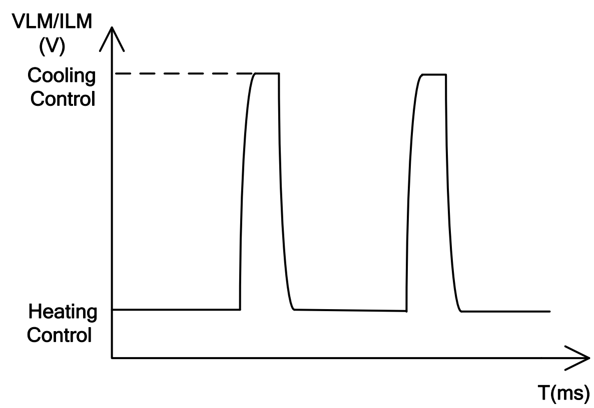


Figure 28. The Waveform on the VLM or ILM Pin @ Operation State

TMGD

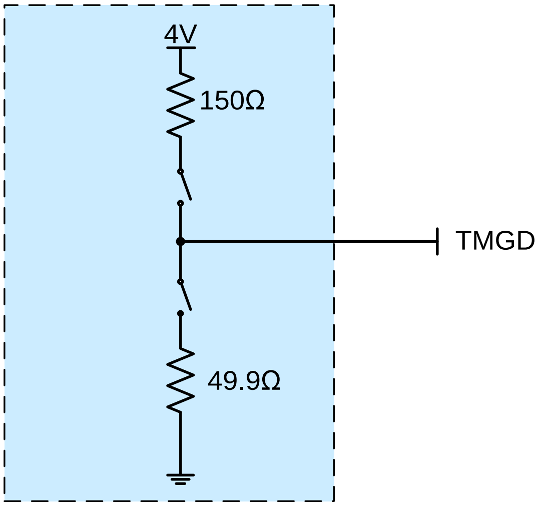


Figure 29. Output Equivalent Circuit for TMGD Pin

The TMGD pin outputs the maximum source current and sink current of 20mA. The output current will cause voltage drop, see Figure 27.

TYPICAL CHARACTERISTICS

Table 6. Measurement Data of Rth vs. Temperature

Temp. (°C)	Rth (kΩ)	TMO (V)	Ideal Linear (V)	Error (V)
15	15.7049	0.05	0.1	−0.05
16	14.9944	0.24	0.3	−0.06
17	14.3198	0.43	0.49	−0.06
18	13.6792	0.63	0.69	−0.06
19	13.0705	0.82	0.88	−0.06
20	12.4922	1.02	1.08	−0.06
21	11.9425	1.22	1.27	−0.05
22	11.4198	1.42	1.47	−0.05
23	10.9227	1.62	1.66	−0.04
24	10.4499	1.82	1.86	−0.04
25	10	2.03	2.05	−0.02

Temp. (°C)	Rth (kΩ)	TMO (V)	Ideal Linear (V)	Error
26	9.5718	2.23	2.25	−0.02
27	9.1642	2.44	2.44	0
28	8.776	2.64	2.64	0
29	8.4063	2.85	2.83	0.02
30	8.0541	3.05	3.03	0.02
31	7.7184	3.25	3.22	0.03
32	7.3985	3.46	3.42	0.04
33	7.0935	3.66	3.61	0.05
34	7.0935	3.86	3.81	0.05
35	6.5251	4.06	4.00	0.06

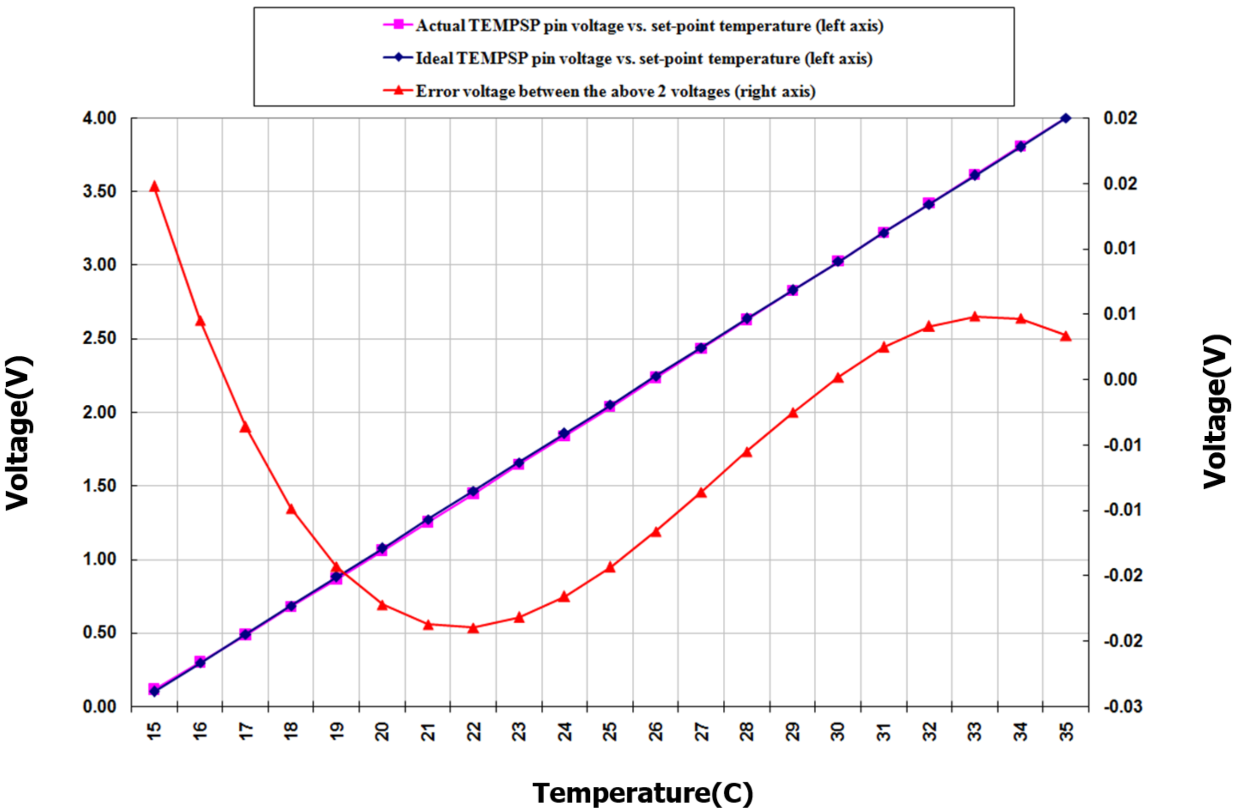


Figure 30. TMO Pin Voltage vs. Set-point Temperature

PCB LAYOUT

The TEC18V10AD is a high output power device, even it has a high efficiency, heat sinking should be considered in PCB layout. Two ways: by using PCB as the heat sink or mounting external heat sink.

A. The TEC18V10AD comes with thermal pads underneath the module. They can be soldered to internal pcb layers which will serve as heat sinks, as shown in Figure xxx.

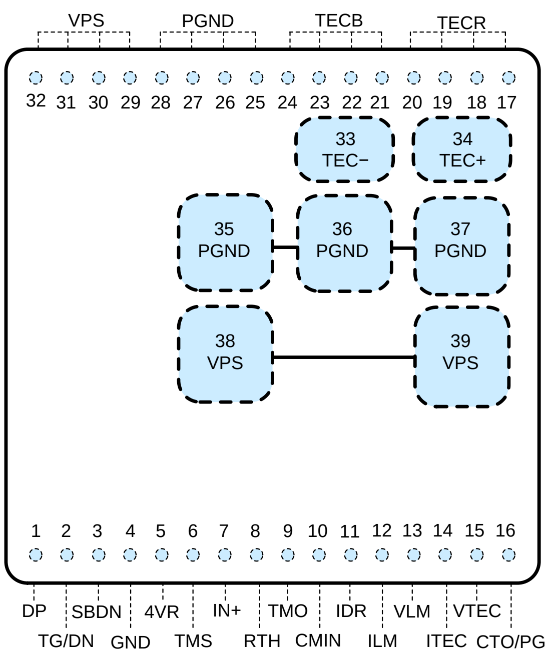


Figure 31.

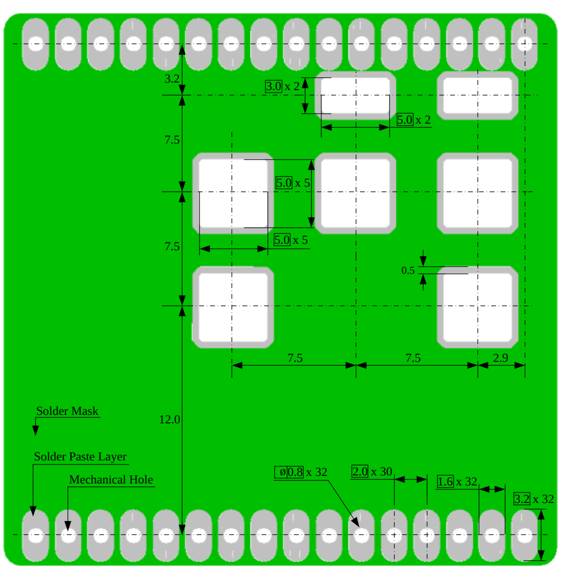


Figure 32.

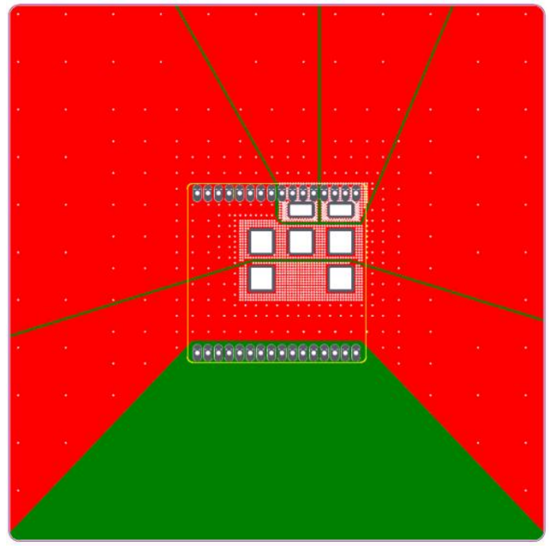


Figure 33.

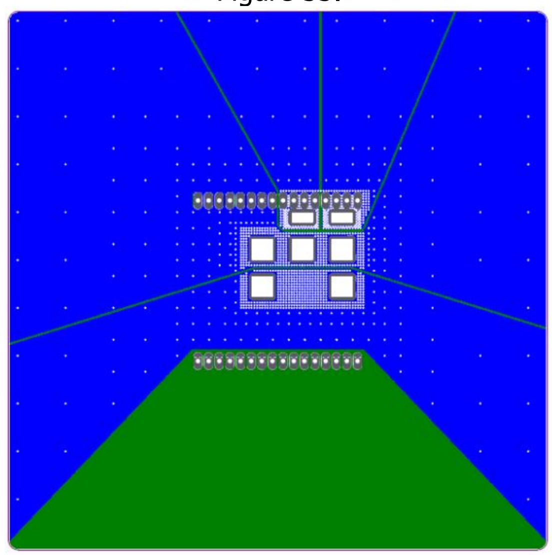


Figure 34.

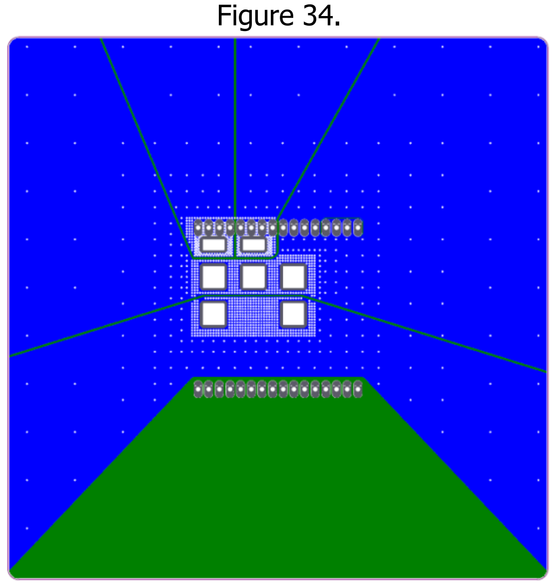


Figure 35.

HEAT DISSIPATION

The heating elements of the TEC18V10A TEC controller are on the top layer next to the shell, so the heat sink needs to be installed on the top of the controller shell. When the output current of the controller is <8A, no heat sink is required. When the output current is >8A, a heat sink is needed to ensure the internal temperature of the controller is <85°C.

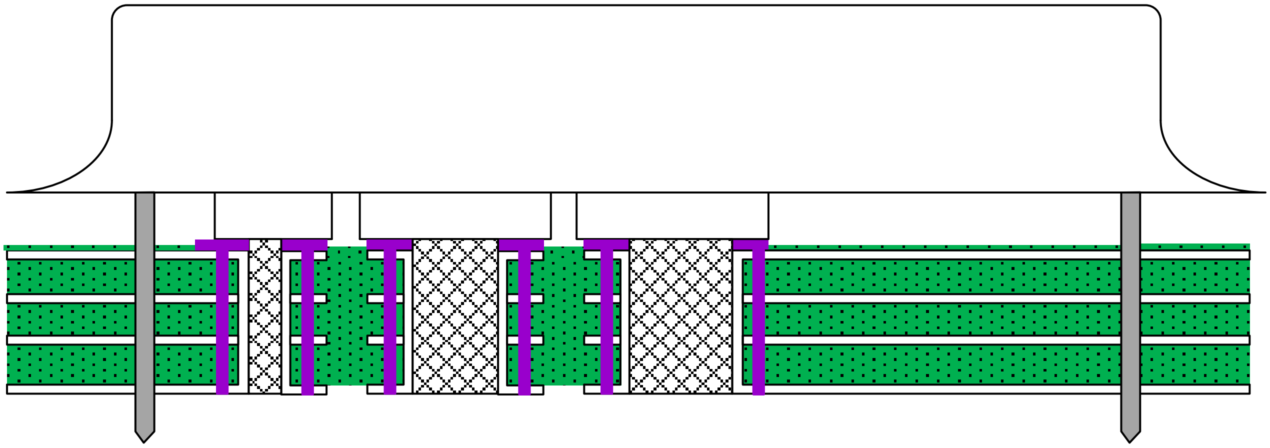


Figure 36.

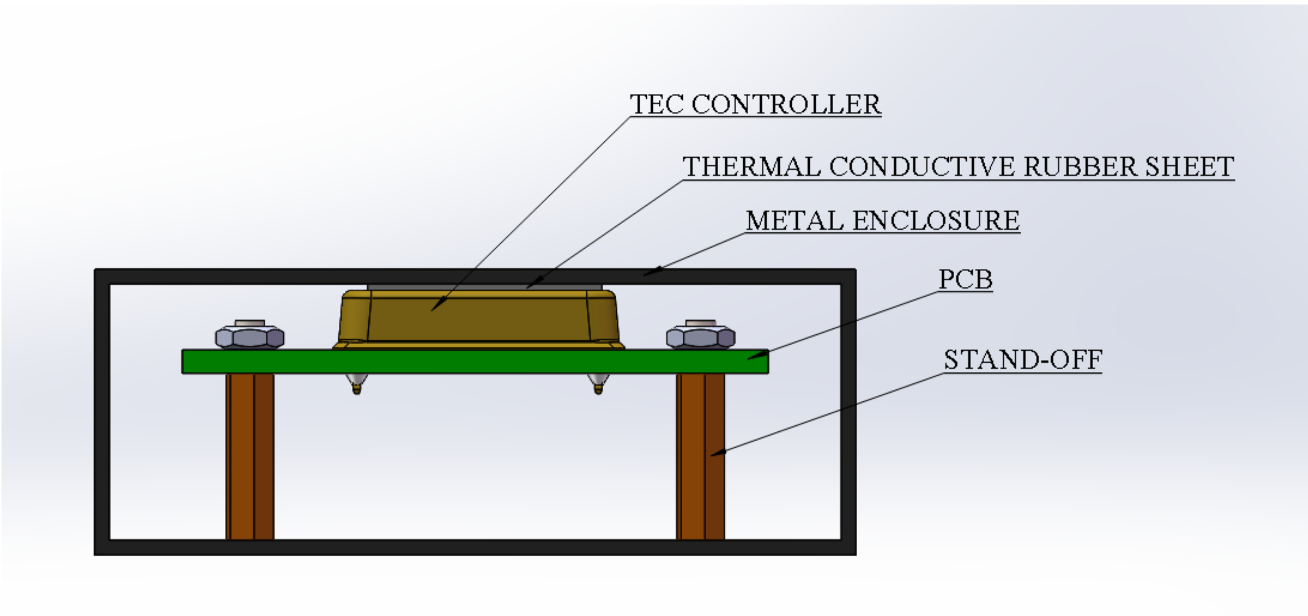


Figure 37. Transferring Heat with Metal Enclosure

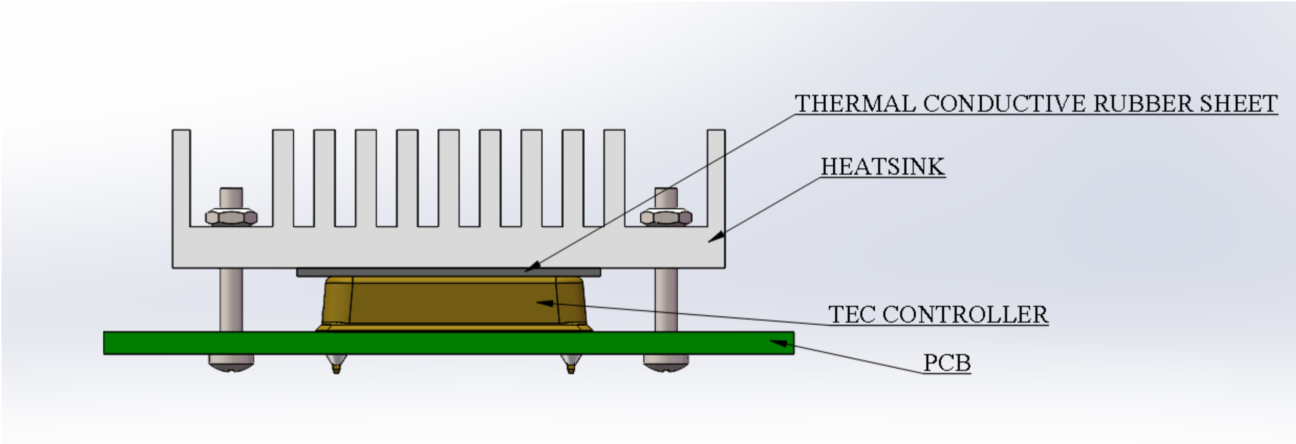


Figure 38. Transferring Heat with Heat Sink

MECHANICAL DIMENSIONS

The through-hole mount controller is often called DIP (Dual Inline package) or D (short for DIP) package and has a part number: TEC18V10AD, Dimensions of this controller is shown in Figure 39.

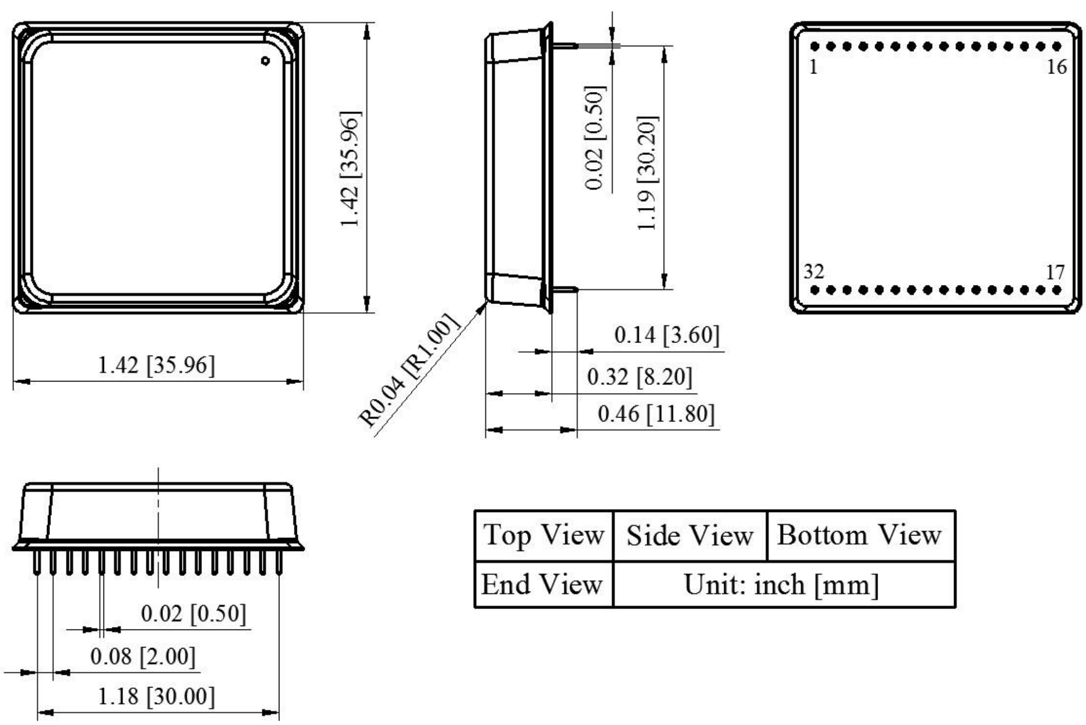


Figure 39. Dimensions of DIP Package

ORDERING INFORMATION

Table 7. Part Number

Part Number	Buy Now
TEC18V10AD	* *

NOTICE

1. It is important to carefully read and follow the warnings, cautions, and product-specific notes provided with electronic components. These instructions are designed to ensure the safe and proper use of the component and to prevent damage to the component or surrounding equipment. Failure to follow these instructions could result in malfunction or failure of the component, damage to surrounding equipment, or even injury or harm to individuals. Always take the necessary precautions and seek professional assistance if unsure about proper use or handling of electronic components.
2. Please note that the products and specifications described in this publication are subject to change without prior notice as we continuously improve our products. Therefore, we recommend checking the product descriptions and specifications before placing an order to ensure that they are still applicable. We also reserve the right to discontinue the production and delivery of certain products, which means that not all products named in this publication may always be available.
3. This means that while ATI may provide information about the typical requirements and applications of their products, they cannot guarantee that their products will be suitable for all customer applications. It is the responsibility of the customer to evaluate whether an ATI product with the specified properties is appropriate for their particular application.
4. ATI warrants its products to perform according to specifications for one year from the date of sale, except when damaged due to excessive abuse. If a product fails to meet specifications within one year of the sale, it can be exchanged free of charge.
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9. ATI retains ownership of all rights for special technologies, techniques, and designs for its products and projects, as well as any modifications, improvements, and inventions made by ATI.
10. Despite operating the electronic modules as specified, malfunctions or failures may occur before the end of their usual service life due to the current state of technology. Therefore, it is crucial for customer applications that require a high level of operational safety, especially in accident prevention or life-saving systems where the malfunction or failure of electronic modules could pose a risk to human life or health, to ensure that suitable measures are taken. The customer should design their application or implement protective circuitry or redundancy to prevent injury or damage to third parties in the event of an electronic module malfunction or failure.