High Efficiency Window TEC Controller

Analog Technologies Inc.

ATW3A314

Figure 1. Physical Photo of the ATW3A314D

FEATURES

- The world's first window based TEC controller: stands by automatically when the target object temperature is within a pre-set temperature window.
- Programmable set-point temperature window
- High efficiency: ǂ90%
- Seebeck voltage available
- Switching frequency synchronizable to an external signal
- Programmable maximum output current: 0 to 3A
- Programmable maximum output voltage: 0 to VPS
- Actual object temperature monitoring
- Completely shielded: zero EMI
- Compact size
- DIP and SMT packages available
- 100 % lead (Pb)-free and RoHS compliant

DESCRIPTIONS

The ATW3A314 is a compact high efficiency electronic module designed to control TECs (Thermo-Electric Coolers) for regulating a target object temperature to be within a pre-set temperature window. When the target object temperature falls within the pre-set temperature window range, the controller puts itself into a standby mode, decreasing energy consumption to a minimum level; when the target object temperature reaches the upper bound of the temperature window, the controller cools down the target object so that its temperature regulated to be equal to the upper bound of the window temperature; when the target object temperature reaches the lower bound of the window, the controller heats up the target object so that its temperature remains to be equal to the lower bound of the window temperature, as shown in Figure 3.

The output stage of the ATW3A314 utilizes a patented PWM-Linear topology, resulting in a high efficiency and small size. The output pins to the TEC terminals are filtered from PWM to a low frequency signal, thus eliminating the heating effect and the interference to other electronics, as opposed to driving the TEC with the PWM signal directly.

Figure 1 is the photo of an actual ATW3A314D.

The ATW3A314 TEC controller module provides interface ports for setting the desired target object temperature window range; the maximum output current; the maximum output voltage across the TEC; shutdown control, standby indication, and switching frequency synchronization input/output. The shut down pin shuts down the whole controller and cuts the power supply current to < 10μA. This shut down pin can also be used to force the controller into standby mode, which only shuts down the output stages, leaving the rest of the circuit active.

The sensing temperature range can be configured by the user conveniently by using 3 external resistors.

The TEC's voltage is monitored in real time. It is worth mentioning that the Seebeck voltage (which is generated by the temperature difference between the 2 TEC plates) can be detected under standby mode, it can be used to measure the temperature difference between the 2 TEC plates.

The TEC's actual current can also be monitored in real time.

In addition, the controller has many other functions: temperature measurement and monitoring, TMO; temperature control loop status indication, TGD; TEC voltage monitoring, VTEC; and current monitoring, ITEC; current limit settings, ILM; synchronization input and output, soft start, and shut down.

The window TEC controller ATW3A314 comes with a high stability low noise 2.5V voltage reference which can be used for setting the output voltage and current limits, and the desired target object temperature window by using POTs (Potentiometers) or a DACs (Digital to Analog Converters). When using this reference for setting the set-point window temperatures, the error in the actual target object temperature is independent of this reference voltage. This is because the internal temperature measurement network also uses the reference voltage as the reference, the errors in setting the temperature and measuring the temperature cancel with each other. This reference can also be utilized by external ADCs (Analog to Digital Converters). For the same reason, the measurement error will also be independent of the reference voltage change, resulting in a more accurate measurement.

The ATW3A314 is packaged in a 6 sided metal enclosure with the case connected to the ground node of the circuit, which blocks EMIs (Electro-Magnetic Interferences) to prevent the controller and other electronics from interfering with each other.

Figure 2 is the top view of the window TEC controller showing the pin names and locations. The ATW3A314 pin functions are shown in Table 1.

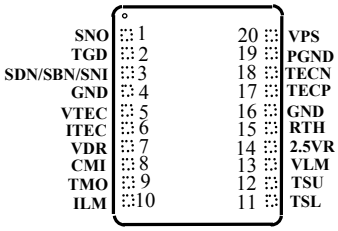

Figure 2. Pin Assignment

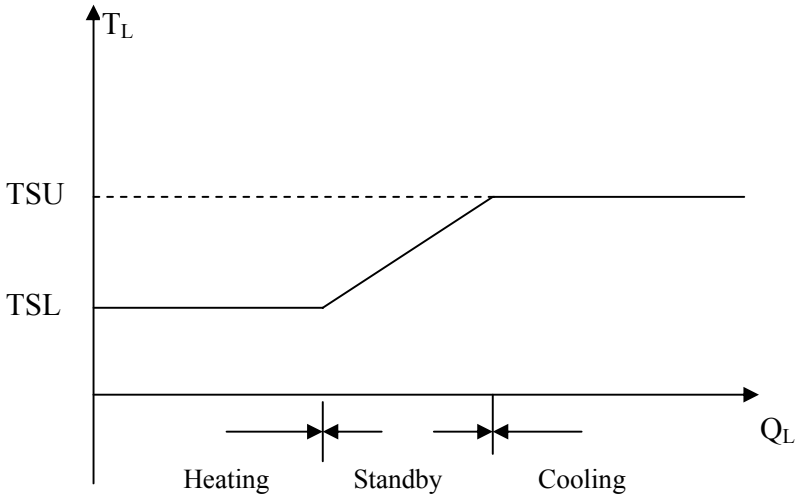

Figure 3. Thermal load temperature vs. Load thermal power

Table 1. Pin Function Descriptions

Pin #	Pin Name	Type	Description
1	SNO	Digital output	Synchronization pulse output. It can be used as the synchronization input signal of another switch-mode TEC controllers, laser drivers or power supplies.
2	TGD	Digital output	Temperature good indication. It goes high when the actual target object temperature is <0.2 C within the temperature window set by TSL and TSU pins. This pin can source or sink up to 20mA current.
3	SDN/SBN/ SNI	Digital input	This is a duplex digital input pin. Its first function is to shut down the whole controller by pulling this pin to ground or NC (Not Connected), <1.7V, reducing the total current draw from the VPS pin to < 10μA; the second function is to force the controller into the standby mode by driving this pin to between 1.7V and 2.2V; the third function is the synchronization input for the PWM output stage. It can be pulsed by a digital signal of 550kHz to 800kHz with which the internal switching can be synchronized, to avoid frequency beating interference with other nearby switch mode electronics, such as switch mode TEC controllers, laser drivers or power supplies.
4	GND	Ground	Signal ground for the potentiometers, ADCs, DACs and the thermistor.
5	VTEC	Analog output	TEC voltage indication. VTEC is an analog voltage output pin with a voltage proportional to the actual voltage across the TEC. The same as above, there is a 1.25V offset voltage on this pin, when the output voltage across the TEC is zero volt, the voltage on this pin would be 1.25V. The output voltage is calculated as: TECP - TECN = 4 × (VTEC(V) - 1.25V).

6	ITEC	Analog output	TEC current indication. ITEC is an analog voltage output pin with a voltage proportional to the actual current going through the TEC. There is a 1.25V offset voltage on this pin, when the current is zero, the output voltage of this pin is 1.25V. The output current is calculated as: I_{TEC} (A) = 2.4 × (VIEC(V) – 1.25V). When the voltage is 2.5V, the output current is 3A, the TEC works under cooling mode; when this voltage is 0V, the output current is negative 3A, the TEC works under heating mode.
7	VDR	Analog input	Compensation input pin for the thermal control loop.
8	CMI	Analog input	Compensation input pin for the thermal control loop.
9	TMO	Analog output	Actual target object temperature indication, its voltage is proportional to the temperature almost linearly. It swings from 0V to 2.5V, corresponding to 10 C to 40 C by default. The detail temperature vs. the voltage relationship is given in page 5.
10	ILM	Analog input	Sets maximum output current across TEC. Figure 5 shows the connections. To set the maximum current to be Imaxc, the resistance of the resistors R_4 and R_5 can be calculated as: $I_H = 5 - \frac{10R_4}{(R_4 // 80K) + R_5}$ I_H: the heating current. R_4//80K refers to R_4 and 80K are connected in parallel. $I_C = 5 - \frac{10(R_5 // 80K)}{R_4 + (R_5 // 80K)}$ I_C: the cooling current. R_5//80K refers to R_5 and 80K are connected in parallel Notice: if you need to use this pin to limit the output current, $I_C > I_H$ forever.
11	TSL	Analog input	Sets the lower temperature limit for the temperature window.
12	TSU	Analog input	Sets the upper temperature limit for the temperature window.
13	VLM	Analog input	Sets the maximum output voltage across TEC. The maximum voltage applied across the TEC can be limited. To set the maximum output voltage to be Vmax, VLM should be set at VLM = Vmax/5. If no limitation is needed, tie this pin to ground.
14	2.5VR	Analog output	Reference voltage output, 2.5V. It can be used by a POT or DAC for setting the set-point temperature window voltages on the TMSU and TMSL pins and/or a DAC for measuring the temperature through the TMO pin. The maximum sourcing current capability is 1.5mA and the maximum sinking is 4mA with a stability of <50ppm/ C max.
15	RTH	Analog input	Connects to the thermistor for sensing the target object temp. The other end of the thermistors is connected to the signal ground, pin 16, or pin 5. The thermistor's value can range from 1K to 100K@25 C. The most commonly used value is 10K@25 C.
16	GND	Ground	Signal ground for the potentiometers, ADCs, DACs and the thermistor.
17	TECP	Analog power output	Connects to TEC positive terminal.
18	TECN	Analog power output	Connects to TEC negative terminal.
19	PGND	Power ground	Power ground for connecting to the power supply.
20	VPS	Power input	Power supply positive rail, the operating range is 3.1V to 5.5V.

SPECIFICATIONS

Table 2. Characteristics ($T_{ambient}$ = 25 C)

Parameter	Test Condition	Value	Unit/ Note
Window temperature default range		10 ~ 40	C
Voltage setting range for TSL and TSU pins		0.1 ~ 2.4	V
Controller trigger-in and trigger-out voltage for the |TMO – TSL| or |TMO – TSU|		20	mV
Voltage limit set VLM range		0 ~ 1.25	V
Current limit set ILM range		0 ~ 1.25	V
Max output current	VPS = 5V, R_{load} = 0.8Ω	3	A
Standby current		5	mA
Shut down current		<10	mA
Efficiency	VPS = 5V, TECP – TECN = 3V, R_{load} = 1Ω	≥ 92	%
PWM frequency		500	KHz
Power supply voltage range	—	3.1 ~ 5.5	V
Operating ambient temp range	V_{in}=5V, R_{load}=0.8Ω	-40 ~ 85	C
Module thermal resistance		10	C/W

BLOCK DIAGRAM

The block diagram of the controller is shown in Figure 4.

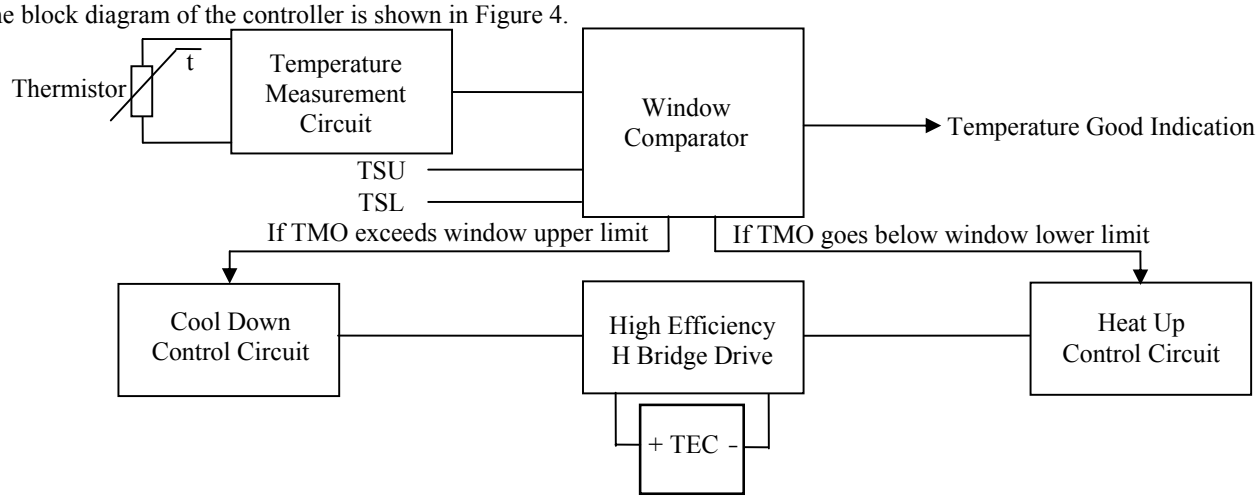

Figure 4. Window TEC Controller Block Diagram

APPLICATIONS

TEC controller connections are shown in Figure 5.

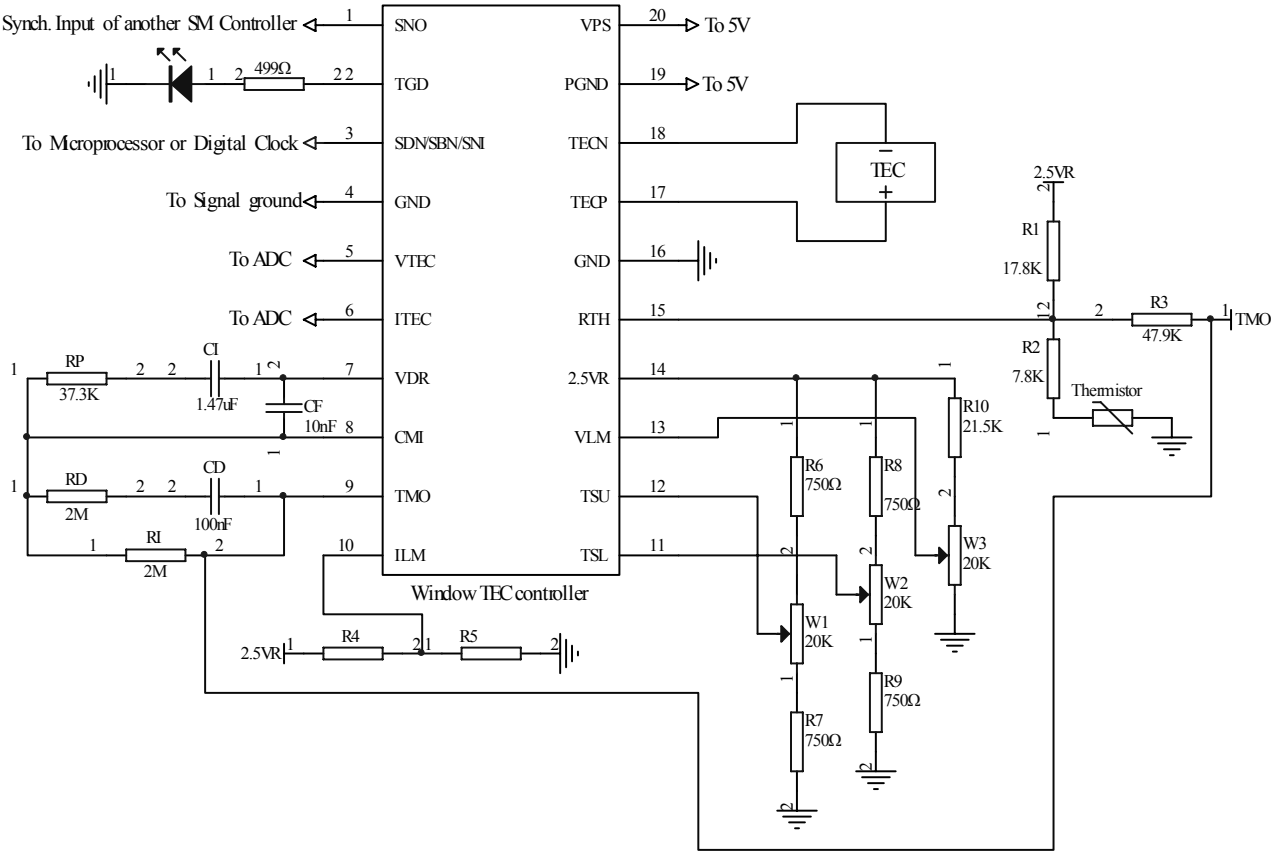

Figure 5. TEC Controller Connections

If you want to use this TEC controller for other applications not discussed here, for example, use it with wave locker controllers, please consult with us. The same as to other customizations, such as setting the TSU and TSL by using a voltage source swings above 2.5V and/or VPS.

After many experiments, according to the parameter and the figuring method of R_{load}, we advise customers to use R_{load} of 0.8Ω, and 5V as the power supply.

CONFIGURE SETPOINT TEMPERATURE RANGE

The default values for Resistors R1, R2 and R3 shown in Figure 5 are optimal for a 10kΩ, β = 3950@25°C thermistor to lock a TEC temperature at 25°C. The sections that follow describe how to configure potentiometers for different negative temperature coefficient (NTC) thermistors.

Thermistor Values

Determine the three thermistor resistance values: R_{HIGH}, R_{MID}, and R_{LOW}. To do this, refer to the thermistor R-T table in our company's ATH10K1R25 thermistor datasheet. (http://www.analogtechnologies.com/document/ATH10K1R25.pdf). This is based on the required TEC thermal control resolution and the target controllable temperature range.

These resistor values correspond to the high, middle, and low setpoint temperatures (T_{HIGH}, T_{MID}, and T_{LOW}).

$$T_{MID} = \frac{T_{HIGH} + T_{LOW}}{2}.$$

T_{MID} is the average temperature, between T_{HIGH} and T_{LOW}. $V_{TEMPOUT}$ is the voltage output at the TEMPOUT pin. It is R_{TH} resistance dependent. $V_{TEMPOUT}$ is a function of R_{TH}, R1, R2, and R3 as:

$$V_{TEMPOUT} = 0.5 \cdot V_{REF} \cdot R3 \cdot \left[\frac{1}{R3} - \frac{1}{R1} + \frac{1}{R2 + R_{TH}}\right].$$

In a design, let $V_{TEMPOUT}$ equal the following values at the three thermistor resistances:

$R_{TH} = R_{HIGH}$ (at T_{HIGH}): $V_{TEMPOUT} = V_{REF}$,

$R_{TH} = R_{MID}$ (at T_{MID}): $V_{TEMPOUT} = 0.5 \times V_{REF}$,

$R_{TH} = R_{LOW}$ (at T_{LOW}): $V_{TEMPOUT} = 0V$.

Resistor Values

To achieve the required $V_{TEMPOUT}$ outputs at the three different setting point temperatures, use the equation:

$$R1 = R_{MID} + \frac{R_{MID}(R_{LOW} + R_{HIGH}) - 2R_{HIGH}R_{LOW}}{R_{HIGH} + R_{LOW} - 2R_{MID}} \quad (1),$$

$$R2 = R1 - R_{MID} \quad (2),$$

$$R3 = \frac{R1(R2 + R_{LOW} - R_{MID})}{R_{LOW} - R_{MID}} \quad (3).$$

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

R_{HIGH} = 6.5341kΩ,

R_{MID} = 10kΩ,

R_{LOW}= 15.717KΩ.

By using equations 1 to 3, the following 3 results established:

R1 = 16.82kΩ,

R2 = 6.82kΩ,

R3 = 36.89kΩ.

Table 3. Measurement Data of Rth vs. Temperature

Temp(℃)	Resistance(KΩ)	Temp(℃)	Resistance(KΩ)	Temp(℃)	Resistance(KΩ)
0	32.738	17	14.327	34	6.8109
1	31.104	18	13.683	35	6.5341
2	29.568	19	13.073	36	6.2711
3	28.109	20	12.494	37	6.0180
4	26.729	21	11.943	38	5.7788
5	25.428	22	11.419	39	5.5496
6	24.205	23	10.923	40	5.3302
7	23.041	24	10.449	41	5.1207
8	21.935	25	10.000	42	4.9211
9	20.908	26	9.5730	43	4.7315
10	19.921	27	9.1658	44	4.5478
11	19.984	28	8.7783	45	4.3740
12	18.100	29	8.4085	46	4.2082
13	17.264	30	8.0586	47	4.0484
14	16.471	31	7.7224	48	3.8944
15	15.717	32	7.4041	49	3.7485
16	15.004	33	7.0995	50	3.6085

TUNE THE COMPENSATION NETWORK

The purpose for this step is to match the controller compensation network with the thermal load characteristics thus that the response time and temperature tracking error are minimized. Changing the set-point temperature TMS just a small amount, simulating a step function. At the same time, connect an oscilloscope at the VDR test pin (on the left side of the evaluation board), set it to a scrolling mode (0.2 Second/Division or slower) and monitor the waveform of VDR as TMS is fed by a step function signal. The circuit in the compensation network is shown in Figure 8 below.

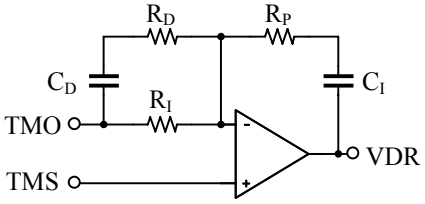

Figure 8 Compensation network

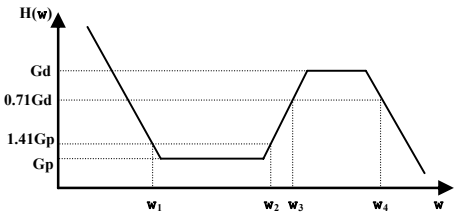

Figure 9 Transfer Function of the Compensation Network

The transfer function of the compensation network, defined as H(w)=VDR(w)/TMO(w), is shown in figure 9.

In principle, these are the impacts of the components to the tuning results:

a. R_P/R_I determines the gain for the proportional component of the feedback signal which is from the thermistor, Gp = R_P/R_I, in the control loop, the higher the gain, the smaller the short term error in the target

temperature (which is of the cold side of the TEC) compared with the set-point temperature, but the higher the tendency of the loop's instability.

b. R_P/R_D determines the gain for the differential component, $Gd = R_P/(R_D//R_I) \approx R_P/R_D$, where symbol "//" stands for two resistors in parallel, since $R_I >> R_D$, $R_D//R_I \approx R_D$. The higher the gain, the shorter the rise time of the response, the more the overshoot and/or the undershoot will be.

c. C_I*R_P determines the corner frequency, $w_1 = 1 / (C_I*R_P)$, where the integral component starts picking up, as the frequency goes down. It determines the cut-off frequency below which the TEC controller will start having a large open loop gain. The higher the open loop gain, the smaller the tracking error will be.

d. C_D*R_I determines the corner frequency, $w_2=1/(C_D*R_I)$, where the differential component starts picking up (see Figure 9), as the frequency goes up.

e. C_D*R_D determines the corner frequency, $w_3=1/(C_D*R_D)$, where the differential component starts getting flat. It determines the cut-off frequency above which the TEC controller will give extra weight or gain in response.

f. $1nF*R_P$ determines the corner frequency, $w_4=1/(1nF*R_P)$, where the differential component starts rolling down. Since this frequency is way higher than being needed for controlling the TEC, w_4 does not need to be tuned. The capacitor is built into the TEC controller module, not the evaluation board.

MECHANICAL DIMENSIONS

In addition to ATW3A314D, we also have ATW3A314S, which is SMT packaged. Dimensions of the DIP packaged controller is shown in Figure 6, dimensions of the SMT packaged controller is shown in Figure 7.

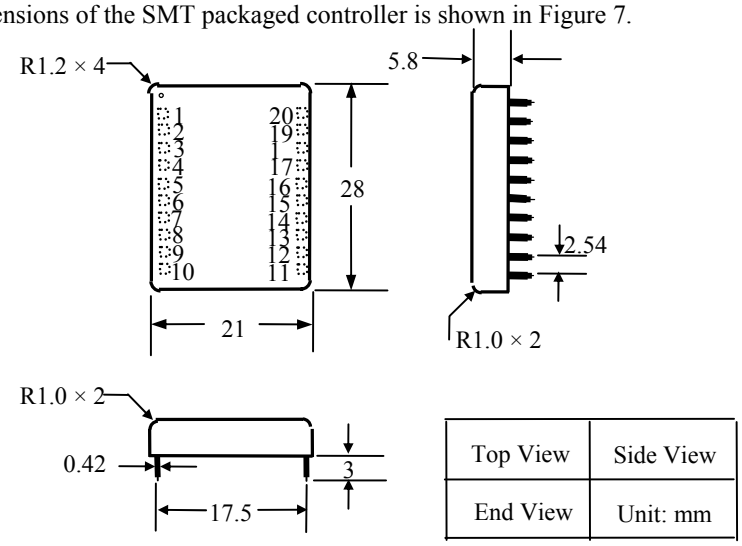

Figure 6. Dimensions of the DIP Package Controller

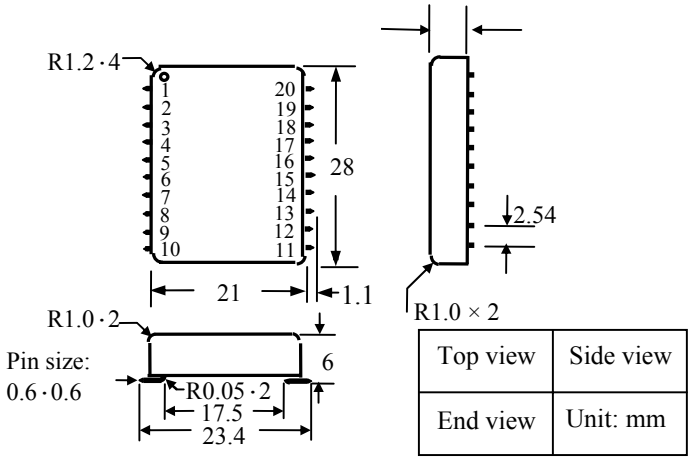

Figure 7. Dimensions of the SMT Package Controller

ORDERING INFORMATIONS

Table 4. Unit Price

Part#	Description	Price				
		1 – 9	10 – 49	50 - 199	200 – 499	≥500
ATW3A314D	DIP (Dual Inline Package) package	$92.4	$87.2	$81.9	$76.7	$71.4
ATW3A314S	SMT (Surface Mount Technology) package	$92.4	$87.2	$81.9	$76.7	$71.4

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