

### General Description

The AQ1541 is a low dropout three terminal voltage regulator, offered in popular fixed options or an adjustable version that can set a precise voltage from 1.22V to 12V with two external resistors.

It drops into the footprint of the popular LM1117 SOT-223 and provides a true fourth pin separated from the output tab. The extra pin allows for an **enable function** that provides a remote turn-off for low power consumption. It draws virtually zero current in shutdown mode. The Enable pin implements Sequential, Ratio-metric, or Simultaneous sequencing schemes.

To assure accuracy within 1.5% over temperature the heart of the AQ1541 is a self-correcting AcuRef™ bandgap reference.

On-chip current limit and thermal shutdown with hysteresis protects against any combination of overload and ambient temperature that might cause the junction temperature to exceed safe limits.

The AQ1541 is featured in the new **SOT223 4-lead TetraPack™** package.

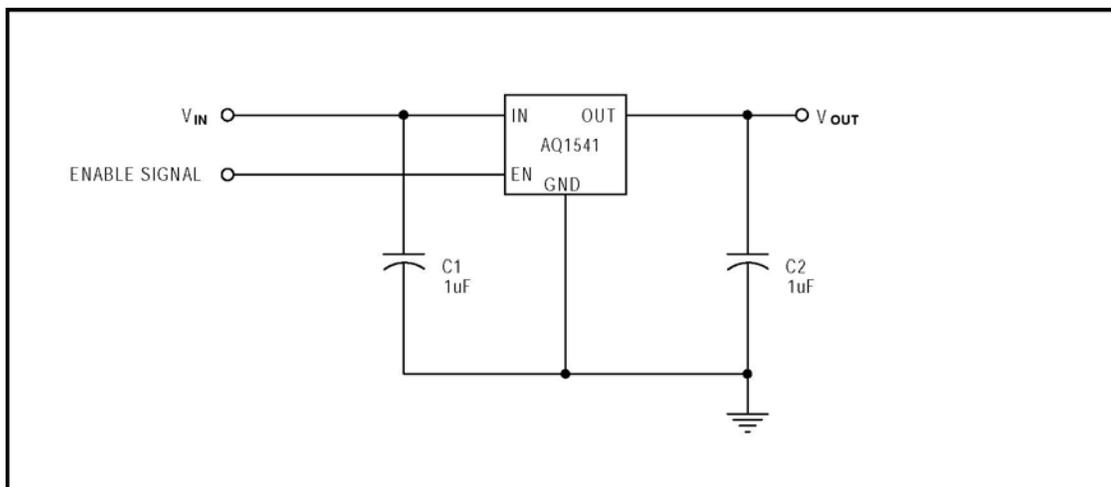
### Applications

- Graphic cards
- PC motherboards
- Switching power supply post-regulation
- Telecom equipment
- DVD video player

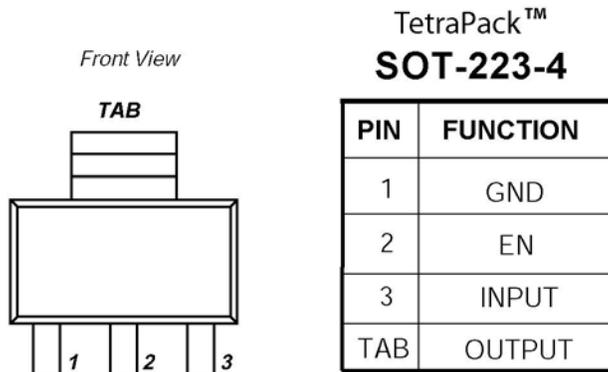
### Features

- Enable pin **implements sequencing** in SOT223-3 footprint
- Vout tolerance 1.5% over temperature
- Eliminates expensive components
- Stable with low cost 1uF capacitor
- Low dropout voltage (1V at 1 Amp)
- Thermal protection with hysteresis
- Short circuit protection
- Offered with 1.8V, 2.5V, and 3.3V fixed or adjustable output
- **RoHS compliant** available

### Typical Application



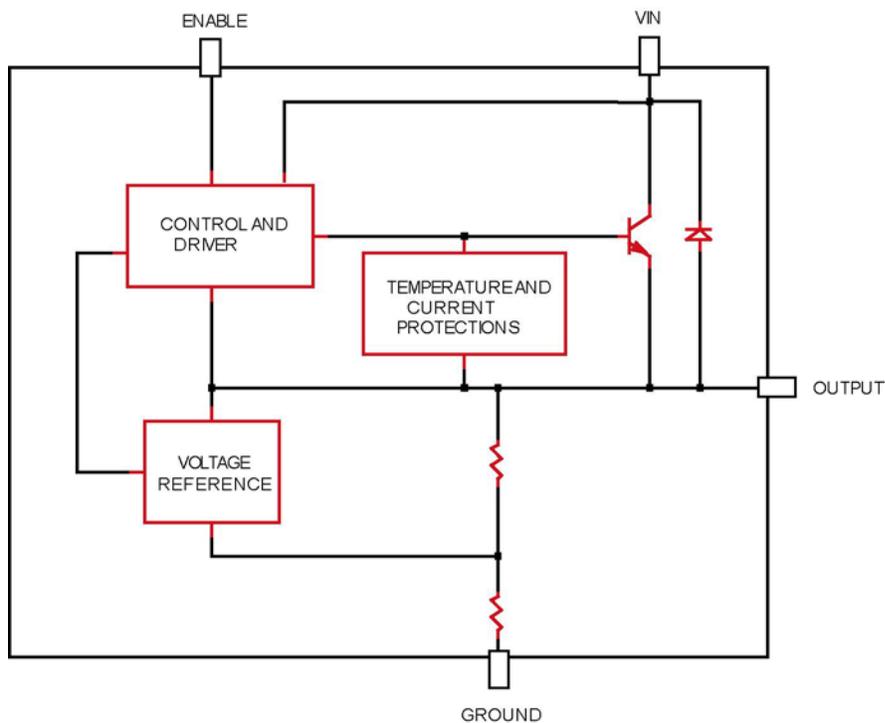
## Pin Configuration



## Pin Descriptions

Pin Name	Function
V <sub>IN</sub>	Accepts + VCC
V <sub>OUT</sub>	Regulated Output
Ground/Adjust	- VCC for fixed option / Adjust pin for adjustable option
ENABLE	Active high, ENABLE > (0.5V + V <sub>OUT</sub> ). Connect to V <sub>IN</sub> when not in use.

## Functional Block Diagram



## Ordering Information

Device	Operating Tj	%Tol	PKG Type	Vout	Wrap	Ordering Number
AQ1541	0C° ≤ 125C°	1.0	SOT-223-4	1.8V	T&R	AQ1541CY-S4-18-TR
AQ1541	0C° ≤ 125C°	1.0	SOT-223-4	1.8V	T&R	AQ1541CY-S4-18-TRL
AQ1541	0C° ≤ 125C°	1.0	SOT-223-4	2.5V	T&R	AQ1541CY-S4-25-TR
AQ1541	0C° ≤ 125C°	1.0	SOT-223-4	2.5V	T&R	AQ1541CY-S4-25-TRL
AQ1541	0C° ≤ 125C°	1.0	SOT-223-4	3.3V	T&R	AQ1541CY-S4-33-TR
AQ1541	0C° ≤ 125C°	1.0	SOT-223-4	3.3V	T&R	AQ1541CY-S4-33-TRL
AQ1541	0C° ≤ 125C°	1.0	SOT-223-4	ADJ	T&R	AQ1541CY-S4-AJ-TR
AQ1541	0C° ≤ 125C°	1.0	SOT-223-4	ADJ	T&R	AQ1541CY-S4-AJ-TRL

Note: The TRL parts are Lead Free and RoHS compliant.

## Absolute Maximum Ratings

Stress greater than those listed under “Absolute Maximum Ratings” may cause permanent damage to the device. These stress ratings only, and functional operation of the device at these or any conditions beyond those indicated under recommended Operating Conditions is not implied. Exposure to “Absolute Maximum Rating” for extended periods may affect device reliability. Use of standard ESD handling precautions is required.

Parameter	Value	Units
Maximum VIN	18	Volts
Maximum VEN	18	Volts
Maximum IEN	10	mA
Power Dissipation (Internally limited)		
Maximum Junction Temperature	150	°C
Operating Junction Temperature Range	0 to 125	°C
Storage Temperature Range	-65 to 150	°C
Lead Temperature (Soldering, 10 sec.) TO packages	300	°C
Lead Temperature (Soldering, 4sec.) SOT- 223 package	300	°C

## Thermal Management

Thermal Resistance (Junction to TAB)	Typical Value	Units
SOT-223	15	°C/W

Thermal Resistance (Junction to Ambient)	Typical Value	Units
SOT-223 (tab soldered to 1 in <sup>2</sup> 1 oz. copper PCB)	46	°C/W

## Electrical Specifications

Electrical characteristics are guaranteed over the full temperature range  $0^{\circ}\text{C} < T_j < 125^{\circ}\text{C}$ . Ambient temperature must be de-rated based upon power dissipation and package thermal characteristics. Unless otherwise specified:  $V_{\text{ENABLE}} = V_{\text{IN}} = (V_{\text{OUT}} + 1.5\text{V})$ ,  $I_{\text{OUT}} = 10 \text{ mA}$ ,  $T_j = 25^{\circ}\text{C}$ . All values in **bold** are over the full temperature range.

Symbol	Parameter	Conditions	Min	Typ	Max	Units
VOUT	Output Voltage (1)		-1	VOUT	+1	%
		$0^{\circ}\text{C} \leq T_j \leq 125^{\circ}\text{C}$	<b>-1.5</b>	VOUT	<b>+1.5</b>	%
LNREG	Line Regulation (1)	$\Delta V_{\text{IN}} = V_{\text{OUT}} + (1.5\text{V to } 10\text{V})$		0.035	<b>0.2</b>	%
LDREG	Load Regulation (1)	$\Delta I_{\text{OUT}} = (10\text{mA to } 1 \text{ Amp})$		0.2	<b>0.4</b>	%
VD	Drop out Voltage (1, 2)	$I_{\text{OUT}} = 100 \text{ mA}$		0.91	<b>0.95</b>	V
		$I_{\text{OUT}} = 500 \text{ mA}$		0.93	<b>0.95</b>	V
		$I_{\text{OUT}} = 1 \text{ Amp}$		0.95	<b>1.0</b>	V
ISC	Current Limit (1)	$V_{\text{IN}} - V_{\text{OUT}} = 2\text{V}$	1.1	1.5		A
IQON	Quiescent Current ON	$V_{\text{IN}} = V_{\text{ENABLE}} = 5\text{V}$		7.5	9.0	mA
		$0^{\circ}\text{C} \leq T_j \leq 125^{\circ}\text{C}$			<b>10</b>	mA
IQOFF	Quiescent Current Off	$V_{\text{IN}} = 5\text{V}$ $V_{\text{ENABLE}} = \text{GND}$		0.1	0.5	$\mu\text{A}$
		$0^{\circ}\text{C} \leq T_j \leq 125^{\circ}\text{C}$		0.1	<b>1.0</b>	$\mu\text{A}$
VIL	Enable Pin Voltage (OFF)	With respect to GND	<b>0.25</b>	0.45		V
VIH	Enable Pin Voltage (ON)	With respect to VOUT		0.5	<b>0.8</b>	V
IIL	Enable Pin Current (OFF)	$\text{ENABLE} = 0\text{V}$ , $V_{\text{IN}} = 5\text{V}$		0.1	1.0	$\mu\text{A}$
IIH	Enable Pin Current (ON)	$\text{ENABLE} = V_{\text{IN}} = 5\text{V}$		10	<b>25</b>	$\mu\text{A}$
VADJ	Reference Voltage	Adjustable version only	1.208	1.220	1.232	V
		$0^{\circ}\text{C} \leq T_j \leq 125^{\circ}\text{C}$	<b>1.202</b>		<b>1.238</b>	V
IADJ	Adjust Pin Current (5)	Adjustable version only		20	<b>40</b>	$\mu\text{A}$
$\Delta$ IADJ	Adjust Pin Current (5) Change	$10\text{mA} \leq I_{\text{OUT}} \leq 1\text{Amp}$ $1.4 \leq V_{\text{IN}} \leq 18\text{V}$		0.2	<b>5.0</b>	$\mu\text{A}$
IQMIN	Minimum Load Current (5)	To Maintain regulation		0.5	<b>2.0</b>	mA
TC	Temperature Coefficient			<b>0.005</b>		$\%/^{\circ}\text{C}$
TS	Temperature Stability			<b>0.5</b>		$\%/^{\circ}\text{C}$
VN	RMS Output Noise (3)			0.003		$\%$ VOUT
PSRR	Ripple Rejection Ratio (4)	$V_{\text{in}} = 5\text{V}$	<b>60</b>	72		dB
TSD	Thermal Shutdown	Junction Temperature		<b>150</b>		$^{\circ}\text{C}$
TSDHYST	TSD Hysteresis			<b>25</b>		$^{\circ}\text{C}$

**Notes:** (1) Low duty cycle pulse testing with Kelvin connections required.

(2) Measure  $(V_{\text{IN}} - V_{\text{OUT}})$  when  $\Delta V_{\text{OUT}}$ , OR  $\Delta V_{\text{REF}} = 1\%$

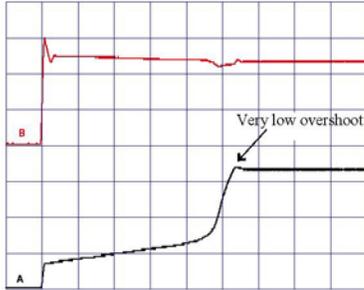
(3) Bandwidth of 10Hz to 10kHz

(4) 120Hz input ripple

(5) Adjustable version only

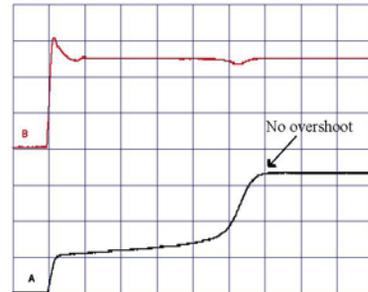
# Typical Response Curves

Output Overshoot With Line, 500mA Load



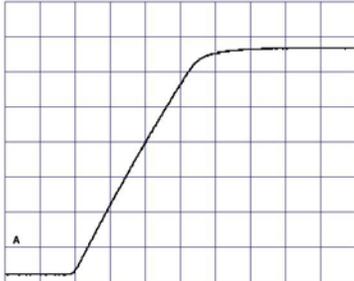
Input Step (B) 0-5V  
Output Response (A) 0-3.3V with 500mA load  
Horizontal: 100us/div

Output Overshoot With Line, No Load



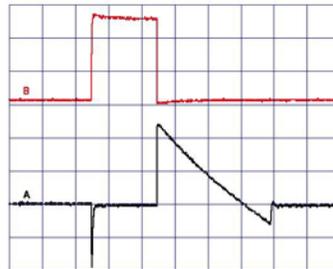
Input Step (B) 0-5V  
Output Response (A) 0-3.3V Zero Load  
Horizontal: 20us/div

Active Load Short Circuit Cycling



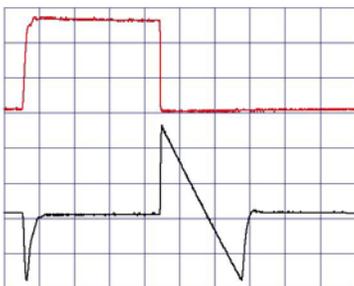
Output Response (A)  
Low duty cycle, repetitive, no thermal limit intervention  
Horizontal: 10us/div Vertical: 500mV/div

Load Step 0mA to 500mA



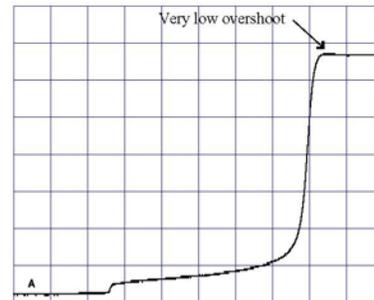
Load Step (B) 0mA to 500mA to 0mA  
Output Response (A) 50mV/div (AC coupled)  
Horizontal: 500us/div

Load Step 10mA to 500mA



Load Step (B) 10mA to 500mA to 10mA  
Output Response (A) 50mV/div (AC coupled)  
Horizontal: 100us/div

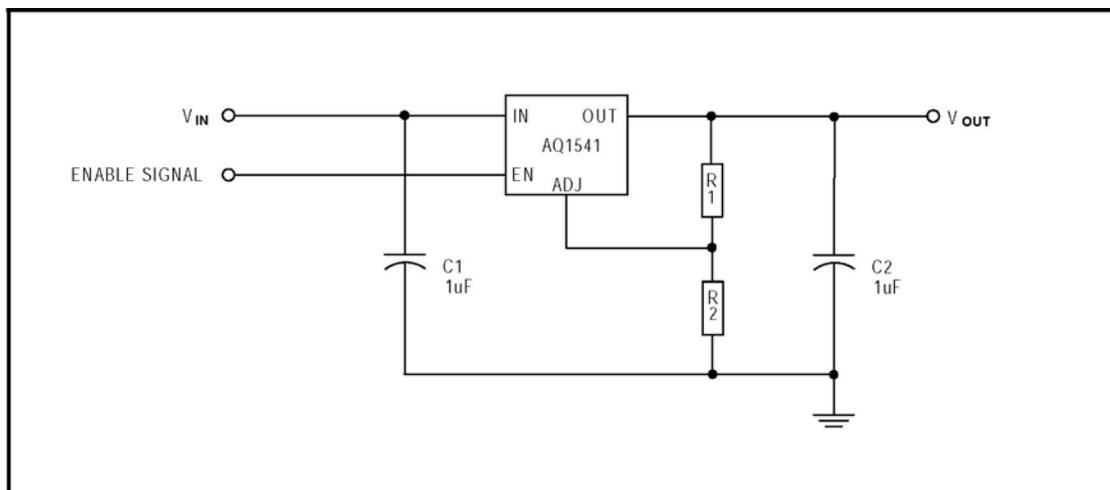
Short Circuit Removal (to no load)



Output Response (A) 0-3.3V  
Output grounded to open circuit, single shot  
Horizontal: 200us/div Vertical: 500mV/div

## Application Notes

### 1. Typical Application



#### Notes:

1. Output voltage is  $1.22V * (R2 + R1)/R1$
2. Input and output capacitors should be located close to the device.
3. The AQ1541 will remain stable with C1 and C2 as low as 1.0µF. Overall transient performance is improved with increased capacitance.
4. The output is fully enabled when EN is 800 mV above the expected output. EN should not be pulled substantially above Vin. EN may be driven by either a digital or analog signal to control either turn-on time or to give full control of risetime.

### 2. Stability

An input capacitor is recommended. A 1.0µF capacitor on the input is a suitable input bypassing for almost all applications. A larger capacitor is also suitable. In the adjustable version the “adjust” terminal can be bypassed to ground with a bypass capacitor ( $C_{ADJ}$ ) to improve ripple rejection. This bypass capacitor prevents ripple from being amplified as the output voltage is increased. At any ripple frequency, the impedance of the  $C_{ADJ}$  should be less than R1 (being R1 the resistor between the output and the adjust pin) to prevent the ripple from being amplified:

$$Z = 1/(2\pi * f_{RIPPLE} * C_{ADJ}) < R1$$

R1 is normally in the range of 1KΩ.

The output capacitor is critical in maintaining regular stability. The AQ1541 is stable with an output capacitor greater than 1µF. Of course any increase of the output capacitor will merely improve the loop stability and the load transient response. In the case of the adjustable regulator, when the  $C_{ADJ}$  is used, a larger output capacitance may be required. Tantalum Capacitors exhibit the best stability over a wide range of loads and are recommended.

### 3. Output Voltage

The AQ1541 adjustable version develops a 1.22V reference voltage between the output and the adjust pin terminal. This voltage is applied across the resistor R1 to generate a constant

current ( $I_1$ ). The current from the adjust terminal could introduce error to the output, but since it is very small ( $< 20\mu\text{A}$ ) compared with the current  $I_1$  and very constant with line and load changes, the error can be ignored. The constant current  $I_1$  then flows through resistor  $R_2$  and sets the output voltage to the desired level.

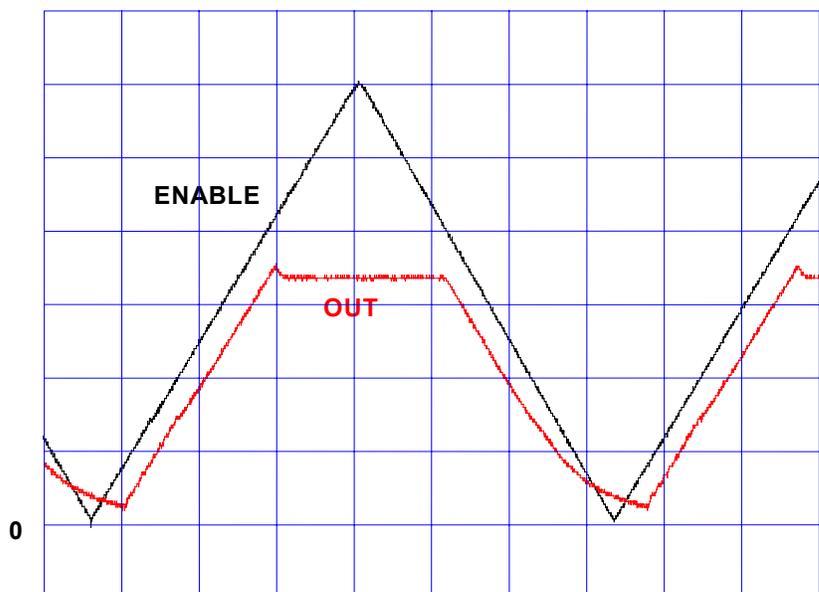
For fixed voltages the resistor  $R_1$  and  $R_2$  are integrated inside the devices.

The AQ1541 regulates the voltage that appears between its output and ground pins or between its output and adjust pins. In some cases, line resistances can introduce errors to the voltage across the load. To obtain the best load regulation a few precautions are needed. For example it is important to minimize the line resistances to the load, so the load itself should be tied directly to the output terminal on the positive side and directly to the ground terminal on the negative side.

When the adjustable regulator is used, the best performance is obtained with the positive side of the resistor  $R_1$  tied directly to the output terminal of the regulator rather than near the load. This will eliminate line drops from appearing effectively in series with the reference and degrading regulation. In addition the ground side of the resistor  $R_2$  can be returned near the ground of the load to provide remote ground sensing and improve load regulation. A capacitor (470pF) between the ADJ pin and system ground will enhance stability.

#### 4. Enable/Sequencing

The AQ1541 provides an enable function. The EN pin has to be at least 800 mV higher than the output voltage for the device to be fully turned on. When the voltage of the EN pin is low the device is in shutdown mode and it will not draw any current from the VIN terminal.



**FIG.2 ENABLE 0-5V, Output follows to 3.3V out  
(1V/div vertical, 200us/div horizontal)**

In addition the enable function includes a sequencing feature, because when the enable pin ramps in voltage the output voltage follows (it will be around 800 mV less than the enable voltage until it reaches the regulation voltage) as shown in Fig. 2 above.

In applications where multiple regulated supply rails are required, it is often required that the relationship between the various supply voltages be controlled during start-up and

shutdown. To this end, the AQ1541 allows for an analog control of the output voltage via the ENBL pin. This allows for sequential, ratio-metric and simultaneous sequencing schemes.

In a simple sequencing scheme, the output voltage can be delayed with respect to the application of  $V_{in}$  by connecting an RC network as shown in figure 3 below. This RC generates a slow ramp at the enable pin; the output follows 800 mV below this ramp until the output reaches regulation.

Virtually no current flows into the enable pin until it reaches the enable voltage which is equal to  $V_{out} + 800\text{ mV}$ . Therefore, the time delay can be reliably set by using the time constant of a known RC to slow the of the enable pin.

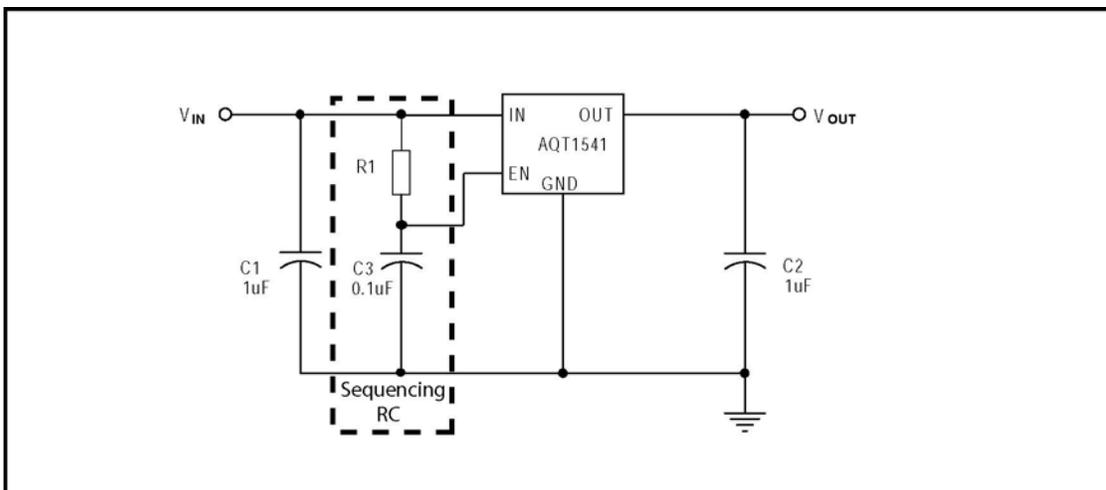


FIG.3 Enable delay circuit

The Enable and Output raise with respect to a  $V_{in}$  is shown in Fig.3 below.  $V_{in} = 5V$ ,  $V_{out} = 2.5V$ ,  $RC = 100\text{ K}\Omega$  and  $100\text{ nF}$ . The output is in regulating 13 ms after the input supply is applied.

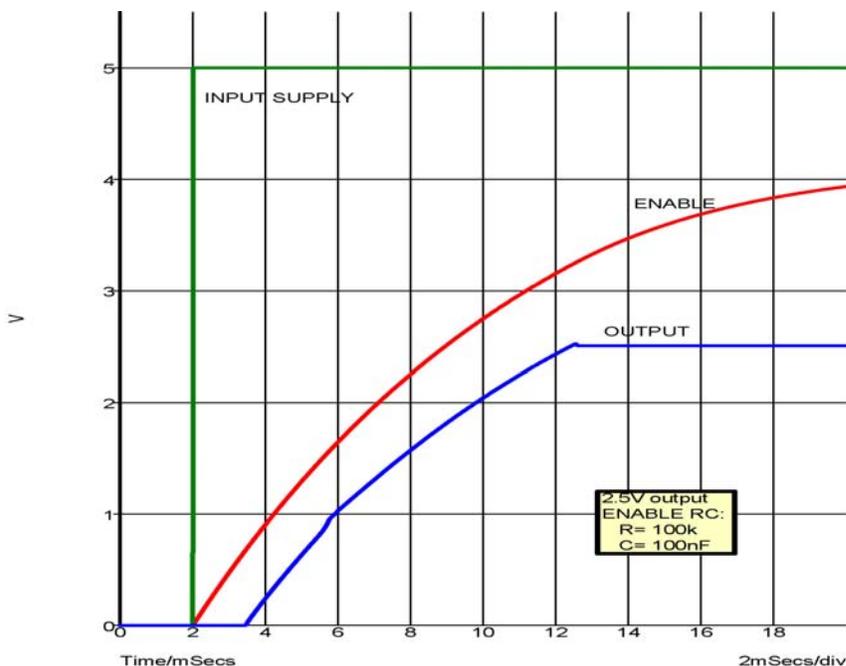


FIG. 4 Enable circuit delays output

## 5. Protection Diodes

Unlike older regulators, the AQ1541 family does not need any protection diodes between the adjustment pin and output or from the output to the input to prevent over-stressing the die. Internal resistors are limiting the internal current paths on the adjustment pin. Therefore, even with capacitors on the adjustment pin, no protection diode is needed to ensure device safety under short circuit conditions. External diodes between the input and output are not usually needed. Only if high value output capacitors are used (> 1000uF) and the input is instantaneously shorted to ground, can damage occur.

## 6. Thermal Considerations

When an integrated circuit operates with an appreciable current, its junction temperature is elevated. It is important to quantify its thermal limits in order to achieve acceptable performance and reliability. This limit is determined by summing the individual parts consisting of a series of temperature rises from the semiconductor junction to the operating environment. The heat generated at the device junction flows through the die to the die attach pad, through the lead frame to the surrounding case material, to the printed circuit board, and eventually to the ambient environment.

The AQ1541 regulators have internal thermal shutdown to protect the device from over-heating. Under all possible operating conditions, the junction temperature of the AQ1541 must be lower than 125°C. A heatsink may be required depending on the maximum power dissipation and maximum ambient temperature of the application.

To determine if a heatsink is needed, the power dissipated by the regulator,  $P_D$ , must be calculated:

$$P_D = (V_{IN} - V_{OUT}) I_L$$

where the  $I_L$  is the load current.

The next parameter which must be calculated is the maximum allowable temperature rise,  $T(\max)$ :

$$T(\max) = T_J(\max) - T_A(\max)$$

where  $T_J(\max)$  is the maximum allowable junction temperature (125°C), and  $T_A(\max)$  is the maximum ambient temperature which will be encountered in the application.

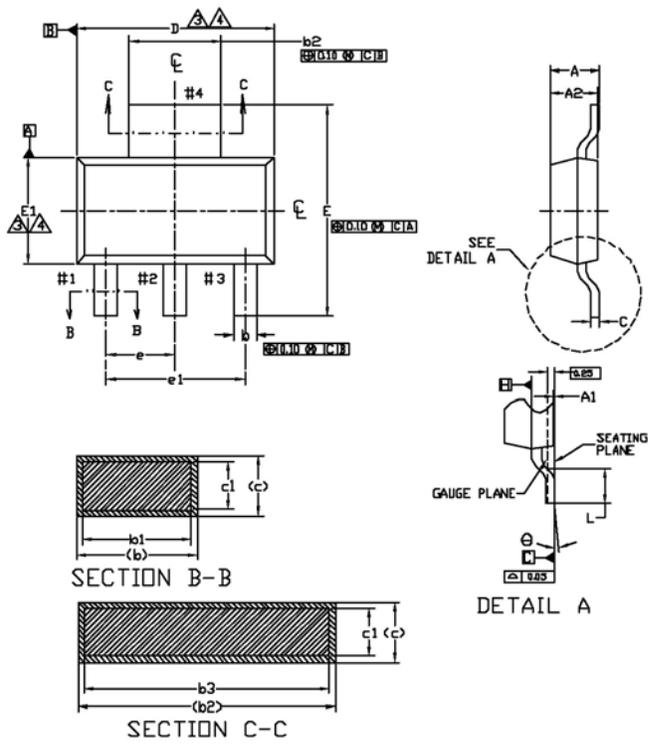
Using the calculated values for  $T(\max)$  and  $P_D$ , the maximum allowable value for the junction to ambient thermal resistance ( $\theta_{JA}$ ) can be calculated:

$$\theta_{JA} = T(\max) / P_D$$

If the maximum allowable value for  $\theta_{JA}$  is found to be greater than the junction to ambient thermal resistance for the package used, no heatsink is needed since the package alone will dissipate enough heat to satisfy these requirements.

# Package Dimensions

## SOT223-4 TetraPack™



Note :

- 1 DIMENSION ARE IN MILLIMETERS
- 2 DIMENSIONS b1, b3, AND c1 APPLY TO BASE METAL ONLY. DIMENSIONS b, b2, AND c APPLY TO PLATED LEAD. THESE DIMENSIONS APPLY TO THE FLAT SECTION OF THE LEAD BETWEEN 0.08mm AND 0.15mm FROM THE LEAD TIP.
- 3 DIMENSIONS D AND E1 ARE DETERMINED AT THE OUTERMOST EXTREMES OF THE PLASTIC BODY EXCLUSIVE OF MOLD FLASH, TIE BAR BURRS, GATE BURRS, AND INTERLEAD FLASH, BUT INCLUDING ANY MISMATCH BETWEEN THE TOP AND BOTTOM OF THE PLASTIC BODY.
- 4 DATUMS A AND B ARE TO BE DETERMINED AT DATUM H.
- 5 CONTROLLING DIMENSION IS MILLIMETER. CONVERTED INCH DIMENSION ARE NOT NECESSARILY EXACT

SYMBOL	ALL DIMENSIONS IN MILLIMETERS		ALL DIMENSIONS IN INCH	
	MINIMUM	MAXIMUM	MINIMUM	MAXIMUM
A	1.57	1.75	0.062	0.069
A1	0.02	0.10	0.0008	0.004
A2	1.55	1.65	0.061	0.065
b	0.66	0.84	0.026	0.033
b1	0.60	0.79	0.024	0.031
b2	2.90	3.10	0.114	0.122
b3	2.84	3.05	0.112	0.120
c	0.23	0.33	0.009	0.013
c1	0.23	0.33	0.009	0.013
D	6.30	6.70	0.248	0.264
E	6.70	7.30	0.264	0.287
E1	3.30	3.70	0.130	0.146
e	2.30 BASIC		0.090 BASIC	
e1	4.60 BASIC		0.180 BASIC	
L	0.90	-	0.035	-
Θ	0°	8°	0°	8°

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