

## 2.5V and 4.096V Voltage References

### DEVICE SELECTION TABLE

Part Number	Nominal Reference Voltage Output (V)	Input Voltage Range (V)
MCP1525	2.5	2.7 - 5.5
MCP1541	4.096	4.3 - 5.5

### FEATURES

- Precision voltage reference
- Output voltages of 2.5V and 4.096V
- Initial accuracy of  $\pm 1\%$  max.
- Temperature drift:  $\pm 50$  ppm/ $^{\circ}\text{C}$ , max.
- Output current drive:  $\pm 2\text{mA}$
- Max operating current:  $100\ \mu\text{A}$  @  $25^{\circ}\text{C}$ , max.
- TO-92, SOT23-3 packages
- Industrial temperature range:  $-40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$

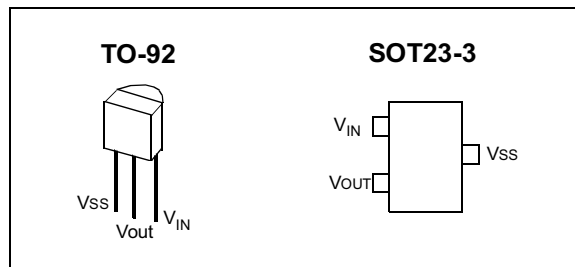
### APPLICATIONS

- Battery Powered Systems
- Handheld Instruments
- Instrumentation and Process Control
- Test Equipment
- Data Acquisition Systems
- Communications Equipment
- Medical Equipment
- Precision Power supplies
- 8-bit, 10-bit, 12-bit A/D Converters
- D/A Converters

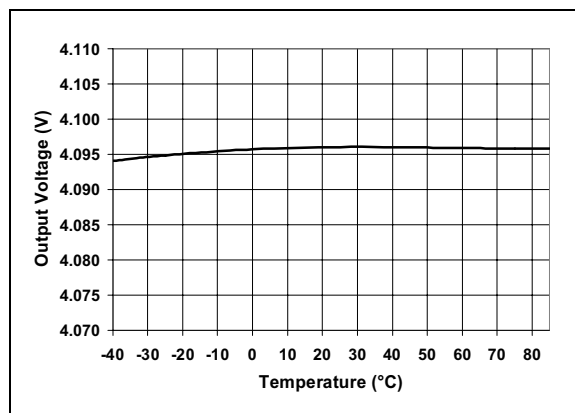
### DESCRIPTION

The Microchip Technology Inc. MCP1525 and MCP1541 devices are 2.5V and 4.096V precision voltage references that use a combination of an advanced CMOS circuit design and EPROM trimming to provide an initial tolerance of 1% (max) and temperature stability of 50 ppm/ $^{\circ}\text{C}$  (max). In addition to a low quiescent current of  $100\ \mu\text{A}$  (max) at  $25^{\circ}\text{C}$ , these devices offer a clear advantage over the traditional zener techniques in terms of stability over time and temperature. The output voltage for the MCP1525 is 2.5V and 4.096V for the MCP1541. These devices are offered in SOT23-3 and TO-92 packages and are specified over the industrial temperature range of  $-40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$ .

### PACKAGES



### MCP1541 TEMPERATURE DRIFT



# MCP1525/1541

## 1.0 ELECTRICAL SPECIFICATIONS

### 1.1 Maximum Ratings\*

\***Notice:** Stresses above those listed under "Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at those or any other conditions above those indicated in the operational listings of this specification is not implied. Exposure to maximum rating conditions for extended periods may affect device reliability.

$V_{IN}$ .....	7.0V
Input Current ( $V_{IN}$ ) .....	20 mA
Output current ( $V_{OUT}$ ) .....	$\pm 20$ mA
Continuous Power Dissipation ( $T_A = 125^\circ\text{C}$ ) .....	140 mW
All inputs and outputs w.r.t. ....	-0.6V to ( $V_{IN} + 1.0\text{V}$ )
Storage temperature .....	$-65^\circ\text{C}$ to $+150^\circ\text{C}$
Ambient temp. with Input voltage applied .....	$-55^\circ\text{C}$ to $+125^\circ\text{C}$
ESD protection on all pins.....	$\geq 4$ kV

## ELECTRICAL CHARACTERISTICS

All parameters apply at $V_{IN} = 5\text{V}$ , $I_{OUT} = 0$ mA, $T_A = 25^\circ\text{C}$ , unless otherwise noted.							
Parameter		Symbol	Min	Typ	Max	Units	Conditions
Output Voltage	MCP1525	$V_{OUT}$	2.475	2.5	2.525	V	$2.7 \leq V_{IN} \leq 5.5$
	MCP1541		4.055	4.096	4.137	V	$4.3 \leq V_{IN} \leq 5.5$
Operating Voltage	MCP1525	$V_{IN}$	2.7	—	5.5	V	$T_A = -40^\circ\text{C}$ to $85^\circ\text{C}$
	MCP1541		4.3	—	5.5	V	$T_A = -40^\circ\text{C}$ to $85^\circ\text{C}$
Output Voltage Drift <sup>(2)</sup>		$TCV_{OUT}$	—	27	50	ppm/ $^\circ\text{C}$	$T_A = -40^\circ\text{C}$ to $85^\circ\text{C}$
Dropout voltage		$V_{DROP}$	—	137	—	mV	$I_{OUT} = 2$ mA
MCP1525 Output Voltage Noise		$e_N$	—	90	—	$\mu\text{Vp-p}$	0.1 Hz to 10 Hz
			—	500	—		10 Hz to 10 kHz
MCP1541 Output Voltage Noise		$e_N$	—	145	—	$\mu\text{Vp-p}$	0.1 Hz to 10 Hz
			—	700	—		10Hz to 10 kHz
Line Regulation		$\frac{\Delta V_{OUT}}{\Delta V_{IN}}$	—	107	300	$\mu\text{V/V}$	$V_{IN} = 2.7\text{V}$ to $5.5\text{V}$ for MCP1525, $V_{IN} = 4.3\text{V}$ to $5.5\text{V}$ for MCP1541
		$\frac{\Delta V_{OUT}}{\Delta V_{IN}}$	—	—	350	$\mu\text{V/V}$	$V_{IN} = 2.7\text{V}$ to $5.5\text{V}$ for MCP1525, $V_{IN} = 4.3\text{V}$ to $5.5\text{V}$ for MCP1541, $T_A = -40^\circ\text{C}$ to $85^\circ\text{C}$
Load Regulation		$\frac{\Delta V_{OUT}}{\Delta I_{OUT}}$	—	0.5	1	mV/mA	$I_{OUT} = 0$ mA to -2 mA
			—	0.6	1		$I_{OUT} = 0$ mA to 2 mA
		$\frac{\Delta V_{OUT}}{\Delta I_{OUT}}$	—	—	1.3	mV/mA	$I_{OUT} = 0$ mA to -2 mA, $T_A = -40^\circ\text{C}$ to $85^\circ\text{C}$
			—	—	1.3		$I_{OUT} = 0$ mA to 2 mA, $T_A = -40^\circ\text{C}$ to $85^\circ\text{C}$
Output Voltage Hysteresis <sup>(1)</sup>		$V_{HYS}$	—	115	—	ppm	
Maximum Load Current		$I_{SC}$	—	$\pm 8$	—	mA	$T_A = -40^\circ\text{C}$ to $85^\circ\text{C}$ , $V_{IN} = 5.5\text{V}$
Long Term Output Stability		$V_{OUT}$	—	2	—	ppm/h	Exposed 1008 hrs @ $125^\circ\text{C}$ (see Figure 4-1), measured @ $25^\circ\text{C}$
Input Current		$I_{IN}$	—	86	100	$\mu\text{A}$	no load
			—	95	120	$\mu\text{A}$	no load, $T_A = -40^\circ\text{C}$ to $85^\circ\text{C}$
<b>Temperature Ranges:</b>							
Specified Temperature Range		$T_A$	-40	—	+85	$^\circ\text{C}$	
Operating Temperature Range		$T_A$	-40	—	+85	$^\circ\text{C}$	
Storage Temperature Range		$T_A$	-65	—	+150	$^\circ\text{C}$	
<b>Thermal Package Resistance:</b>							
Thermal Resistance, TO-92		$\theta_{JA}$	—	132	—	$^\circ\text{C/W}$	
Thermal Resistance, SOT23-3		$\theta_{JA}$	—	336	—	$^\circ\text{C/W}$	

**Note 1:** Output Voltage Hysteresis is defined as the change in output voltage measured at  $25^\circ\text{C}$  before and after cycling the temperature to  $85^\circ\text{C}$  and  $-40^\circ\text{C}$  per Section 4.0.10.

**2:** Output temperature coefficient is measured using a "box" method where the  $25^\circ\text{C}$  output voltage is trimmed as close to typical as possible, then the  $85^\circ\text{C}$  output voltage is again trimmed to zero out the tempco.

## 2.0 TYPICAL PERFORMANCE CURVES

Note: Unless otherwise indicated,  $V_{IN} = 5V$ ,  $I_{OUT} = 0\text{ mA}$ ,  $C_L = 1\text{ }\mu\text{F}$ ,  $T_A = 25^\circ\text{C}$

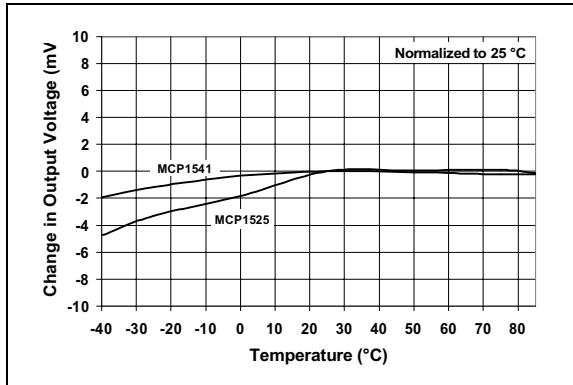


FIGURE 2-1: Change in Output Voltage vs. Temperature.

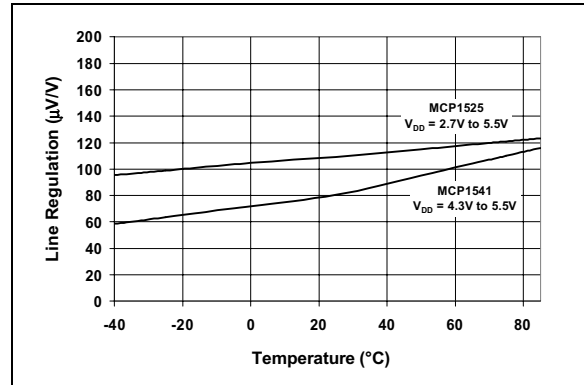


FIGURE 2-4: Line Regulation vs. Temperature.

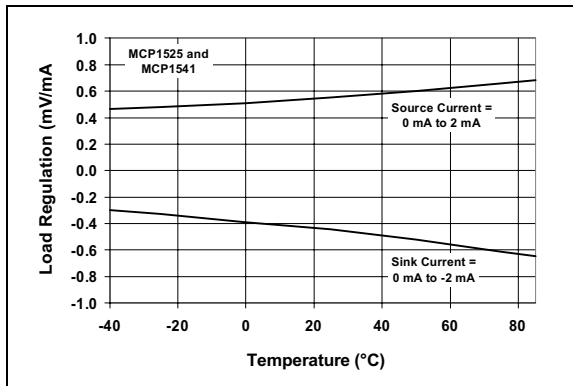


FIGURE 2-2: Load Regulation vs. Temperature.

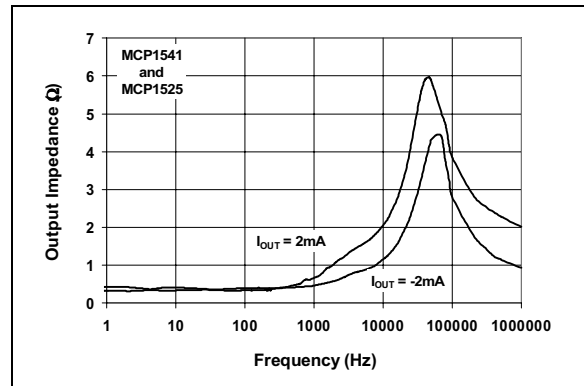


FIGURE 2-5: Output Impedance vs. Frequency.

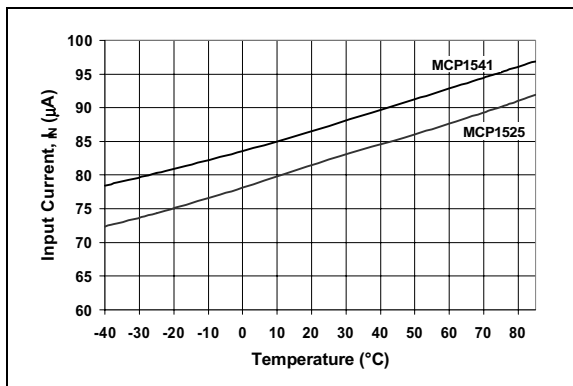


FIGURE 2-3: Input Current vs. Temperature.

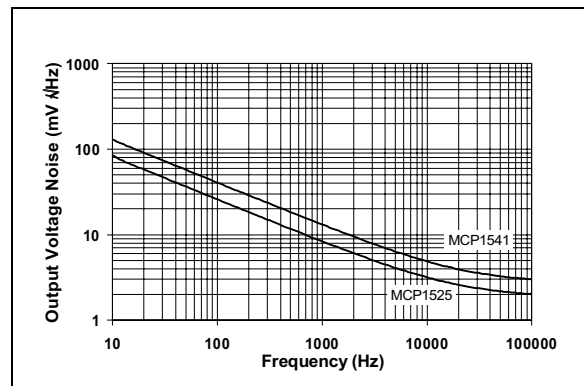


FIGURE 2-6: Output Voltage Noise vs. Frequency.

# MCP1525/1541

Note: Unless otherwise indicated,  $V_{IN} = 5V$ ,  $I_{OUT} = 0\text{ mA}$ ,  $C_L = 1\ \mu F$ ,  $T_A = 25^\circ C$

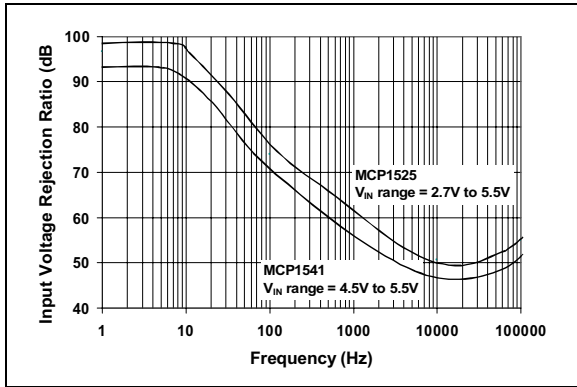


FIGURE 2-7: Input Voltage Rejection Ratio vs. Frequency.

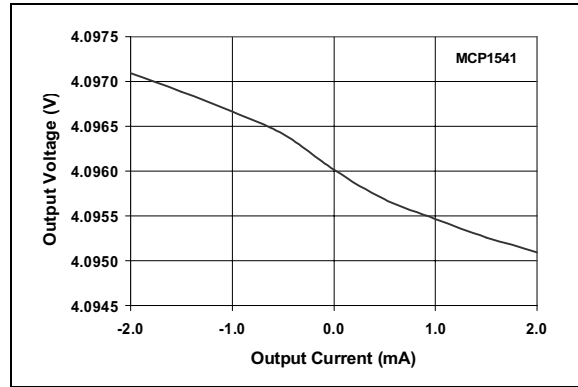


FIGURE 2-10: MCP1541 Output Voltage vs. Output Current.

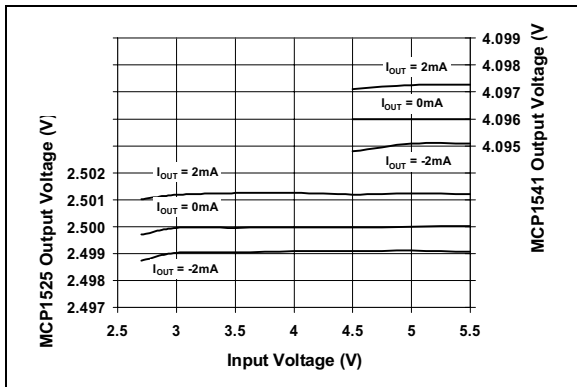


FIGURE 2-8: Output Voltage vs. Input Voltage.

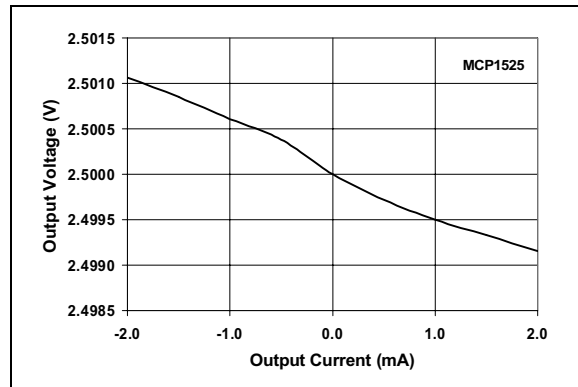


FIGURE 2-11: MCP1525 Output Voltage vs. Output Current.

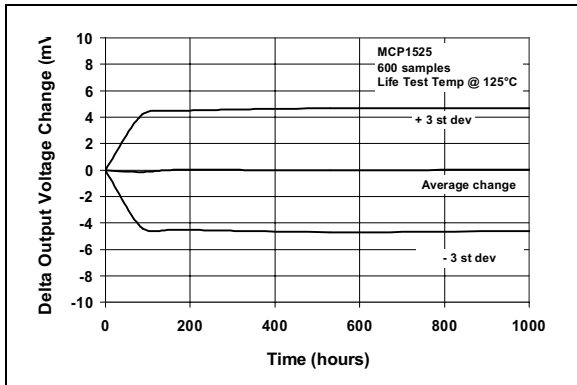


FIGURE 2-9: Delta Output Voltage Change vs. Time (DLT Data).

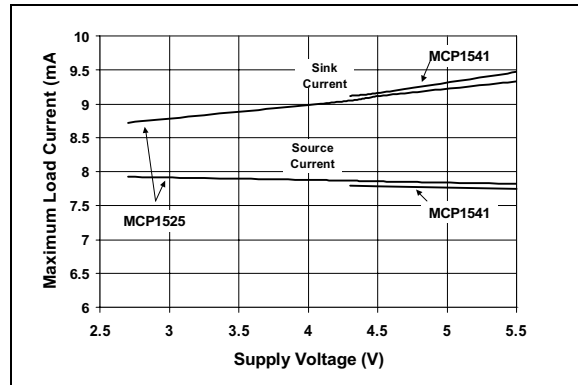
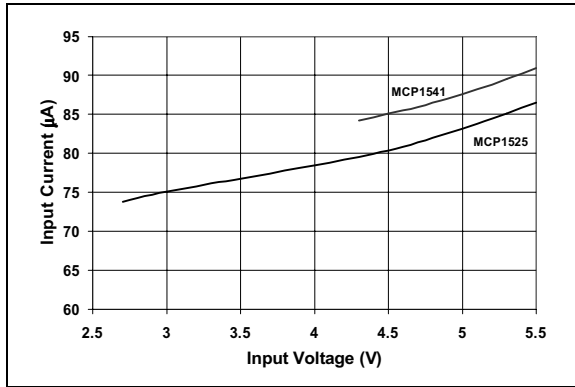


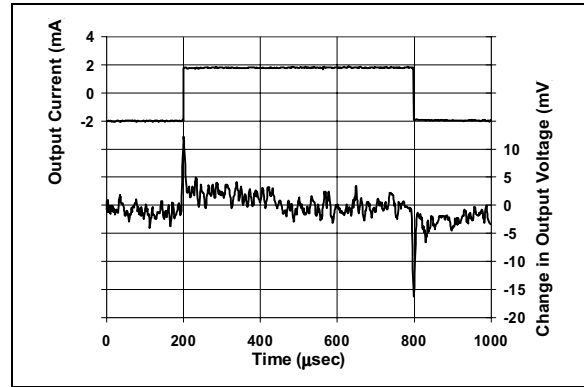
FIGURE 2-12: Maximum Load Current vs. Input Voltage.

# MCP1525/1541

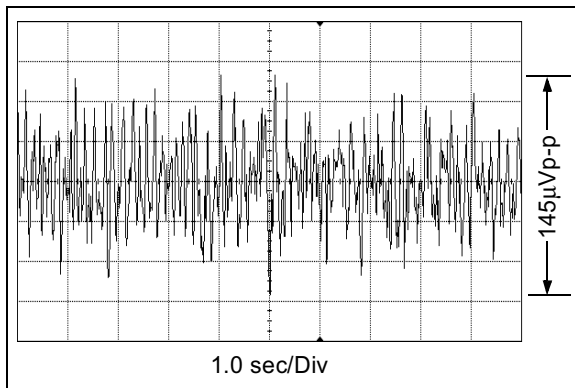
**Note:** Unless otherwise indicated,  $V_{IN} = 5V$ ,  $I_{OUT} = 0\text{ mA}$ ,  $C_L = 1\text{ }\mu\text{F}$ ,  $T_A = 25^\circ\text{C}$



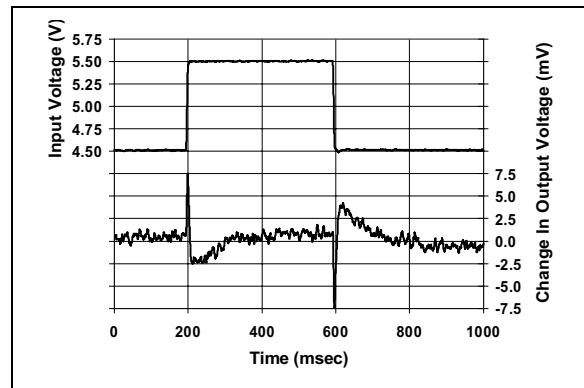
**FIGURE 2-13:** Input Current vs. Input Voltage.



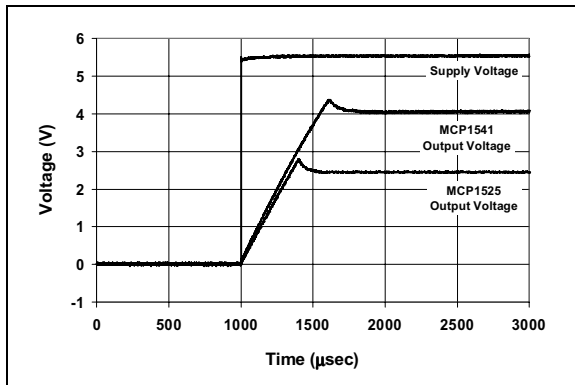
**FIGURE 2-16:** MCP1525 Load Transient Response.



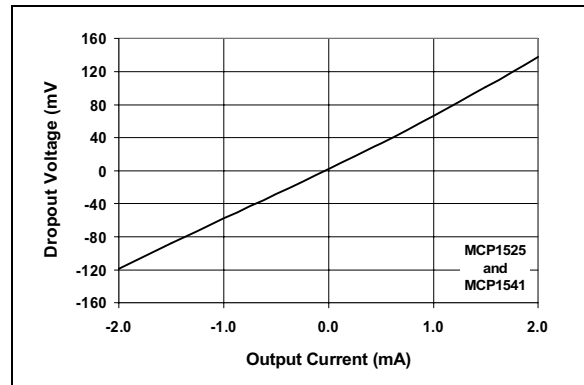
**FIGURE 2-14:** MCP1541 0.1 Hz to 10 Hz Output Noise.



**FIGURE 2-17:** MCP1525 Line Transient Response.



**FIGURE 2-15:** Turn-on Transient Time.



**FIGURE 2-18:** Dropout Voltage vs. Output Current.

# MCP1525/1541

## 3.0 PIN FUNCTIONS

Name	Function
Output Pin ( $V_{OUT}$ ):	Reference Output
Input Pin ( $V_{IN}$ ):	Positive Input Voltage
Ground Pin ( $V_{SS}$ ):	Negative Supply or Ground Connection

## 4.0 DETAILED DESCRIPTION

### 4.0.1 OUTPUT VOLTAGE

Output Voltage is the reference voltage that is available on the output pin ( $V_{OUT}$ ).

### 4.0.2 OPERATING (INPUT) VOLTAGE

Input voltage is the range of voltage that can be applied to the  $V_{IN}$  pin and still have the device produce the designated output voltage on the  $V_{OUT}$  pin.

### 4.0.3 OUTPUT VOLTAGE DRIFT ( $TCV_{OUT}$ )

The output temperature coefficient or voltage drift is a measure of how much the output voltage ( $V_{OUT}$ ) will vary from its initial value with changes in temperature. The value specified in the electrical specifications is measured and equal to:

$$TCV_{OUT} = \frac{\left(\frac{\Delta V_{OUT}}{V_{NOM}}\right)}{\Delta T} \text{ \{in ppm/}^\circ\text{C}\}$$

Where:

$$V_{NOM} = 2.5V \text{ for the MCP1525 and } 4.096V \text{ for the MCP1541.}$$

### 4.0.4 DROPOUT VOLTAGE

The dropout voltage of these devices is measured by reducing  $V_{IN}$  in voltage to the point where the output drops by 1%. Under these conditions the dropout voltage is equal to:

$$V_{DROP} = V_{IN} - V_{OUT}$$

The dropout voltage is affected by temperature and load current.

In Figure 2-18, the dropout voltage is shown over a negative and positive range of output current. For currents above zero milliamperes, the dropout voltage is positive. In this case, the voltage reference is primarily powered by  $V_{IN}$ . With output currents below zero milliamperes, the dropout voltage is negative. As the output current becomes more negative the input current,  $I_{IN}$ , reduces. Under this condition, the output current begins to provide the needed power to the voltage reference.

### 4.0.5 LINE REGULATION

This is a measure of the change in output voltage ( $V_{OUT}$ ) as a function of a change in the input voltage ( $V_{IN}$ ). This is expressed as  $\Delta V_{OUT}/\Delta V_{IN}$  and is measured in either  $\mu V/V$  or ppm. For example, a  $1 \mu V$  change in  $V_{OUT}$  caused by a 500 mV change in  $V_{IN}$  would net a  $\Delta V_{OUT}/\Delta V_{IN}$  of  $2 \mu V/V$  or 2 ppm.

### 4.0.6 LOAD REGULATION ( $\Delta V_{OUT}/\Delta I_{OUT}$ )

Load regulation is a measure of the change in the output voltage,  $V_{OUT}$ , as a function of the change in output current ( $I_{OUT}$ ). Load regulation is usually measured in mV/mA.

### 4.0.7 INPUT CURRENT

The input (operating) current is the current that sinks from  $V_{IN}$  to  $V_{SS}$  without a load current on the output pin. This current is affected by temperature and the output current.

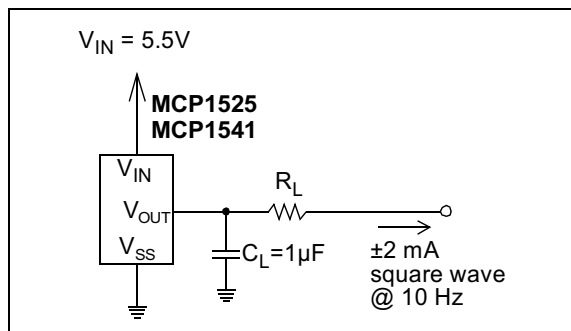
### 4.0.8 INPUT VOLTAGE REJECTION RATIO

The input voltage rejection ratio is a measure of the change in output voltage versus the change in input voltage over frequency as shown in Figure 2-7. The calculation used for this specification is:

$$\text{Input Voltage Rejection Ratio (dB)} = 20 \log \left( \frac{\delta V_{IN}}{\delta V_{OUT}} \right)$$

### 4.0.9 LONG TERM OUTPUT STABILITY

The long term output stability is measured by exposing the devices to a temperature of 125°C while configured in the circuit shown in Figure 4-1. In this test, all electrical specifications of the devices are measured periodically at 25°C as shown in Figure 2-9.



**FIGURE 4-1:** Dynamic Life Test Configuration

### 4.0.10 OUTPUT VOLTAGE HYSTERESIS

The output voltage hysteresis is a measure of the output voltage error after the powered devices are cycled over the entire operating temperature range. The amount of hysteresis can be quantified by measuring the change in the 25°C output voltage after temperature excursions from +25°C to +85°C to +25°C and also from +25°C to -40°C to +25°C.

## 5.0 APPLICATIONS INFORMATION

### 5.1 Bypass Capacitor

The MCP1525 and MCP1541 voltage references do not require an input capacitor across  $V_{IN}$  to  $V_{SS}$ , but for added stability and input voltage transient noise reduction, a 0.1  $\mu\text{F}$  ceramic capacitor is recommended, as shown in Figure 5-1. This capacitor should be as close to the device as possible (within one inch).

### 5.2 Load Capacitor

The output capacitor from  $V_{OUT}$  to  $V_{SS}$  acts as a frequency compensation for the references and cannot be omitted. Values between 1.0  $\mu\text{F}$  to 10  $\mu\text{F}$  adequately compensate these devices. A higher value output capacitor will slightly improve the noise at the output of the reference as well as provide additional charge for fast transients from the load.

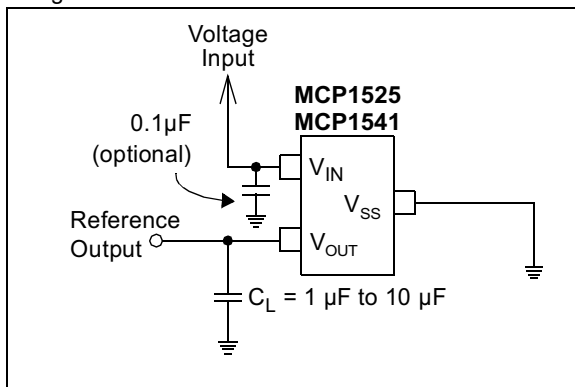
### 5.3 Printed Circuit Board Layout Considerations

Mechanical stress due to PC board mounting can cause the output voltage to shift from its initial value. Devices in the SOT23-3 package are generally more prone to assembly stress than devices in the TO-92 package. To reduce stress related output voltage shifts, mount the reference on low stress areas on the PC board, such as the board edges or corners.

### 5.4 Typical Application Circuits

#### 5.4.1 BASIC CIRCUIT CONFIGURATION

The MCP1525 and MCP1541 voltage reference devices should be applied in all applications as shown in Figure 5-1.



**FIGURE 5-1:** Basic circuit configuration for the MCP1525 and MCP1541.

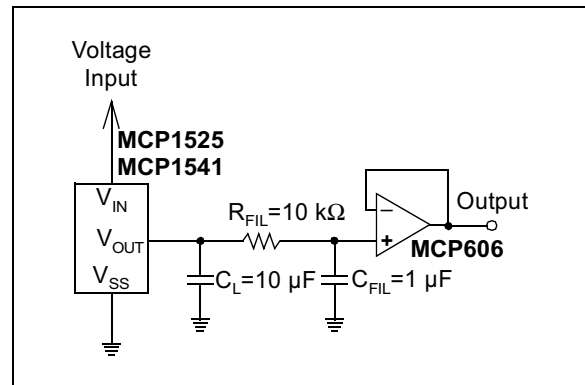
As shown in Figure 5-1, the input voltage is connected to the device at the  $V_{IN}$  input with an optional 0.1  $\mu\text{F}$  ceramic capacitor. This capacitor would be required if the input voltage has excess noise. A 0.1  $\mu\text{F}$  would reject input voltage noise at approximately 1 MHz to 2 MHz. Noise below this frequency will be amply

rejected by the input voltage rejection of the voltage reference. Noise at frequencies above 2 MHz will be beyond the bandwidth of the voltage reference and consequently not transmitted from the input pin through the device to the output.

The load capacitance,  $C_L$ , is required in order to stabilize the voltage reference.

#### 5.4.2 OUTPUT FILTERING

If the noise at the output of these voltage references is too high for the particular application, it can be easily filtered with an external R/C pair and amplifier.



**FIGURE 5-2:** The output noise of these voltage references can be further reduced with a simple low pass filter.

The R/C pair is selected for a desired cut-off frequency which is equal to:

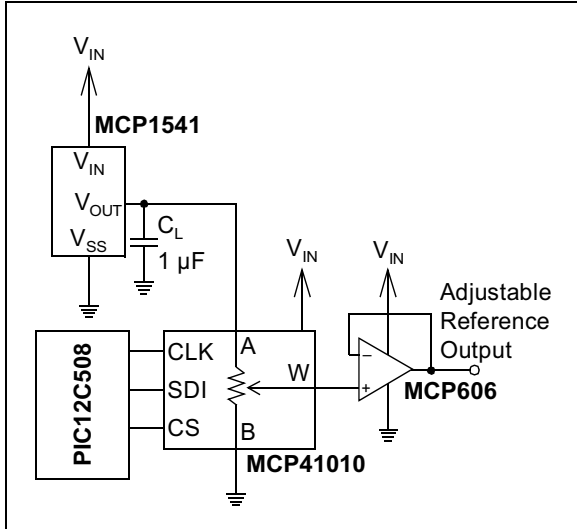
$$f_{CUTOFF} = \frac{1}{(2\pi R_{FIL} \cdot C_{FIL})}$$

The values that are shown in Figure 5-2 (10 k $\Omega$  and 1  $\mu\text{F}$ ) will create a first order low pass filter at the output of the amplifier. The corner frequency of this filter 15.9 Hz with an attenuation of 20 dB/decade. The MCP606 amplifier isolates the loading of this low pass filter from the remainder of the application circuit. This amplifier also provides additional drive and with a faster response time as compared to the voltage reference.

#### 5.4.3 PRECISION ADJUSTABLE REFERENCE

A precision adjustable voltage reference can be configured with the circuit shown in Figure 5-3.

# MCP1525/1541

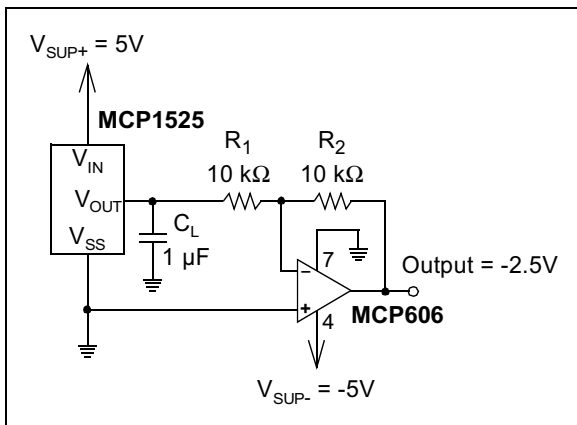


**FIGURE 5-3:** Adjustable Voltage Reference

In this circuit, the MCP1541 voltage reference is used to drive the resistor element of the MCP41010 digital potentiometer. The MCP41010 is a 256-tap potentiometer, 10 kΩ programmed using the SPI™ interface. The range of this adjustable reference is from ground to 4.096V in 16 mV increments.

## 5.4.4 NEGATIVE VOLTAGE REFERENCE

A negative precision voltage reference can be generated by using the MCP1525 or MCP1541 in the configuration shown in Figure 5-4.



**FIGURE 5-4:** Negative Voltage Reference

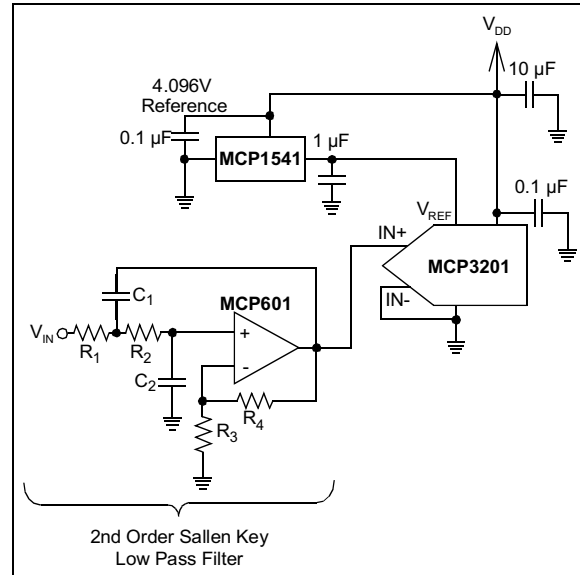
In this circuit, the voltage divider configuration is implemented using the MCP606 and two equal resistors. The voltage at the output of the MCP1525 voltage reference drives  $R_1$  which is connected to the inverting input of the MCP606 amplifier. Since the non-inverting input of the amplifier is biased to ground, the inverting input will also be approximately at ground potential. The second 10 kΩ resistor is placed around the feedback loop of the amplifier. Since the inverting input of the amplifier is high impedance, the current generated

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through  $R_1$  will also flow through  $R_2$ . As a consequence, the output voltage of the amplifier is equal to -2.5V.

## 5.4.5 A-TO-D CONVERTER REFERENCE

The MCP1525 and MCP1541 were carefully designed to provide a voltage reference for Microchip's 10-bit and 12-bit family of A/D converters.



**FIGURE 5-5:** A/D Converter Reference Circuit.

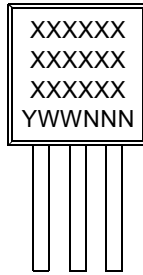
The circuit shown in Figure 5-5 shows a MCP1541 configured to provide the reference to the MCP3201, a 12-bit A/D Converter. Use Microchip's Filter Lab™ software to design the Sallen Key filter. For additional information, refer to AN699, "Anti-Aliasing, Analog Filters for Data Acquisition Systems", DS00699.



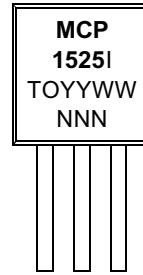
## 6.0 PACKAGING INFORMATION

### 6.1 Package Marking Information

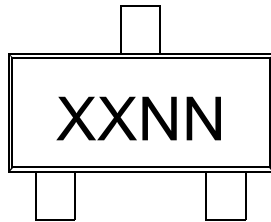
#### 3-Lead TO-92



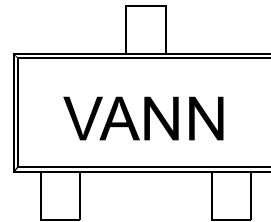
#### Example:



#### 3-Lead SOT23-3



#### Example:



#### SOT23 PARTS LABELING:

The table below identifies the first 2 characters (XX) in the 4-character field (XXNN) for marking of the 3-Lead SOT23 package.

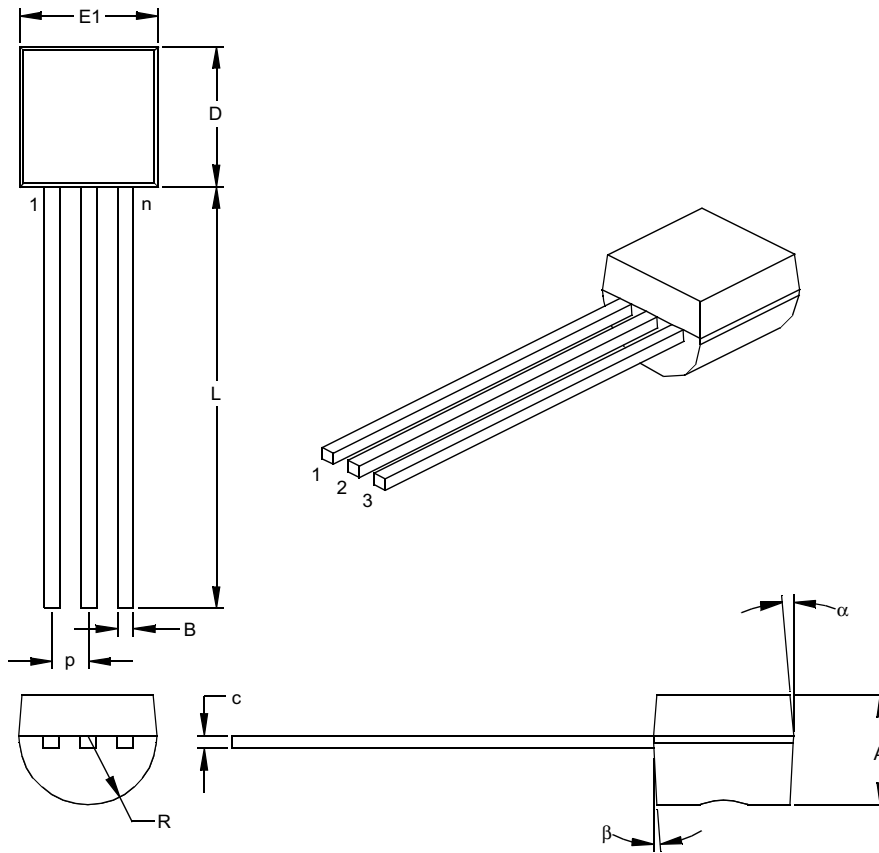
Mark	Part Number	Mark	Part Number
VA	MCP1525T-I/TT	VB	MCP1541T-I/TT

<b>Legend:</b>	XX...X	Customer specific information*
	YY	Year code (last 2 digits of calendar year)
	WW	Week code (week of January 1 is week '01')
	NNN	Alphanumeric traceability code
<b>Note:</b>	In the event the full Microchip part number cannot be marked on one line, it will be carried over to the next line thus limiting the number of available characters for customer specific information.	

- \* Standard marking consists of Microchip part number, year code, week code, traceability code (facility code, mask rev#, and assembly code). For marking beyond this, certain price adders apply. Please check with your Microchip Sales Office.

# MCP1525/1541

## 3-Lead Plastic Transistor Outline (TO) (TO-92)



Dimension Limits	Units	INCHES*			MILLIMETERS		
		MIN	NOM	MAX	MIN	NOM	MAX
Number of Pins	n		3			3	
Pitch	p		.050			1.27	
Bottom to Package Flat	A	.130	.143	.155	3.30	3.62	3.94
Overall Width	E1	.175	.186	.195	4.45	4.71	4.95
Overall Length	D	.170	.183	.195	4.32	4.64	4.95
Molded Package Radius	R	.085	.090	.095	2.16	2.29	2.41
Tip to Seating Plane	L	.500	.555	.610	12.70	14.10	15.49
Lead Thickness	c	.014	.017	.020	0.36	0.43	0.51
Lead Width	B	.016	.019	.022	0.41	0.48	0.56
Mold Draft Angle Top	$\alpha$	4	5	6	4	5	6
Mold Draft Angle Bottom	$\beta$	2	3	4	2	3	4

\*Controlling Parameter

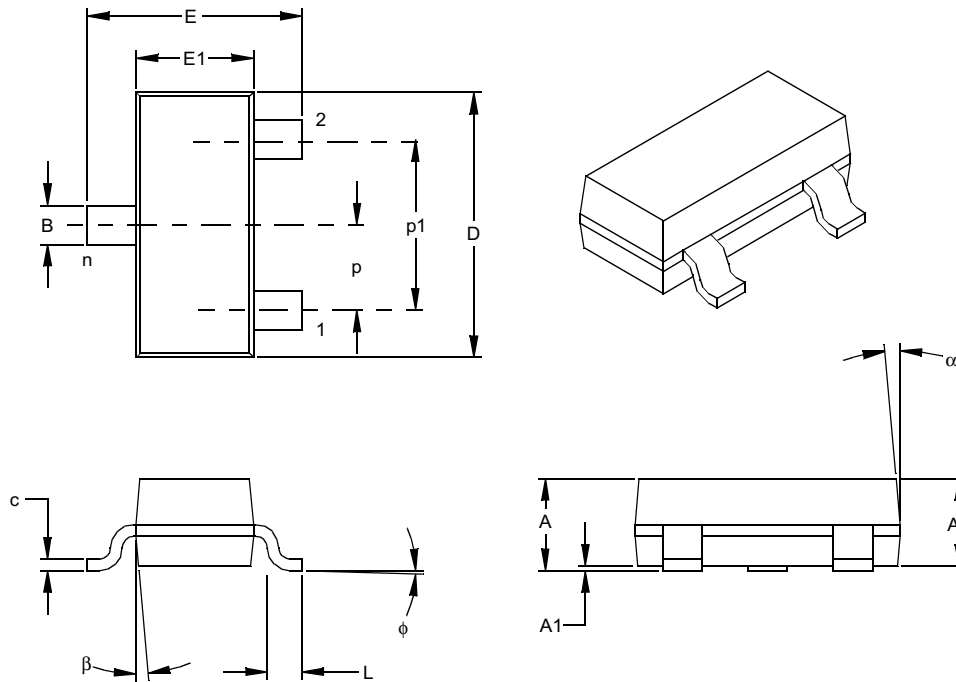
Notes:

Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .010" (0.254mm) per side.

JEDEC Equivalent: TO-92

Drawing No. C04-101

## 3-Lead Plastic Small Outline Transistor (TT) (SOT23)



Units		INCHES*			MILLIMETERS		
Dimension Limits		MIN	NOM	MAX	MIN	NOM	MAX
Number of Pins	n		3			3	
Pitch	p		.038			0.96	
Outside lead pitch (basic)	p1		.076			1.92	
Overall Height	A	.035	.040	.044	0.89	1.01	1.12
Molded Package Thickness	A2	.035	.037	.040	0.88	0.95	1.02
Standoff §	A1	.000	.002	.004	0.01	0.06	0.10
Overall Width	E	.083	.093	.104	2.10	2.37	2.64
Molded Package Width	E1	.047	.051	.055	1.20	1.30	1.40
Overall Length	D	.110	.115	.120	2.80	2.92	3.04
Foot Length	L	.014	.018	.022	0.35	0.45	0.55
Foot Angle	φ	0	5	10	0	5	10
Lead Thickness	c	.004	.006	.007	0.09	0.14	0.18
Lead Width	B	.015	.017	.020	0.37	0.44	0.51
Mold Draft Angle Top	α	0	5	10	0	5	10
Mold Draft Angle Bottom	β	0	5	10	0	5	10

\* Controlling Parameter  
 § Significant Characteristic

Notes:

Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .010" (0.254mm) per side.

JEDEC Equivalent: TO-236

Drawing No. C04-104

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Device	MCP1525: = 2.5V Voltage Reference MCP1541: = 4.096 Voltage Reference	
Temperature Range	I = -40°C to +85°C	
Package	TO = TO-92, Plastic Transistor Outline, 3-Lead TT = SOT23, Plastic Small Outline Transistor, 3-Lead	

**Examples:**

- MCP1525T-I/TT: Tape and Reel, Industrial Temperature, SOT23 package.
- MCP1525-I/TO: Industrial Temperature, TO-92 package.
- MCP1541T-I/TT: Tape and Reel, Industrial Temperature, SOT23 package.
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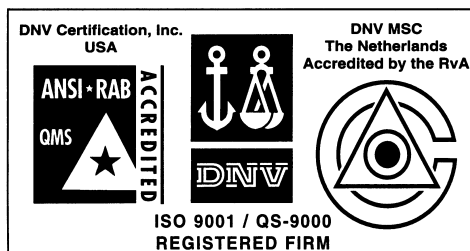
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