MCP1502

High-Precision Buffered Voltage Reference

Features

- Maximum Temperature Coefficient: 7 ppm/°C from -40°C to +125°C
- Initial Accuracy: 0.1%
- Operating Temperature Range: -40°C to +125°C
- Low Typical Operating Current: 140 µA
- Line Regulation: 50 ppm/V Maximum
- Load Regulation: 40 ppm/V Maximum
- 10 Voltage Variants Available:
  - 1.024V
  - 1.250V
  - 1.800V
  - 2.048V
  - 2.500V
  - 3.000V
  - 3.300V
  - 4.096V
  - 4.500V
  - 5.000V
- Output Noise: 30 μV_{RMS}, 0.1 Hz to 10 kHz (1.024V)
- AEC-Q100 Qualified (Automotive Applications)
  - (Grade 1) Temperature range: -40°C to +125°C

Applications

- Precision Data Acquisition Systems
- Electric Vehicle Battery Management Systems
- High-Resolution Data Converters
- Medical Equipment Applications
- Industrial Controls
- Battery-Powered Devices

Related Parts

- MCP1501 High-Precision Buffered Voltage Reference (DS20005474)

General Description

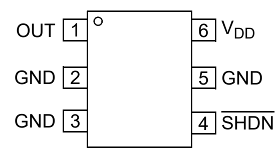
The MCP1502 is a buffered voltage reference capable of sinking and sourcing 20 mA of current. The voltage reference is a low drift band gap-based reference. The band gap uses chopper-based amplifiers, effectively reducing the drift to zero.

The MCP1502 is available in the following package:

- 6-Lead SOT-23

Package Types

MCP1502
6-Lead SOT-23



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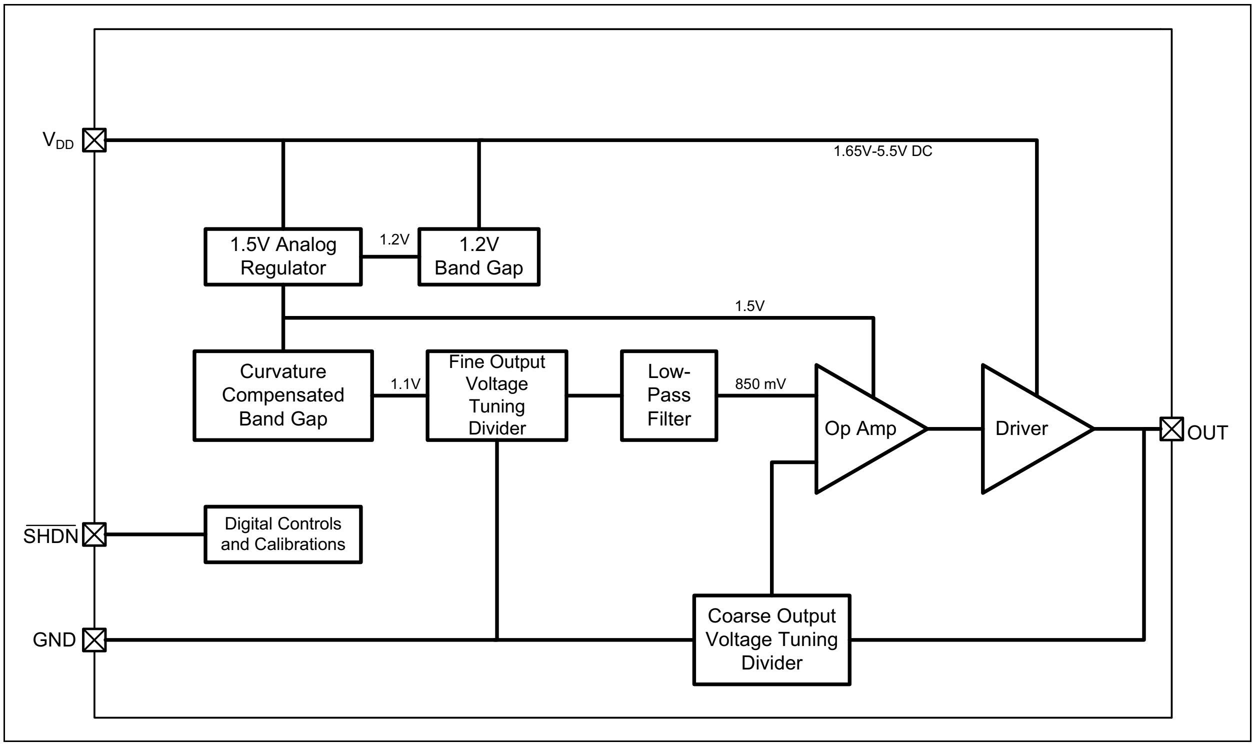
BLOCK DIAGRAM



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1.0 PIN FUNCTION TABLE

The pin functions are described in Table 1-1.

TABLE 1-1: PIN FUNCTION TABLE

SOT-23	Symbol	Function
1	OUT	V_{REF} Output
2, 3, 5	GND	System Ground
4	$\overline{SHDN}$	Shutdown Pin Active-Low
6	V_{DD}	Power Supply Input

1.1 Buffered V_{REF} Output (OUT)

This is the buffered reference output. The output driver is tri-stated when in shutdown.

1.2 System Ground (GND)

This is the power supply return and should be connected to system ground.

1.3 Shut down Pin ($\overline{SHDN}$)

This is a digital input that will place the device in shutdown. The device should be allowed to power up before using this feature. This pin is active-low. When this pin is low, there will be no output.

> **Note:** Before using the shut down pin, the device should first be powered up. Once the device is fully powered up, the shut down pin can be used.

1.4 Power Supply Input (V_{DD})

This power pin also serves as the input voltage for the voltage reference. Refer to **Section 2.0 "Electrical Characteristics"** to determine minimum voltage based on the device. It is recommended to connect a 0.1 µF capacitor very close to the V_{DD} pin.

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NOTES:

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2.0 ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings(†)

V_{DD}....................6.0V
Maximum current into V_{DD} pin .... 30 mA
Clamp current, Iκ (V_{PIN} < 0 or V_{PIN} > V_{DD})....................±20 mA
Maximum output current sunk by OUT pin....................30 mA
Maximum output current sourced by OUT pin ....30 mA
ESD Protection on All Pins (HBM; CDM; MM)....................(2 kV:±1.5 kV:200V)

† **Notice**: Stresses above those listed under "Absolute 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 operation listings of this specification is not implied. Exposure above maximum rating conditions for extended periods may affect device reliability.

TABLE 2-1: DC CHARACTERISTICS

Electrical Characteristics: Unless otherwise specified, $V_{DD(MIN)} \leq V_{DD} \leq 5.5V$ at $-40°C \leq T_A \leq +125°C$.

Characteristic	Sym.	Min.	Typ.	Max.	Units	Conditions
Supply Voltage	V_{DD}	1.65	—	5.5	V	MCP1502-10
	V_{DD}	1.65	—	5.5	V	MCP1502-12
	V_{DD}	2.0	—	5.5	V	MCP1502-18
	V_{DD}	2.25	—	5.5	V	MCP1502-20
	V_{DD}	2.70	—	5.5	V	MCP1502-25
	V_{DD}	3.2	—	5.5	V	MCP1502-30
	V_{DD}	3.5	—	5.5	V	MCP1502-33
	V_{DD}	4.3	—	5.5	V	MCP1502-40
	V_{DD}	4.7	—	5.5	V	MCP1502-45
	V_{DD}	5.2	—	5.5	V	MCP1502-50
Power-on Reset Release Voltage (**Note 1**)	V_{POR}	—	1.45	—	V	
Power-on Reset Rearm Voltage (**Note 2**)	—	—	0.8	—	V	

Note 1: On rising V_{DD}, the voltage at which the device internal Reset will get released.

2: On dropping V_{DD}, the voltage at which the internal Reset circuit will reset. On dropping V_{DD}, it is recommended to bring the V_{DD} below this voltage to get a proper Reset.

3: Before using the $\overline{SHDN}$ pin, the device should first be powered up. Once the device is fully powered up, then the shut down pin can be used.

4: μV_{PP} is six times the value of μV_{RMS}.

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TABLE 2-1: DC CHARACTERISTICS (CONTINUED)

Electrical Characteristics: Unless otherwise specified, $V_{DD(MIN)} \le V_{DD} \le 5.5V$ at $-40°C \le T_A \le +125°C$.							
Characteristic		**Sym.**	**Min.**	**Typ.**	**Max.**	**Units**	**Conditions**
Output Voltage	MCP1502-10	V_{OUT}	1.0230	1.0240	1.0250	V	Temperature @ +25°C
	MCP1502-12		1.2488	1.2500	1.2513	V	
	MCP1502-18		1.7982	1.800	1.8018	V	
	MCP1502-20		2.0460	2.0480	2.0500	V	
	MCP1502-25		2.4975	2.500	2.5025	V	
	MCP1502-30		2.9970	3.000	3.0030	V	
	MCP1502-33		3.2967	3.300	3.3033	V	
	MCP1502-40		4.0919	4.0960	4.1001	V	
	MCP1502-45		4.4995	4.500	4.5045	V	
	MCP1502-50		4.995	5.00	5.0050	V	
Temperature Coefficient	MCP1502-XX	T_C	—	5	7	ppm/°C	
Line Regulation	MCP1502-XX	$\Delta V_{OUT}/\Delta V_{IN}$	—	5	50	ppm/V	
	MCP1502-50		—	5	—		
Load Regulation		$\Delta V_{OUT}/\Delta I_{OUT}$	—	5 ppm – sink	40 ppm – sink	ppm/mA	$-5 mA < I_{LOAD}$
Load Regulation		$\Delta V_{OUT}/\Delta I_{OUT}$	—	5 ppm – source	70 ppm – source	ppm/mA	$I_{LOAD} < +5 mA$
Dropout Voltage		V_{DO}	—	—	200	mV	$-5 mA < I_{LOAD} < +5 mA$
Power Supply Rejection Ratio		PSRR	—	94	—	dB	All device options, V_{IN} = 5.5V, 60 Hz at 100 mV_{P-P}
Shutdown (**Note 3**)		V_{IL}	—	1.35	—	V	V_{IN} = 5V, refer to **Section 1.3 "Shut down Pin (SHDN)"**
		V_{IH}	—	3.80	—	V	
Output Voltage Hysteresis		ΔV_{OUT_HYST}	—	300	—	µV	Refer to **Section 2.1.9 "Output Voltage Hysteresis"** for additional details on testing conditions
Output Noise (**Note 4**)	MCP1502-10	e_N	—	18	—	μV_{PP}	0.1 Hz to 10 Hz, T_A = +25°C
			—	30	—	μV_{RMS}	10 Hz to 10 kHz, T_A = +25°C
	MCP1502-40	e_N	—	57	—	μV_{PP}	0.1 Hz to 10 Hz, T_A = +25°C
			—	97	—	μV_{RMS}	10 Hz to 10 kHz, T_A = +25°C
Maximum Load Current		I_{LOAD}	—	±20	—	mA	T_A = +25°C, all device options
Supply Current		I_{DD}	—	140	550	µA	No load
			—	—	350		No load, T_A = +25°C
Shutdown Current		I_{SHDN}	—	205	—	nA	T_A = +25°C, all device options

Note 1: On rising V_{DD}, the voltage at which the device internal Reset will get released.

2: On dropping V_{DD}, the voltage at which the internal Reset circuit will reset. On dropping V_{DD}, it is recommended to bring the V_{DD} below this voltage to get a proper Reset.

3: Before using the $\overline{SHDN}$ pin, the device should first be powered up. Once the device is fully powered up, then the shut down pin can be used.

4: μV_{PP} is six times the value of μV_{RMS}.

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TABLE 2-2: TEMPERATURE SPECIFICATIONS

Electrical Specifications: Unless otherwise indicated, all parameters apply at $V_{DD} = V_{DD(MIN)}$ to 5.5V.						
Parameters	**Sym.**	**Min.**	**Typ.**	**Max.**	**Units**	**Conditions**
Temperature Ranges						
Operating Temperature Range	T_A	-40	—	+125	°C	
Storage Temperature Range	T_A	-65	—	+150	°C	
Thermal Package Resistance						
Thermal Resistance for 6-Lead SOT-23	θ_{JA}	—	+190.5	—	°C/W	

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2.1 Terminology

2.1.1 OUTPUT VOLTAGE (V_{OUT})

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

2.1.2 INPUT VOLTAGE (V_{IN})

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

2.1.3 TEMPERATURE COEFFICIENT (T_C)

The output Temperature Coefficient (T_C) or voltage drift is a measure of how much the output voltage will vary from its initial value with changes in ambient temperature. The value specified in the electrical specifications is measured as shown in Equation 2-1.

EQUATION 2-1: T_C CALCULATION

$$Tc = \frac{V_{OUT(MAX)} - V_{OUT(MIN)}}{\Delta T \times V_{OUT(NOM)}} \times 10^6 ppm/°C$$

Where:

$V_{OUT(MAX)}$	=	Maximum output voltage over the temperature range
$V_{OUT(MIN)}$	=	Minimum output voltage over the temperature range
$V_{OUT(NOM)}$	=	Average output voltage over the temperature range
ΔT	=	Temperature range over which the data were collected

2.1.4 DROPOUT VOLTAGE (V_{DO})

The Dropout Voltage (V_{DO}) is defined as the voltage difference between V_{DD} and V_{OUT} under a 5 mA load, where V_{OUT} is reduced by 1% from the nominal value.

2.1.5 LINE REGULATION

An ideal voltage reference will maintain a constant output voltage, regardless of any changes to the input voltage. However, when real devices are considered, a small error may be measured on the output when an input voltage change occurs.

Line regulation is defined as the change in Output Voltage (ΔV_{OUT}) as a function of a change in the Input Voltage (ΔV_{IN}), and expressed as a percentage, as shown in Equation 2-2.

EQUATION 2-2:

$$\frac{\Delta V_{OUT}}{\Delta V_{IN}} \times 100\% = \%\ Line\ Regulation$$

Line regulation may also be expressed as %/V or in ppm/V, as shown in Equation 2-3 and Equation 2-4, respectively.

EQUATION 2-3:

$$\frac{\left(\frac{\Delta V_{OUT}}{V_{OUT(NOM)}}\right)}{\Delta V_{IN}} \times 100\% = \frac{\%}{V}\ Line\ Regulation$$

EQUATION 2-4:

$$\frac{\left(\frac{\Delta V_{OUT}}{V_{OUT(NOM)}}\right)}{\Delta V_{IN}} \times 10^6 = \frac{ppm}{V}\ Line\ Regulation$$

As an example, if the MCP1502-20 is implemented in a design and a 2 µV change in output voltage is measured from a 250 mV change on the input, then the error in percent and ppm/volt will be as shown in Equation 2-5 and Equation 2-6.

EQUATION 2-5:

$$\left(\frac{\Delta V_{OUT}}{\Delta V_{IN}} \times 100\%\right) \times \left(\frac{2\ \mu V}{250\ mV} \times 100\%\right) = .0008\%$$

EQUATION 2-6:

$$\frac{\Delta V_{OUT}}{\Delta V_{IN}} \times 10^6 = \left(\frac{\left(\frac{2\ \mu V}{2.048 V}\right)}{250\ mV}\right) \times 10^6 = 3.90625\ \frac{ppm}{V}$$

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2.1.6 LOAD REGULATION

An ideal voltage reference will maintain the specified output voltage regardless of the load's current demand. However, real devices experience a small error voltage that deviates from the specified output voltage when a load is present.

Load regulation is defined as the voltage difference when under no load (V_{OUT} @ $I_{OUT|0}$) and under maximum load (V_{OUT} @ $I_{OUT|MAX}$), and is expressed as a percentage, as shown in Equation 2-7.

EQUATION 2-7:

$$\frac{V_{OUT} @ I_{OUT|0} - V_{OUT} @ I_{OUT|MAX}}{V_{OUT} @ I_{OUT|0}} \times 100\% = \%\ Load\ Regulation$$

Similar to line regulation, load regulation may also be expressed as %/mA or in ppm/mA, as shown in Equation 2-8 and Equation 2-9, respectively.

EQUATION 2-8:

$$\frac{\left(\frac{\Delta V_{OUT}}{V_{OUT(NOM)}}\right)}{\Delta I_{OUT}} \times 100\% = \frac{\%}{mA}\ Load\ Regulation$$

EQUATION 2-9:

$$\frac{\left(\frac{\Delta V_{OUT}}{V_{OUT(NOM)}}\right)}{\Delta I_{OUT}} \times 10^6 = \frac{ppm}{mA}\ Load\ Regulation$$

As an example, if the MCP1502-20 is implemented in a design and a 10 µV change in output voltage is measured from a 2 mA change in the output load, then the error in percent, ppm/mA, is as shown in Equation 2-10 and Equation 2-11.

EQUATION 2-10:

$$\frac{2.048V - 2.04799V}{2.04799V} \times 100\% = .0004882\%$$

EQUATION 2-11:

$$\frac{\left(\frac{\Delta V_{OUT}}{V_{OUT(NOM)}}\right)}{\Delta I_{OUT}} \times 10^6 = \left(\frac{\left(\frac{10\ \mu V}{2.048V}\right)}{2\ mA}\right) \times 10^6 = 2.441\ \frac{ppm}{mA}$$

2.1.7 POWER SUPPLY REJECTION RATIO (PSRR)

Power Supply Rejection Ratio (PSRR) is a measure of the change in Output Voltage (ΔV_{OUT}) relative to the change in Input Voltage (ΔV_{IN}) over frequency.

2.1.8 LONG-TERM DRIFT

The long-term output stability is measured by exposing the devices to an ambient temperature of +25°C.

2.1.9 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 +125°C to +25°C, and also from +25°C to -40°C to +25°C.

2.1.10 LAYOUT CONSIDERATION FOR LOAD REGULATION

For applications which require high currents and/or highly variable currents, the PCB layout is important for minimizing the load coefficient (variation in output voltage vs. load current) of the device. Of particular importance is the grounding of the device to a large ground plane with good thermal mass. The MCP1502 should not be placed on a small daughter card or connected to ground via long traces or single vias if the load coefficient is to be optimized; the additional power dissipation caused by the high load current will cause a small change in the output voltage due to self-heating of the device.

For systems with high ground currents, variations in the local ground can also be a source of the load coefficient. These are usually solved by ensuring the local ground for the device is shared with the Point-of-Load (POL). In some cases, it may be necessary to ensure the device ground is specifically Kelvin sourced from the Point-of-Load, such that a zero IR drop from unassociated circuitry is seen on the device output voltage.

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3.0 TYPICAL OPERATING CURVES

Note:	The graphs and tables provided following this note are a statistical summary based on a limited number of samples and are provided for informational purposes only. The performance characteristics listed herein are not tested or guaranteed. In some graphs or tables, the data presented may be outside the specified operating range (e.g., outside specified power supply range) and therefore outside the warranted range.

Note: Unless otherwise specified, maximum values are: $V_{DD(MIN)} \leq V_{DD} \leq 5.5V$ at $T_A = +25°C$.

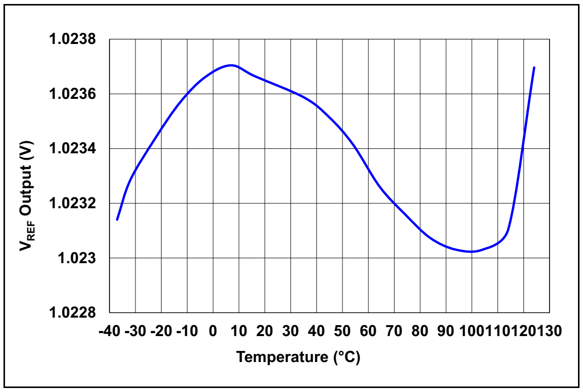

FIGURE 3-1: *MCP1502-10 V_{REF} Output vs. Temperature, V_{DD} = 5.5V.*

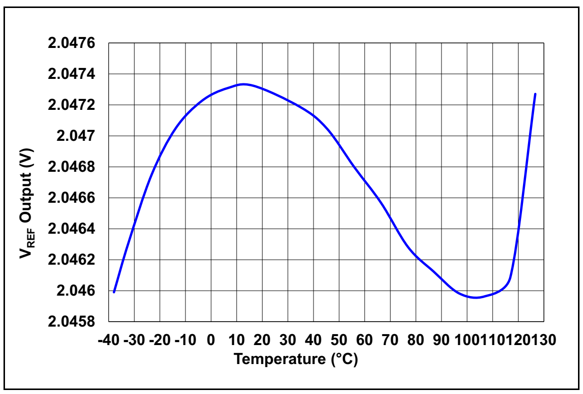

FIGURE 3-2: *MCP1502-20 V_{REF} Output vs. Temperature, V_{DD} = 5.5V.*

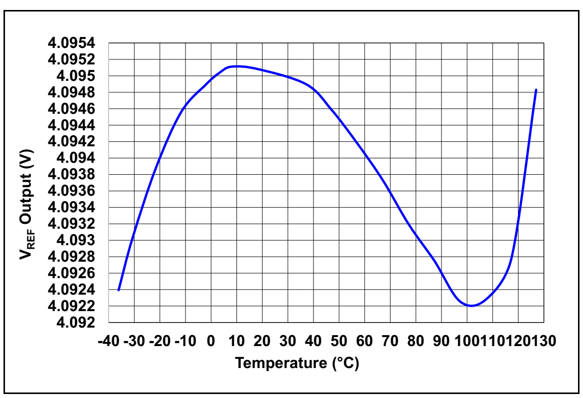

FIGURE 3-3: *MCP1502-40 V_{REF} Output vs. Temperature, V_{DD} = 5.5V.*

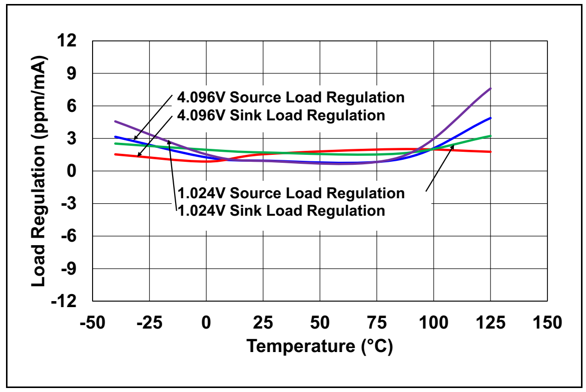

FIGURE 3-4: *Load Regulation vs. Temperature.*

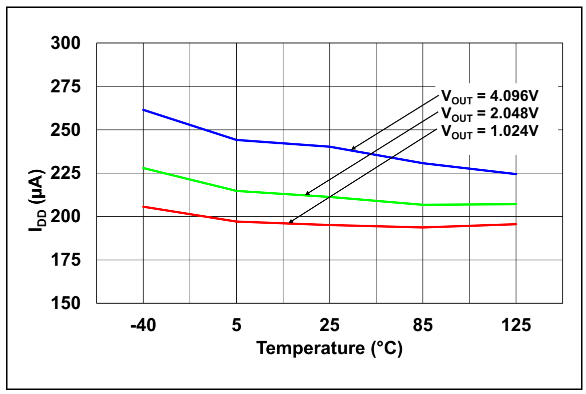

FIGURE 3-5: *I_{DD} vs. Temperature.*

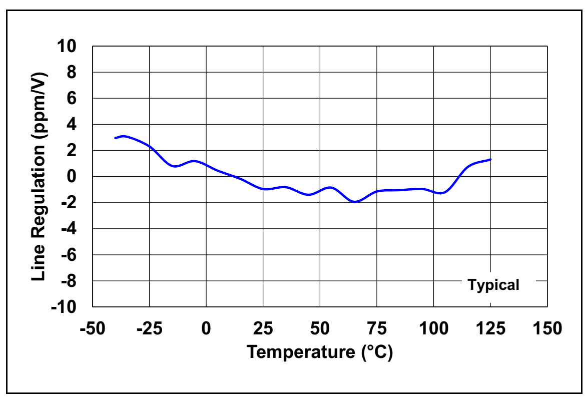

FIGURE 3-6: *MCP1502 – Line Regulation vs. Temperature.*

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Note: Unless otherwise specified, maximum values are: $V_{DD(MIN)} \leq V_{DD} \leq 5.5V$ at T_A = +25°C.

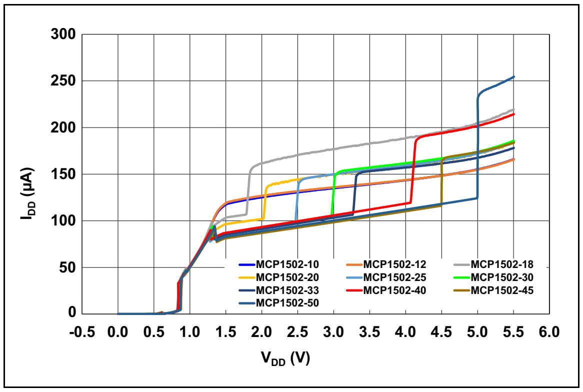

FIGURE 3-7: *I_{DD} vs. V_{DD} for All Options.*

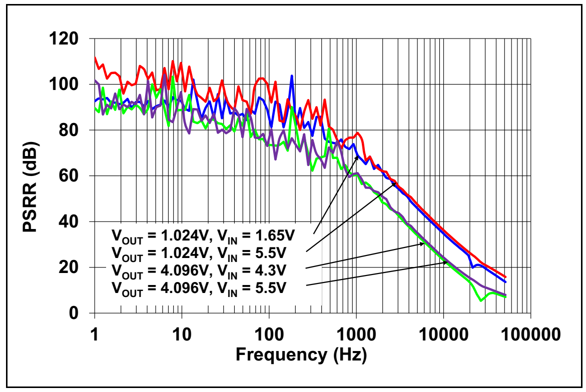

FIGURE 3-10: *PSRR vs. Frequency, 1 kΩ Load, T_A = +25°C.*

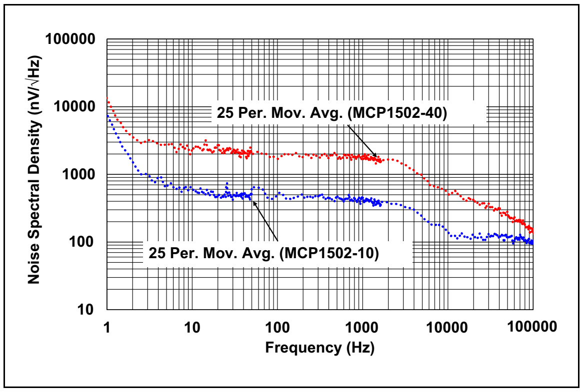

FIGURE 3-8: *Noise vs. Frequency, No Load, T_A = +25°C.*

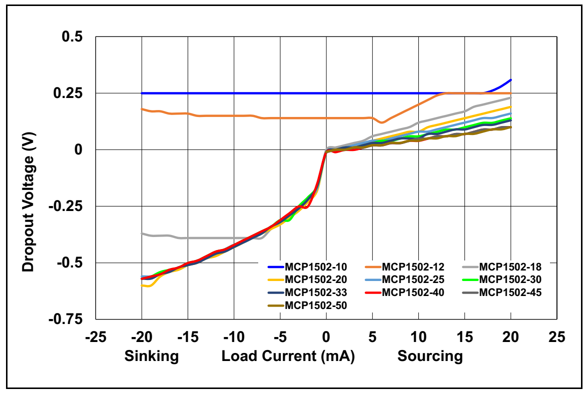

FIGURE 3-11: *Dropout Voltage vs. Load, T_A = +25°C.*

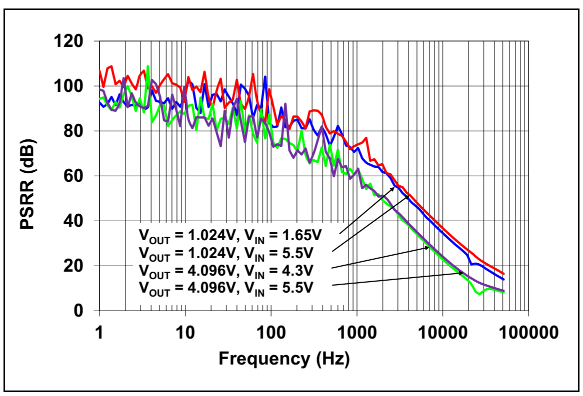

FIGURE 3-9: *PSRR vs. Frequency, No Load, T_A = +25°C.*

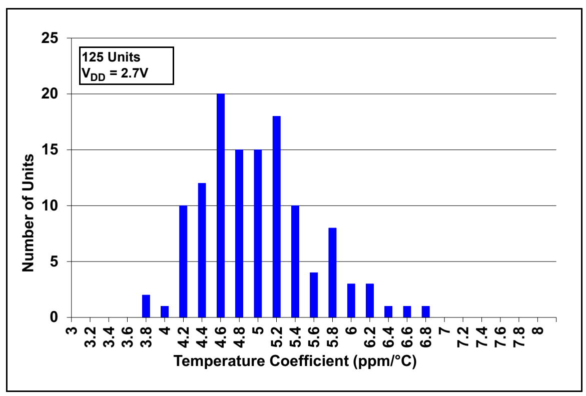

FIGURE 3-12: *MCP1502 Tempco Distribution, No Load, V_{DD} = 2.7V.*

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Note: Unless otherwise specified, maximum values are: $V_{DD(MIN)} \leq V_{DD} \leq 5.5V$ at $T_A = +25°C$.

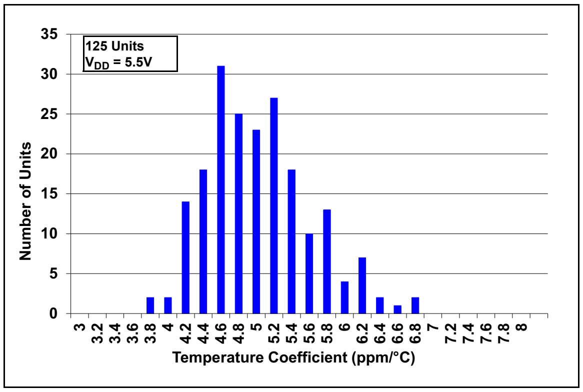

FIGURE 3-13: *MCP1502 Tempco Distribution, No Load, V_{DD} = 5.5V.*

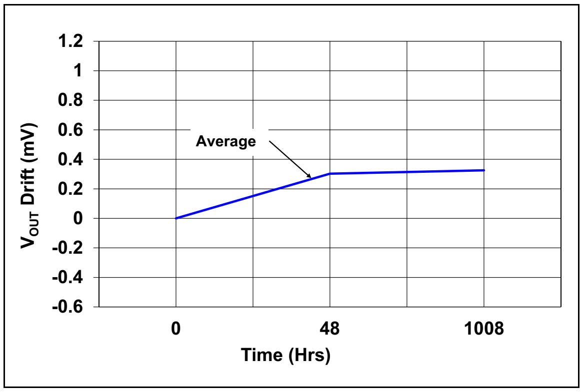

FIGURE 3-14: *V_{OUT} Drift vs. Time, T_A = +25°C, No Load, 800 Units.*

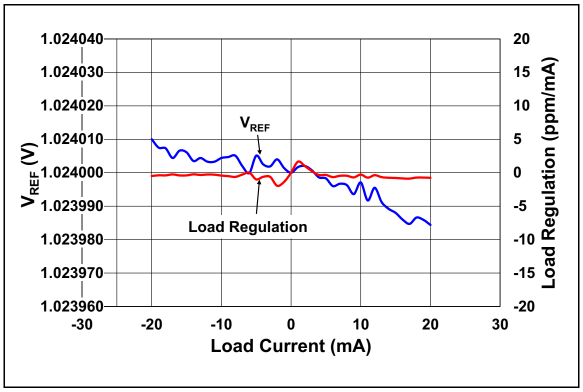

FIGURE 3-15: *MCP1502-10 V_{REF} and Load Regulation vs. Load Current.*

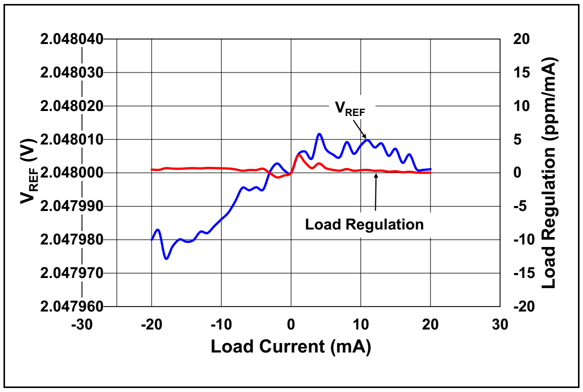

FIGURE 3-16: *MCP1502-20 V_{REF} and Load Regulation vs. Load Current.*

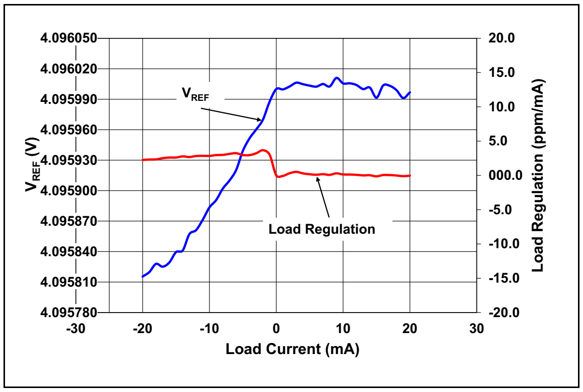

FIGURE 3-17: *MCP1502-40 V_{REF} and Load Regulation vs. Load Current.*

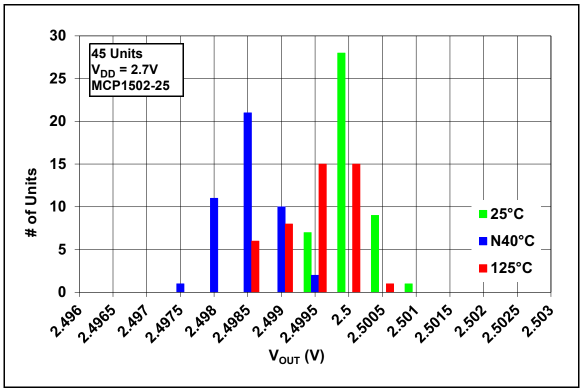

FIGURE 3-18: *MCP1502 Output Voltage Histogram, V_{DD} = 2.7V.*

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Note: Unless otherwise specified, maximum values are: $V_{DD(MIN)} \le V_{DD} \le 5.5V$ at $T_A = +25°C$.

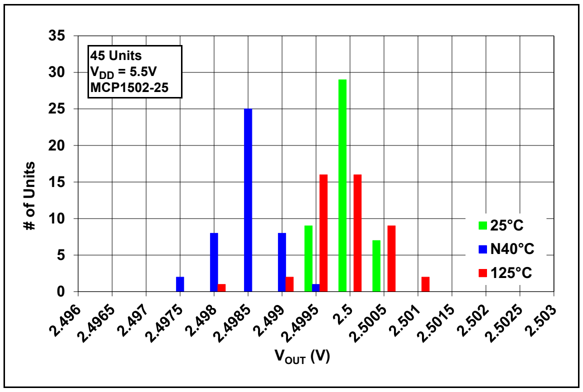

FIGURE 3-19: *MCP1502 Output Voltage Histogram, V_{DD} = 5.5V.*

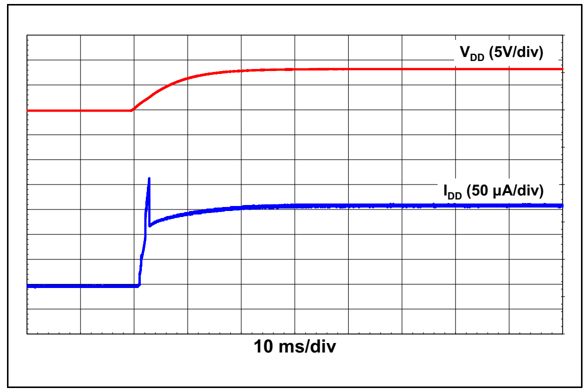

FIGURE 3-22: *I_{DD} Turn-On Transient Response.*

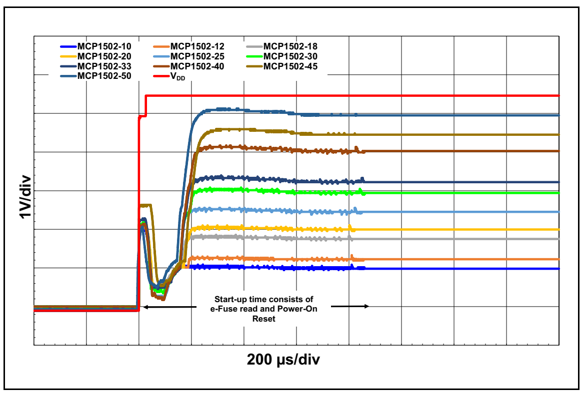

FIGURE 3-20: *Fast Ramp Start-up @ +25°C for All Options.*

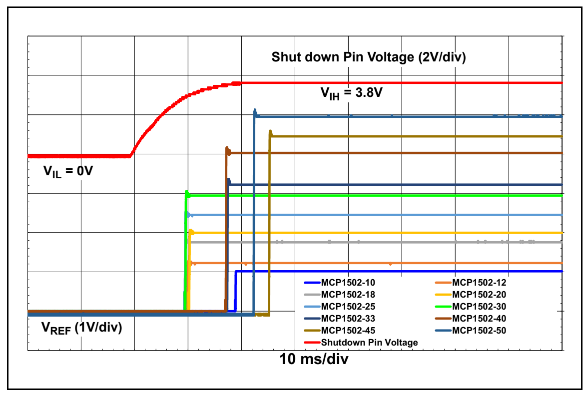

FIGURE 3-23: *Shut down Low-to-High Slow Ramp Turn-On Transient Response @ +25°C for All Options.*

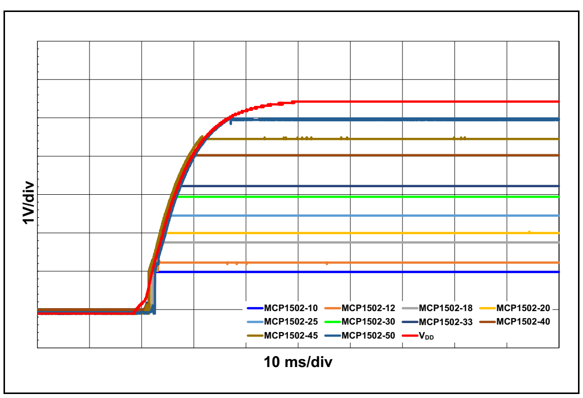

FIGURE 3-21: *Slow Ramp Start-up @ +25°C for All Options.*

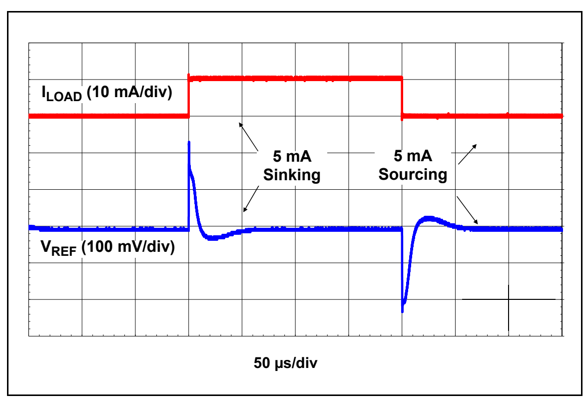

FIGURE 3-24: *Load Regulation Transient Response @ +25°C for All Options.*

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Note: Unless otherwise specified, maximum values are: $V_{DD(MIN)} \leq V_{DD} \leq 5.5V$ at $T_A = +25°C$.

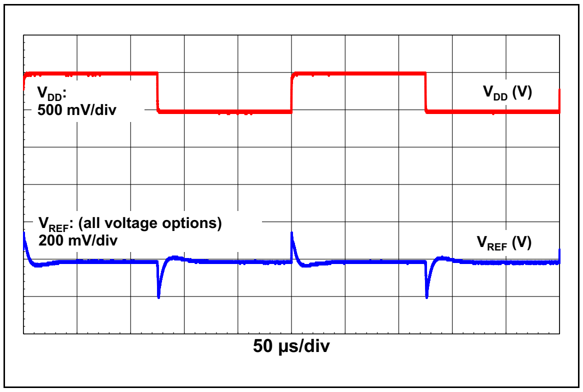

FIGURE 3-25: *Line Regulation Transient Response @ +25°C for All Options.*

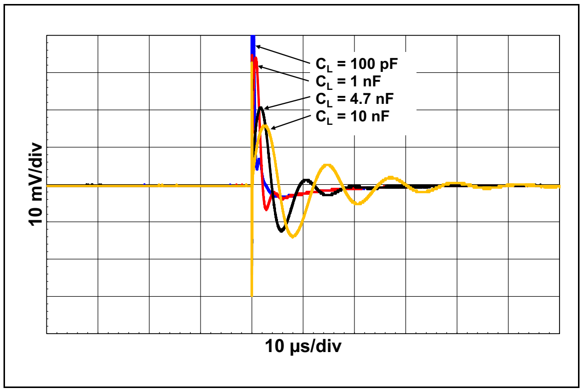

FIGURE 3-26: *MCP1502-10 Transient Response vs. Capacitive Load, V_{DD} = 5V.*

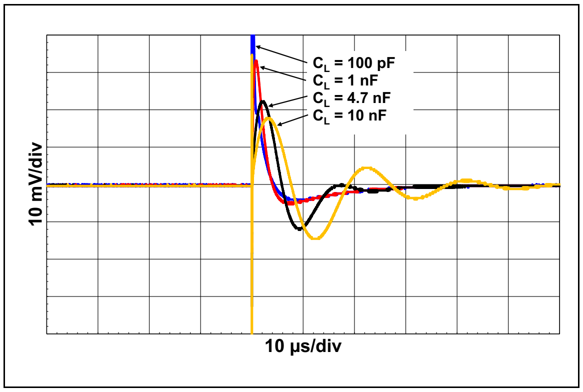

FIGURE 3-27: *MCP1502-20 Transient Response vs. Capacitive Load, V_{DD} = 5V.*

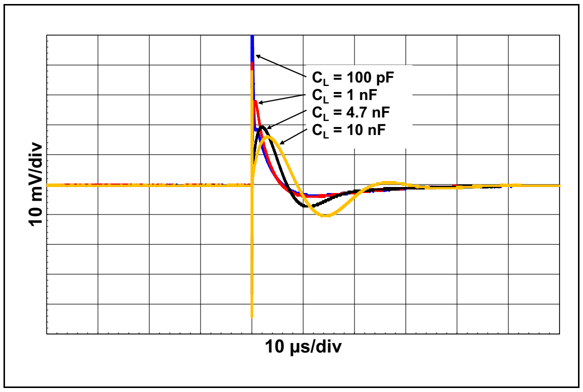

FIGURE 3-28: *MCP1502-40 Transient Response vs. Capacitive Load, V_{DD} = 5V.*

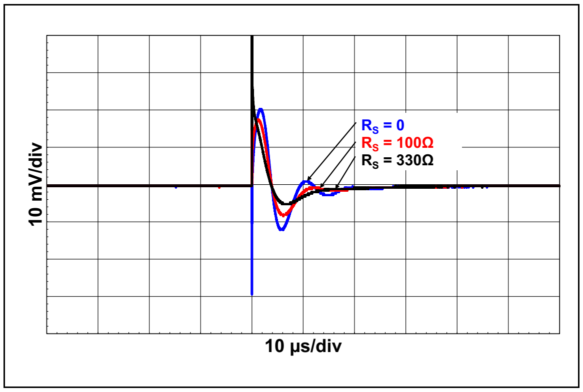

FIGURE 3-29: *MCP1502-10 Transient Response vs. R_S, V_{DD} = 5V, C_L = 4.7 nF.*

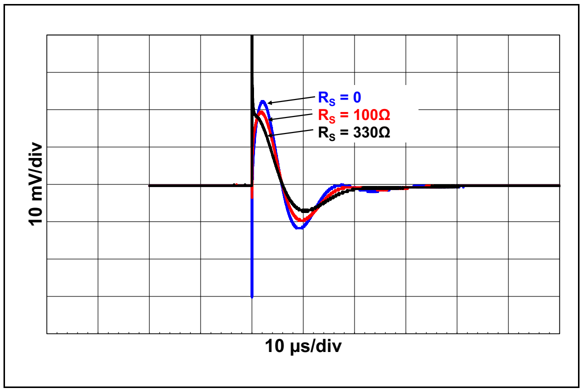

FIGURE 3-30: *MCP1502-20 Transient Response vs. R_S, V_{DD} = 5V, C_L = 4.7 nF.*

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Note: Unless otherwise specified, maximum values are: $V_{DD(MIN)} \leq V_{DD} \leq 5.5V$ at T_A = +25°C.

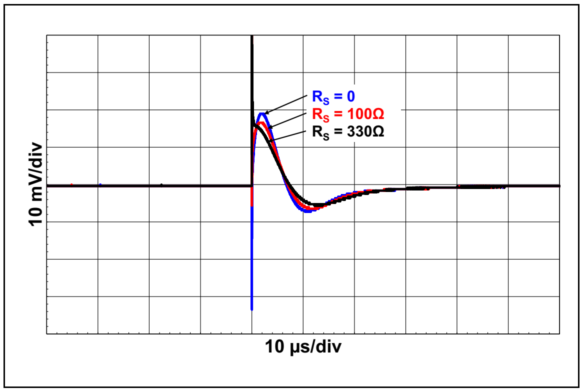

FIGURE 3-31: *MCP1502-40 Transient Response vs. R_S, V_{DD} = 5V, C_L = 4.7 nF.*

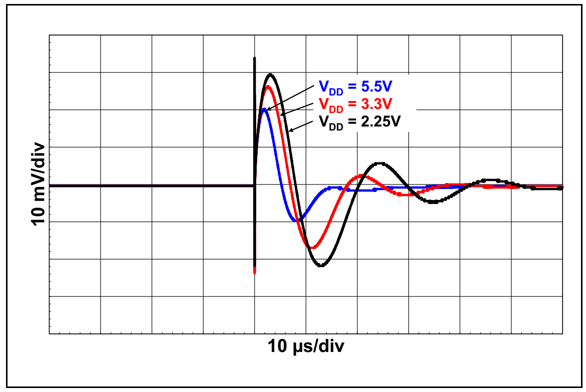

FIGURE 3-33: *MCP1502-20 Transient Response vs. V_{DD}, C_L = 4.7 nF.*

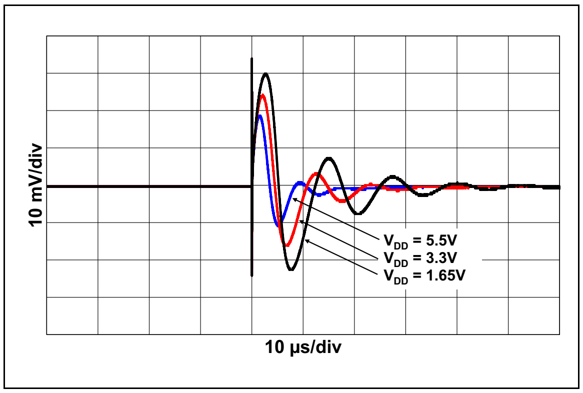

FIGURE 3-32: *MCP1502-10 Transient Response vs. V_{DD}, C_L = 4.7 nF.*

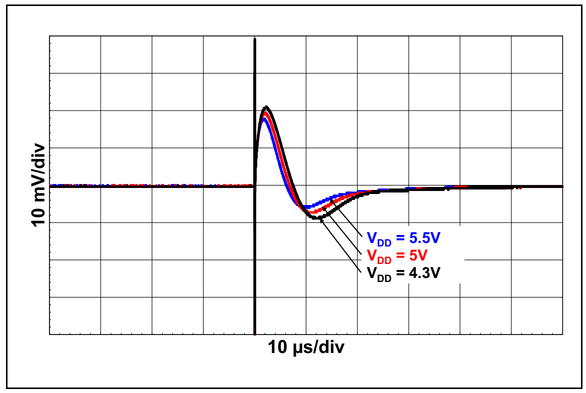

FIGURE 3-34: *MCP1502-40 Transient Response vs. V_{DD}, C_L = 4.7 nF.*

4.0 THEORY OF OPERATION

The MCP1502 is a buffered voltage reference that is capable of operating over a wide input supply range, while providing a stable output across the input supply range. Refer to the **Block Diagram** for the details of the MCP1502. As with all band gap circuits, the internal reference sums together two voltages having an opposite temperature coefficient, which allows a voltage reference that is practically independent from temperature.

MCP1502 band gap is based on a second-order temperature compensated circuit. This allows the MCP1502 to achieve high initial accuracy and a low-temperature coefficient operation across voltage and temperature. The band gap curvature compensation is determined during device characterization and is trimmed for optimal accuracy.

The MCP1502 also includes a chopper-based amplifier architecture that ensures excellent low noise operation, which further reduces temperature-dependent offsets that would otherwise increase the temperature coefficient of the MCP1502 and significantly improves long-term drift performance. Additional circuitry is included to eliminate the chopping frequency from the output of the device.

After the band gap voltage is compensated, it is attenuated, buffered and provided to the output drive circuit. The device has excellent performance when sinking or sourcing load currents (±20 mA).

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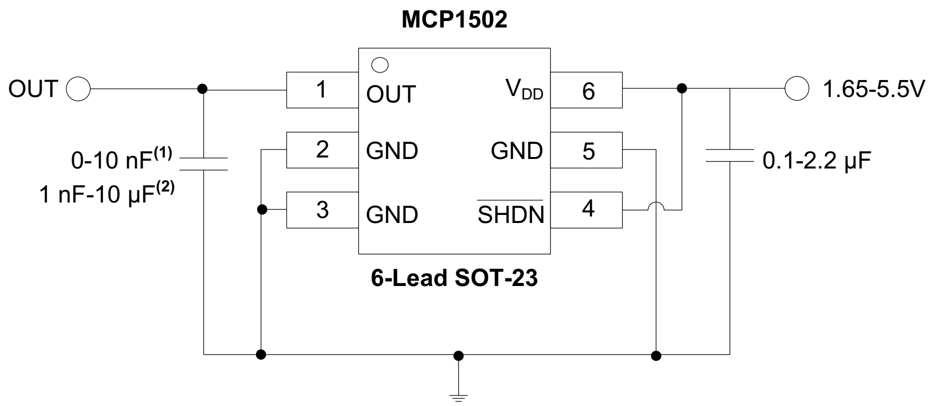
5.0 APPLICATION CIRCUITS

5.1 Application Tips

5.1.1 BASIC APPLICATION CIRCUIT

Figure 5-1 illustrates a basic circuit configuration of the MCP1502.



Note 1: With no series resistance.

2: With R_S = 100Ω and 1 kΩ to ground.

FIGURE 5-1: *Basic Circuit Configuration.*

An output capacitor is not required for stability of the voltage reference, but may be optionally added to provide noise filtering or act as a charge reservoir for switching loads (e.g., Successive Approximation Register (SAR), Analog-to-Digital Converter (ADC)). As shown in Figure 5-5, the input voltage is connected to the device at the V_{DD} input, with an optional 2.2 μf ceramic capacitor. This capacitor would be required if the input voltage has excessive noise. A 2.2 μf capacitor would reject input voltage noise at approximately 1 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.

If the noise at the output of the voltage references is too high for the particular application, it can be easily filtered with an external RC filter and op amp buffer (see Figure 5-2).

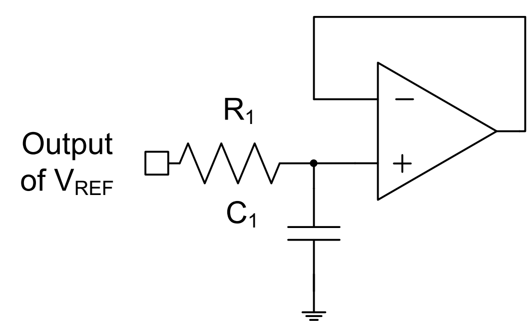


FIGURE 5-2: *Output Noise Reducing Filter.*

The RC filter values are selected for a desired cutoff frequency, as shown in Equation 5-1.

EQUATION 5-1:

$$f_C = \frac{1}{2\pi(R1 \times C1)}$$

The values that are shown in Figure 5-5 (1 kΩ and 10 μF) will create a first-order, low-pass filter at the output of the amplifier. The cutoff frequency of this filter is 15.9 Hz, and the attenuation slope is 20 dB/decade. The MCP6286 amplifier isolates the loading of this low-pass filter from the remainder of the application circuit. This amplifier also provides additional drive with a faster response time than the voltage reference.

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5.1.2 LOAD CAPACITOR

The maximum capacitive load without series resistance is 10 nF. However, larger capacitors may be implemented if a resistor is used in series with a larger load capacitor. Refer to Figure 3-29, Figure 3-30 and Figure 3-31 for the transient response with the series resistor and capacitive load.

5.1.3 PRINTED CIRCUIT BOARD LAYOUT CONSIDERATIONS

Mechanical stress due to Printed Circuit Board (PCB) mounting can cause the output voltage to shift from its initial value. To reduce stress-related output voltage shifts, mount the reference on low stress areas of the PCB (i.e., away from PCB edges, screw holes and large components).

5.2 Typical Applications Circuits

5.2.1 NEGATIVE VOLTAGE REFERENCE

A negative voltage reference can be generated using any of the devices in the MCP1502 family. A typical application is shown in Figure 5-3. In this circuit, the voltage inversion is implemented using the MCP6061 and two equal resistors. The voltage at the output of the MCP1502 voltage reference drives R1, which is connected to the inverting input of the MCP6061 amplifier. Since the noninverting input of the amplifier is biased to ground, the inverting input will also be close to 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 through R1 will also flow through R2. As a consequence, the output voltage of the amplifier is equal to -2.5V for the MCP1502-25 and -4.096V for the MCP1502-40.

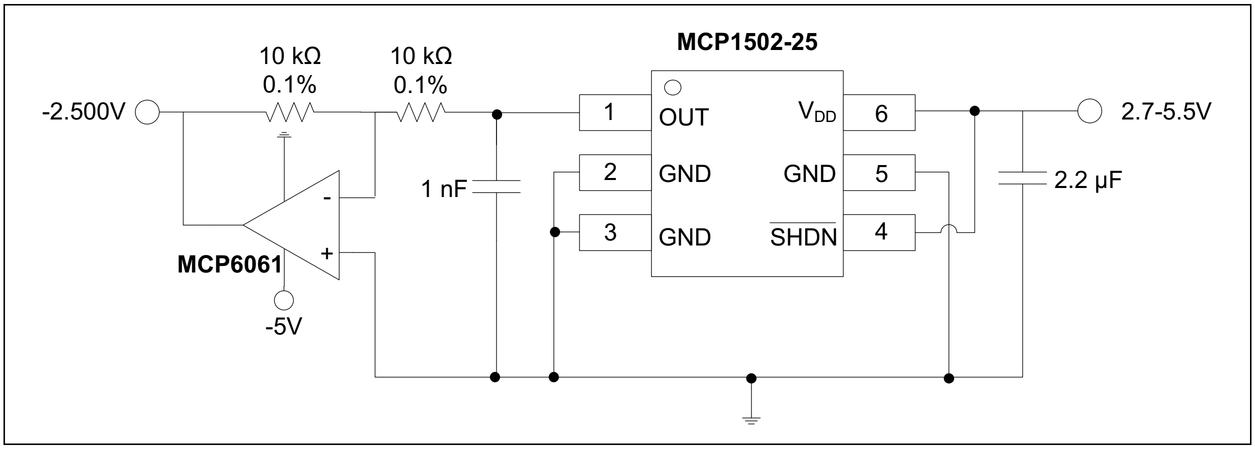

FIGURE 5-3: *Negative Voltage Reference.*

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5.2.2 A/D CONVERTER REFERENCE

The MCP1502 product family was carefully designed to provide a precision, low-noise voltage reference for the Microchip families of ADCs. The circuit shown in Figure 5-4 shows a MCP1502-25 configured to provide the reference to the MCP3201, a 12-bit ADC.

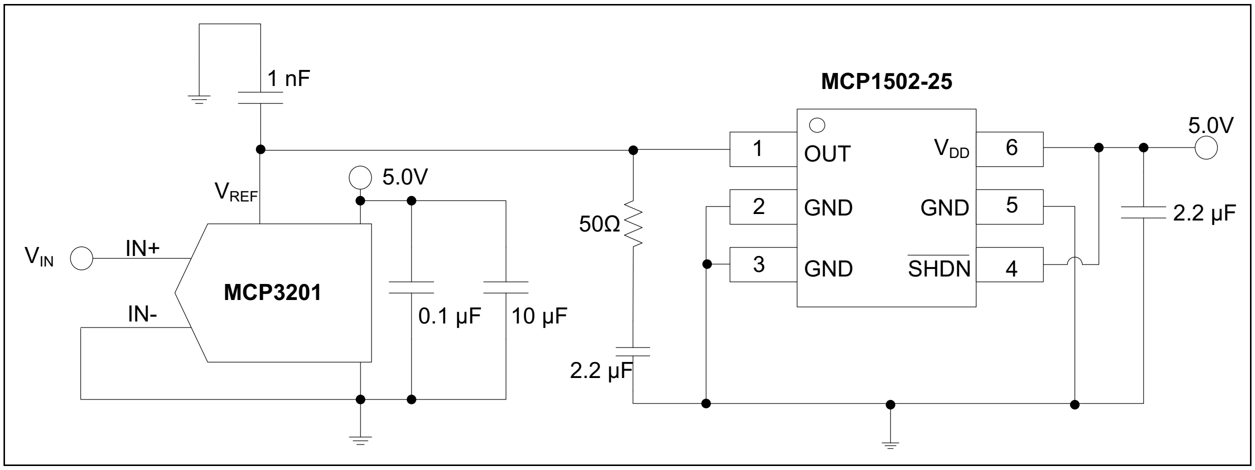


FIGURE 5-4: *ADC Example Circuit.*

The circuit shown in Figure 5-5 shows a MCP1502-40 configured to provide the reference to a SAR ADC. Refer to the MCP331X1D 16/14/12-Bit, 1 Msps SAR ADC Evaluation Kit User's Guide (DS50002733).

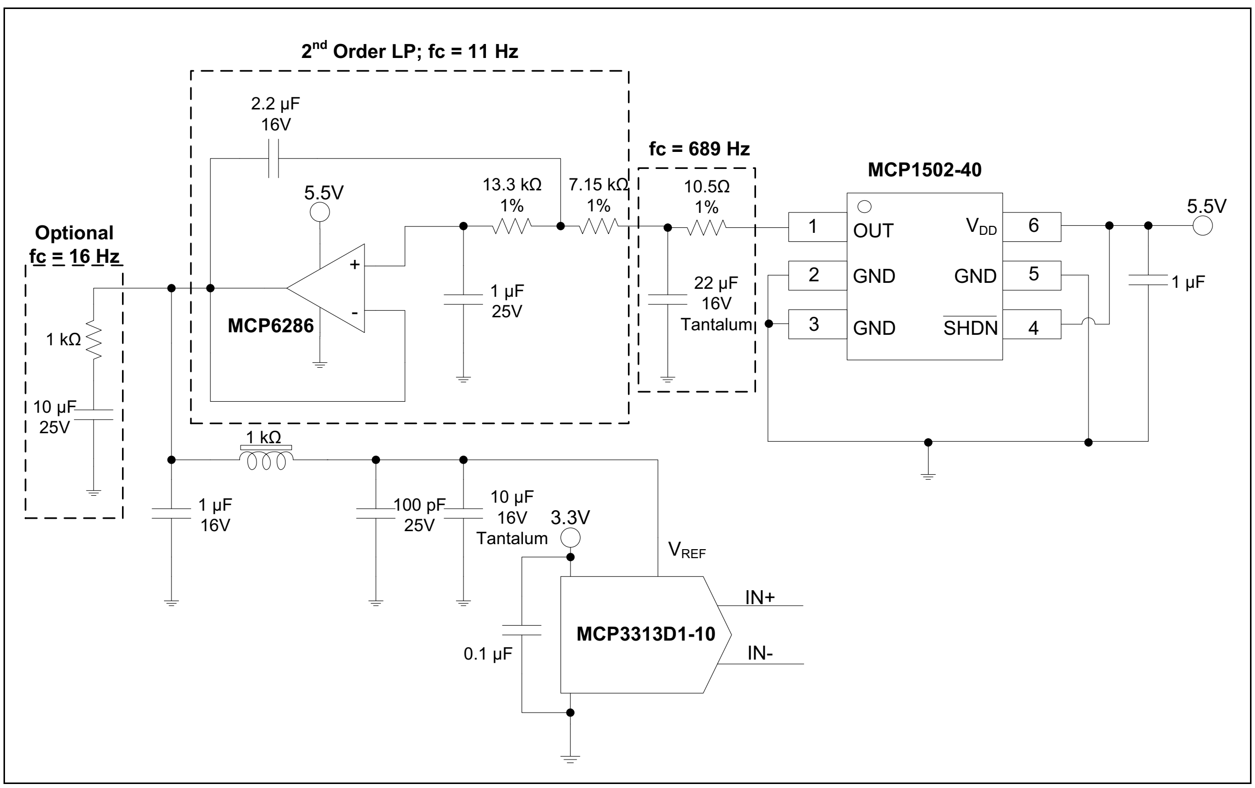
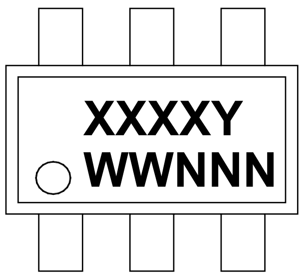


FIGURE 5-5: *SAR ADC Example Circuit.*

6.0 PACKAGE INFORMATION

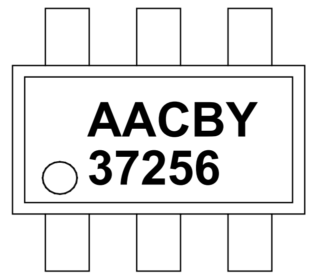
6.1 Package Markings

6-Lead SOT-23



Device	Code
MCP1502T-10E/CHY	AACBY
MCP1502T-12E/CHY	AACCY
MCP1502T-18E/CHY	AACDY
MCP1502T-20E/CHY	AACEY
MCP1502T-25E/CHY	AACFY
MCP1502T-30E/CHY	AACGY
MCP1502T-33E/CHY	AACHY
MCP1502T-40E/CHY	AACJY
MCP1502T-45E/CHY	AAFGY
MCP1502T-50E/CHY	AAFHY

Example



Legend:	XX...X	Customer-specific information
	Y	Year code (last digit of calendar year)
	YY	Year code (last 2 digits of calendar year)
	WW	Week code (week of January 1 is week ‘01’)
	NNN	Alphanumeric traceability code
	(e3)	Pb-free JEDEC® designator for Matte Tin (Sn)
	*	This package is Pb-free. The Pb-free JEDEC designator ((e3)) can be found on the outer packaging for this package.

Note: 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.

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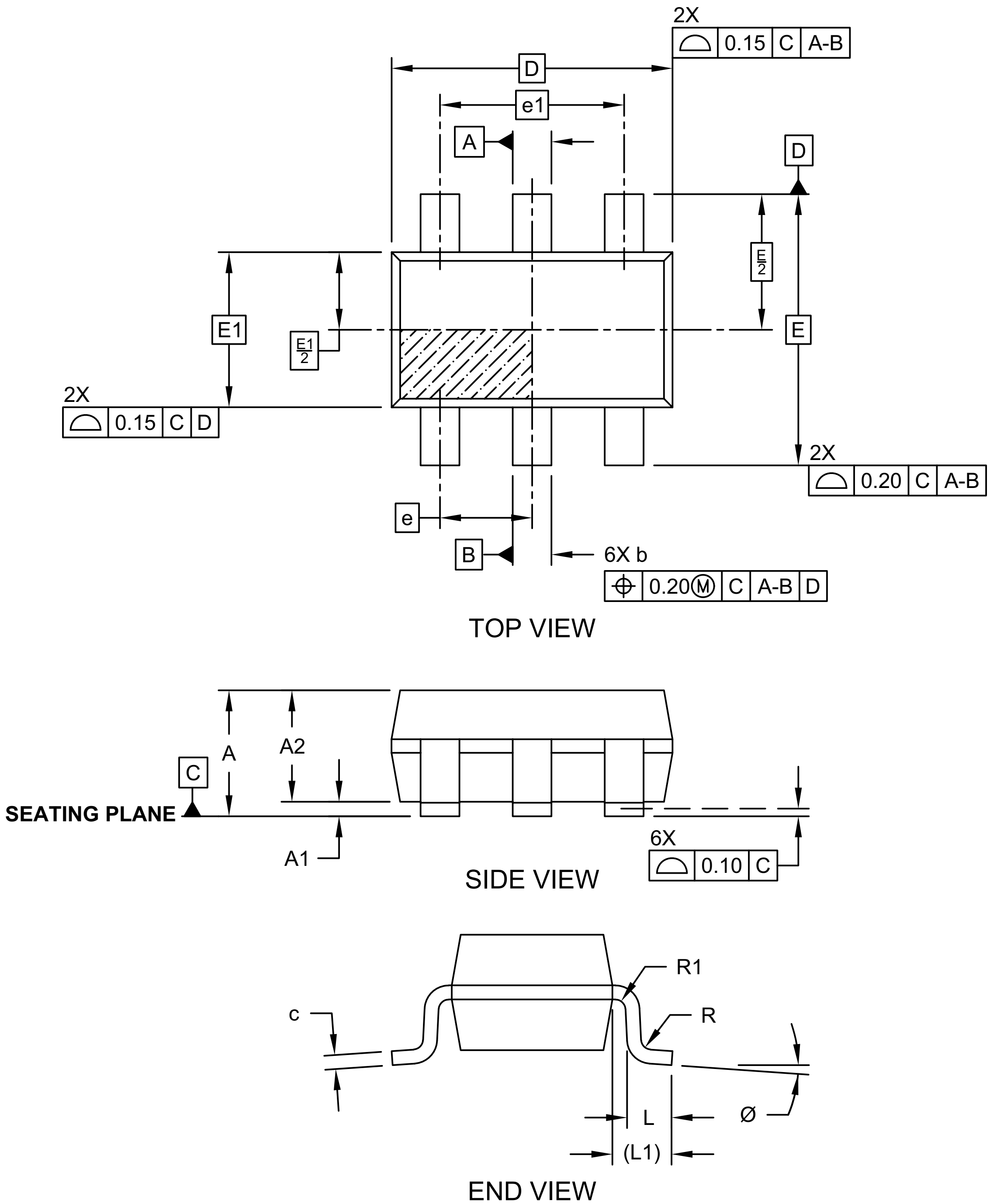
6-Lead Plastic Small Outline Transistor (CH) [SOT-23]

Note:	For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



Microchip Technology Drawing C04-028-CH Rev. F Sheet 1 of 2

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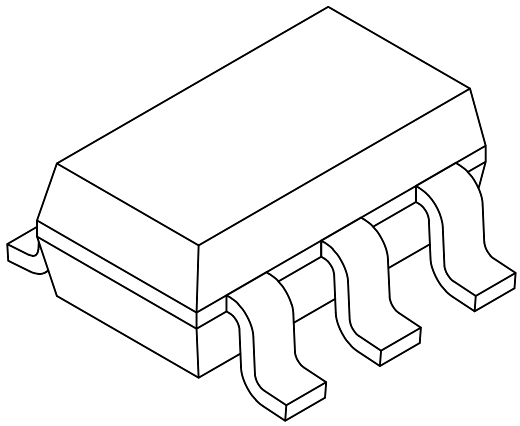
6-Lead Plastic Small Outline Transistor (CH) [SOT-23]

Note:	For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



Units		MILLIMETERS		
Dimension Limits		MIN	NOM	MAX
Number of Leads	N		6	
Pitch	e		0.95 BSC	
Outside lead pitch	e1		1.90 BSC	
Overall Height	A	0.90	-	1.45
Molded Package Thickness	A2	0.89	1.15	1.30
Standoff	A1	0.00	-	0.15
Overall Width	E		2.80 BSC	
Molded Package Width	E1		1.60 BSC	
Overall Length	D		2.90 BSC	
Foot Length	L	0.30	0.45	0.60
Footprint	L1		0.60 REF	
Foot Angle	Ø	0°	-	10°
Lead Thickness	c	0.08	-	0.26
Lead Width	b	0.20	-	0.51

Notes:

1. Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.25mm per side.
2. Dimensioning and tolerancing per ASME Y14.5M
   BSC: Basic Dimension. Theoretically exact value shown without tolerances.
   REF: Reference Dimension, usually without tolerance, for information purposes only.

Microchip Technology Drawing C04-028-CH Rev.F Sheet 2 of 2

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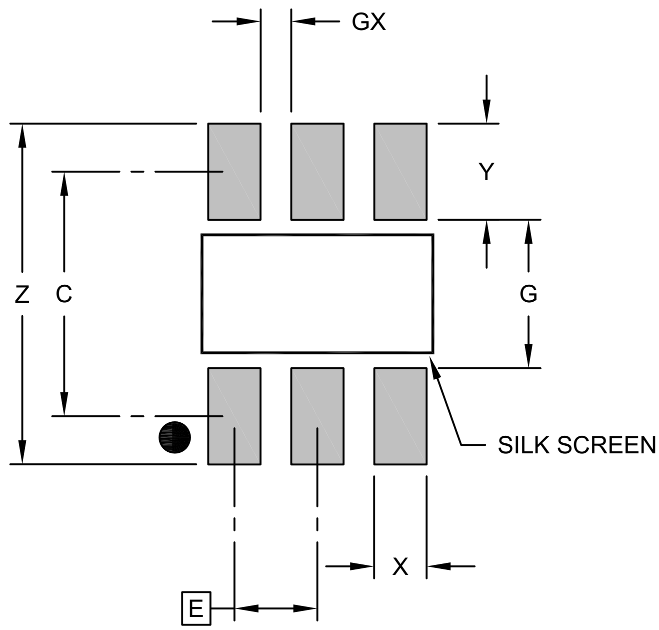
6-Lead Plastic Small Outline Transistor (CH) [SOT-23]

Note:	For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



RECOMMENDED LAND PATTERN

	Units	MILLIMETERS		
	Dimension Limits	MIN	NOM	MAX
Contact Pitch	E	0.95 BSC		
Contact Pad Spacing	C		2.80	
Contact Pad Width (X6)	X			0.60
Contact Pad Length (X6)	Y			1.10
Distance Between Pads	G	1.70		
Distance Between Pads	GX	0.35		
Overall Width	Z			3.90

Notes:

1. Dimensioning and tolerancing per ASME Y14.5M

   BSC: Basic Dimension. Theoretically exact value shown without tolerances.

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NOTES:

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APPENDIX A: REVISION HISTORY

Revision C (April 2024)

- Updated Absolute Maximum Ratings(†) section.

Revision B (February 2022)

- Added 4.5V and 5V options throughout the document.
- Updated 6.0 Package Information

Revision A (September 2021)

Original Release of this Document.

NOTES:

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PRODUCT IDENTIFICATION SYSTEM

To order or obtain information, e.g., on pricing or delivery, refer to the factory or the listed sales office.

PART NO.	[X][(1)]	X	/XX
Device	Tape and Reel	Output Voltage Option	Package

Device:	MCP1502 – 7 ppm maximum thermal drift buffered reference
Tape and Reel Option:	Blank = Standard packaging (tube or tray)
	T = Tape and Reel[(1)]
Output Voltage Option:	10 = 1.024V
	12 = 1.250V
	18 = 1.800V
	20 = 2.048V
	25 = 2.500V
	30 = 3.000V
	33 = 3.300V
	40 = 4.096V
	45 = 4.500V
	50 = 5.000V
Package:	CHY* = 6-Lead Plastic Small Outline Transistor (SOT-23)
	*Y = Nickel palladium gold manufacturing designator. Only available on the SOT-23 package.

Examples:

a) MCP1502T-10E/CHY: 1.024V, 6-Lead SOT-23 Package, Tape and Reel

Note 1: Tape and Reel identifier only appears in the catalog part number description. This identifier is used for ordering purposes and is not printed on the device package. Check with your Microchip sales office for package availability for the Tape and Reel option.

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