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MCP1501

High-Precision Buffered Voltage Reference

Features

- Maximum Temperature Coefficient: 50 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/mA Maximum
- 10 Voltage Variants Available:
  - 1.024V
  - 1.250V
  - 1.800V
  - 2.048V
  - 2.500V
  - 3.000V
  - 3.300V
  - 4.096V
  - 4.500V (6-Lead SOT-23 package only)
  - 5.000V (6-Lead SOT-23 package only)
- Output Noise: 30 µVRMS, 0.1 Hz to 10 kHz (1.024V)
- AEC-Q100 Qualified (Automotive Applications)
  - Package qualified: 6-Lead SOT-23

Applications

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

Related Parts

- MCP1502 High-Precision Buffered Voltage Reference (DS20006593)

General Description

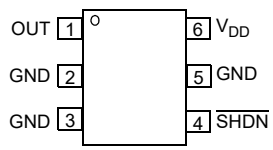
The MCP1501 is a buffered voltage reference capable of sinking and sourcing 20 mA of current. The voltage reference is a low-drift band gap based reference. The band gap uses chopper-based amplifiers, effectively reducing the drift to zero.

The MCP1501 is available in the following packages:

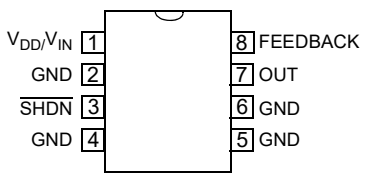
- 6-Lead SOT-23
  - This package is AEC-Q100 automotive qualified.
- 8-Lead SOIC
- 8-Lead 2 mm x 2 mm WDFN

Package Types

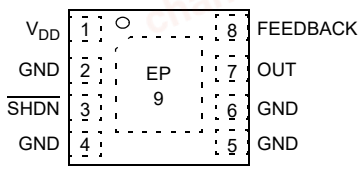
MCP1501
6-Lead SOT-23



MCP1501
8-Lead SOIC



MCP1501
2x2 WDFN*

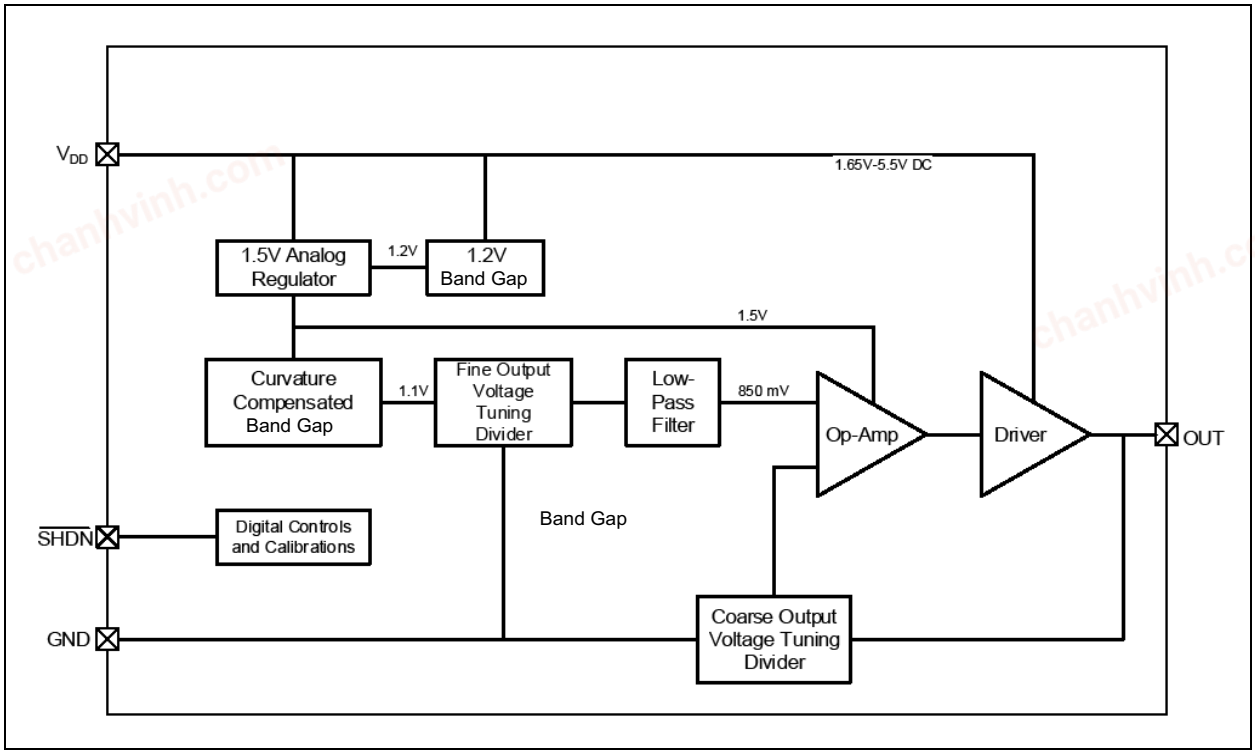


*Includes Exposed Thermal Pad (EP). See Table 1-1

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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	SOIC	2 x 2 WDFN	Symbol	Function
1	7	7	OUT	V_{REF} Output
—	8	8	FEEDBACK	V_{REF} Feedback
2, 3, 5	2, 4, 5, 6	2, 4, 5, 6	GND	System Ground
4	3	3	$\overline{SHDN}$	Shutdown Pin Active Low
6	1	1	V_{DD}	Power Supply Input
—	—	9	EP	Exposed Thermal Pad

1.1 Buffered V_{REF} Output (OUT)

This is the Buffered Reference Output. On the WDFN and SOIC package, this should be connected to the FEEDBACK pin at the device. The output driver and the feedback are tristated when in shutdown.

1.2 Buffered V_{REF} Feedback (FEEDBACK)

This is the buffer amplifier FEEDBACK pin. On the WDFN and SOIC package, this should be connected to the OUT pin at the device. This connection is internal on the SOT-23 package. Note that if there is routing impedance or IR-drop between the OUT and FEEDBACK pins, it is the FEEDBACK pin which accurately holds the output voltage. This can be used in an application to remove IR-drop effects on output voltage caused by the Printed Circuit Board (PCB) or interconnect resistance with a high-current load.

1.3 System Ground (GND)

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

1.4 Shutdown 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 Shutdown pin, the device should first be powered up. Once the device is fully powered up, the Shutdown pin can be used.

1.5 Power Supply Input (V_{DD})

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

1.6 Exposed Thermal Pad (EP)

Not internally connected, but grounding is recommended. This can be soldered to the ground on the PCB.

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

Note: **† 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, $V_{DD(MIN)} \le V_{DD} \le 5.5V$ at $-40°C \le T_A \le +125°C$.							
Characteristic		**Sym.**	**Min.**	**Typ.**	**Max.**	**Units**	**Conditions**
Supply Voltage		V_{DD}	1.65	—	5.5	V	MCP1501-10
		V_{DD}	1.65	—	5.5	V	MCP1501-12
		V_{DD}	2.0	—	5.5	V	MCP1501-18
		V_{DD}	2.25	—	5.5	V	MCP1501-20
		V_{DD}	2.70	—	5.5	V	MCP1501-25
		V_{DD}	3.2	—	5.5	V	MCP1501-30
		V_{DD}	3.5	—	5.5	V	MCP1501-33
		V_{DD}	4.3	—	5.5	V	MCP1501-40
		V_{DD}	4.7	—	5.5	V	MCP1501-45
		V_{DD}	5.2	—	5.5	V	MCP1501-50
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 a rising V_{DD}, the voltage at which device internal reset will get released.

2: On dropping V_{DD}, the voltage at which the internal reset circuit will reset. On the 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, the Shutdown pin can be used.

4: µVPP is six times the value of the µVRMS.

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TABLE 2-1: DC CHARACTERISTICS

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	MCP1501-10	V_{OUT}	1.0230	1.0240	1.0250	V	Temperature at +25°C
	MCP1501-12		1.2488	1.2500	1.2513	V	
	MCP1501-18		1.7982	1.800	1.8018	V	
	MCP1501-20		2.0460	2.0480	2.0500	V	
	MCP1501-25		2.4975	2.500	2.5025	V	
	MCP1501-30		2.9970	3.000	3.0030	V	
	MCP1501-33		3.2967	3.300	3.3033	V	
	MCP1501-40		4.0919	4.0960	4.1001	V	
	MCP1501-45		4.4955	4.500	4.5045	V	
	MCP1501-50		4.995	5.000	5.0050	V	
Temperature Coefficient	MCP1501-XX	T_C	—	10	50	ppm/°C	
Line Regulation	MCP1501-XX	$\Delta V_{OUT}/\Delta V_{IN}$	—	5	50	ppm/V	
	MCP1501-50		—	5	—		
Load Regulation		$\Delta V_{OUT} / \Delta I_{OUT}$	—	10 ppm – sink	40 ppm – sink	ppm/mA	-5 mA < I_{LOAD}
Load Regulation		$\Delta V_{OUT} / \Delta I_{OUT}$	—	15 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} = 5.5V Refer to **Section 1.4 "Shutdown 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**)	MCP1501-10	e_N	—	18	—	µVPP	0.1 Hz to 10 Hz, T_A = +25°C
			—	30	—	µVRMS	0.1 Hz to 10 kHz, T_A = +25°C
	MCP1501-40	e_N	—	57	—	µVPP	0.1 Hz to 10 Hz, T_A = +25°C
			—	97	—	µVRMS	0.1 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 a rising V_{DD}, the voltage at which device internal reset will get released.

2: On dropping V_{DD}, the voltage at which the internal reset circuit will reset. On the 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, the Shutdown pin can be used.

4: µVPP is six times the value of the µVRMS.

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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 SOT-23-6	θ_{JA}	—	+190.5	—	°C/W	
Thermal Resistance for SOIC-8	θ_{JA}	—	+149.5	—	°C/W	
Thermal Resistance for DFN-8	θ_{JA}	—	+141.3	—	°C/W	

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2.1 Terminology

2.1.1 OUTPUT VOLTAGE

Output voltage is the reference voltage that is available on the OUT pin.

2.1.2 INPUT VOLTAGE

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 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: TC_{OUTPUT} 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 was collected

2.1.4 DROPOUT VOLTAGE

The dropout voltage is defined as the voltage difference between V_{DD} and V_{OUT} under 5 mA load.

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 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 MCP1501-20 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, ppm, percent/volt and ppm/volt, 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 MCP1501-20 is implemented in a design and a 10 µV change in output voltage is measured from a 2 mA change on the input, then the error in percent, ppm, ppm/output, 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:

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

2.1.7 POWER SUPPLY REJECTION RATIO

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, as shown in Figure 3-14.

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 that 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 MCP1501 should not be placed on a small daughter card or connected to ground via long traces or single vias if 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 load coefficient. These are usually solved by ensuring the local ground for the device is shared with the point of load. In some cases, it may be necessary to ensure the device ground is specifically kelvin-sourced from the point of load such that zero IR drop from unassociated circuitry is seen on the device output voltage.

Additionally, for the SOIC-8 and WDFN-8 packages, there are both OUTPUT and FEEDBACK pins available. If these pins are shorted on the PCB adjacent to the device, then any trace impedance between the device and the load will cause a small voltage drop. These pins can be routed separately and connected near the point of load to reduce or eliminate routing-related voltage drop in a system.

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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 $T_A = +25°C$.

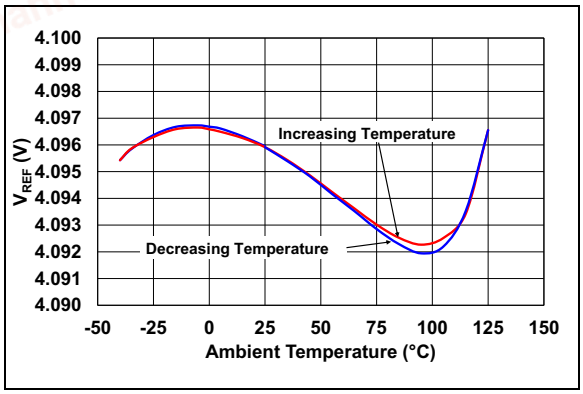


FIGURE 3-1: *V_{OUT} vs. Temperature, No Load, 4.096V Option.*

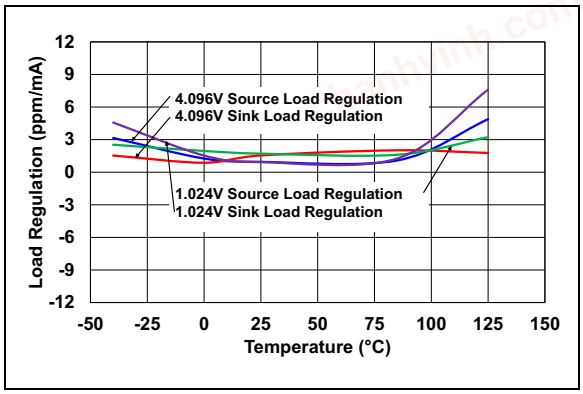


FIGURE 3-4: *Load Regulation vs. Temperature.*

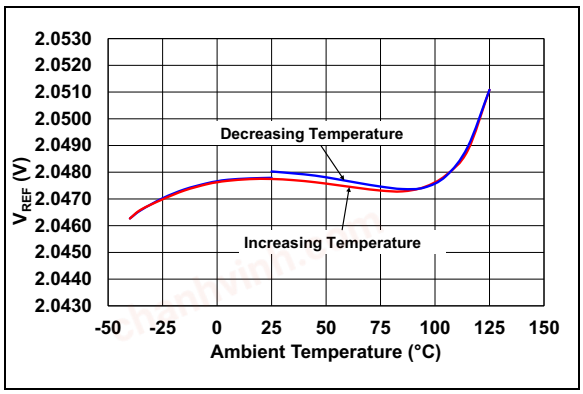


FIGURE 3-2: *V_{OUT} vs. Temperature, No Load, 2.084V Option.*

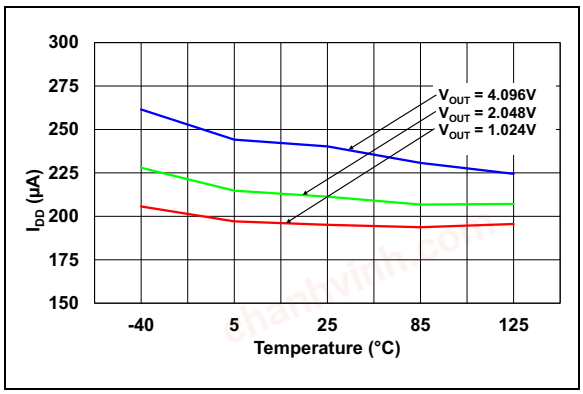


FIGURE 3-5: *I_{DD} vs. Temperature.*

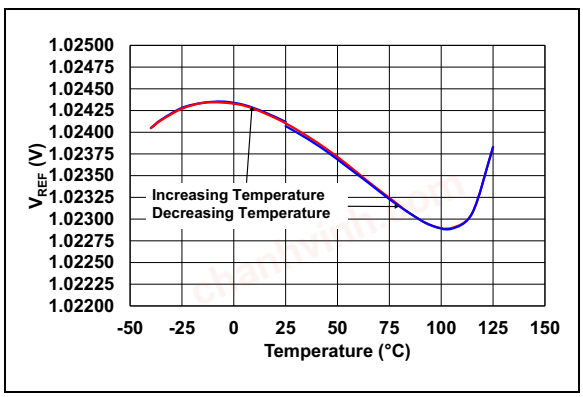


FIGURE 3-3: *V_{OUT} vs. Temperature, No Load, 1.024V Option.*

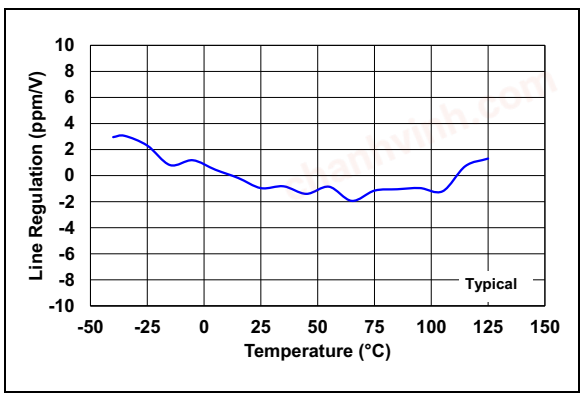


FIGURE 3-6: *MCP1501 - Line Regulation vs. Temperature.*

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

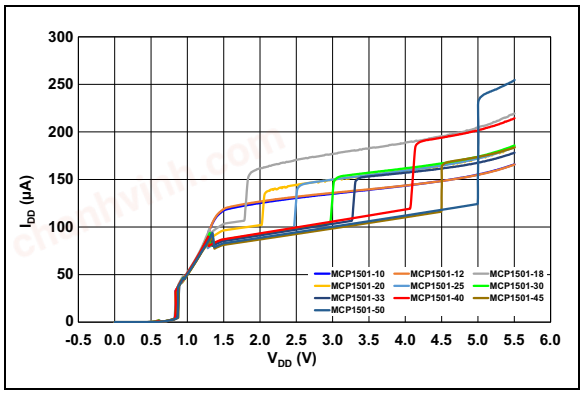


FIGURE 3-7: *I_{DD} vs. V_{DD} for All Options.*

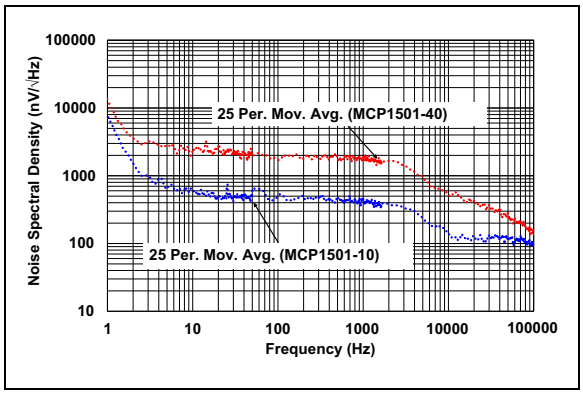


FIGURE 3-8: *Noise vs. Frequency, No Load, $T_A = +25°C$.*

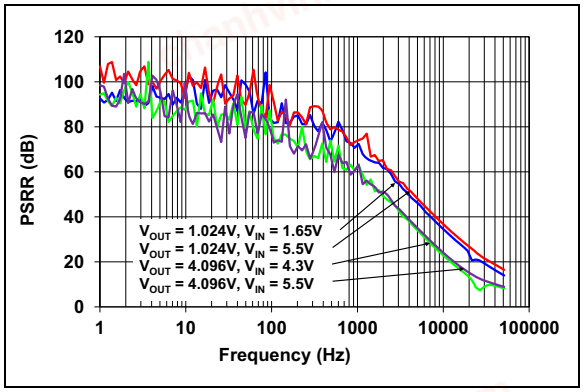


FIGURE 3-9: *PSRR vs. Frequency, No Load, $T_A = +25°C$.*

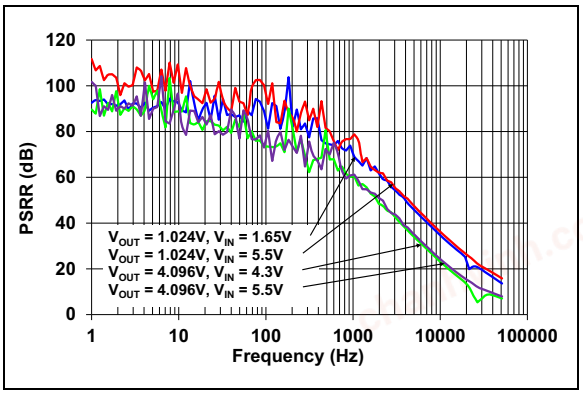


FIGURE 3-10: *PSRR vs. Frequency, 1 kΩ Load, $T_A = +25°C$.*

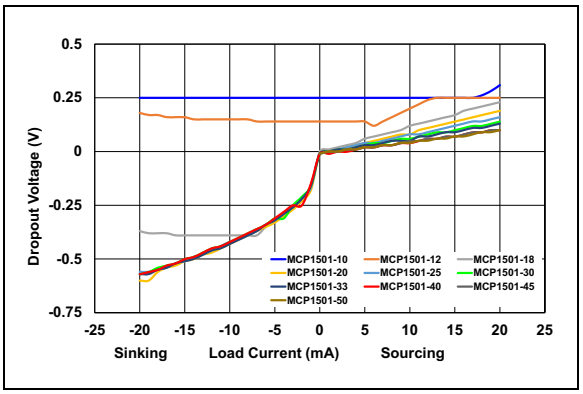


FIGURE 3-11: *Dropout Voltage vs. Load, $T_A = +25°C$.*

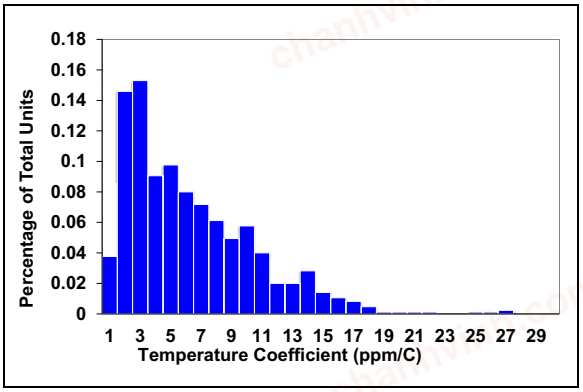


FIGURE 3-12: *Tempco Distribution, No Load, $V_{DD} = 2.7V$, 50 Units.*

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

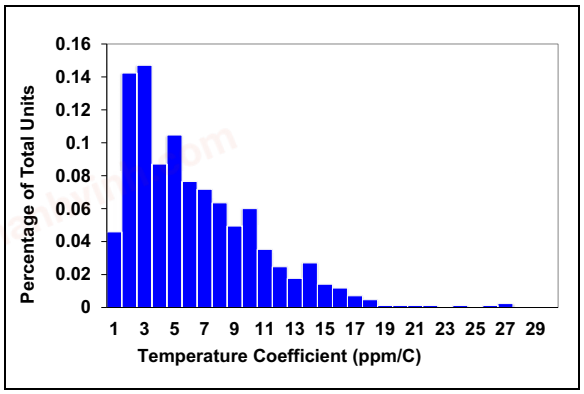


FIGURE 3-13: *Tempco Distribution, No Load, V_{DD} = 5.5V, 50 Units.*

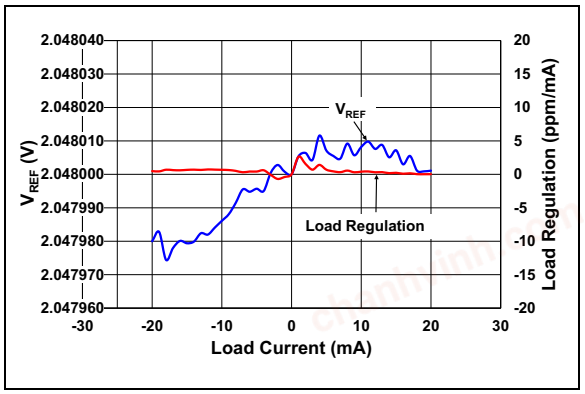


FIGURE 3-16: *MCP1501-20 V_{REF} and Load Regulation vs. Load Current.*

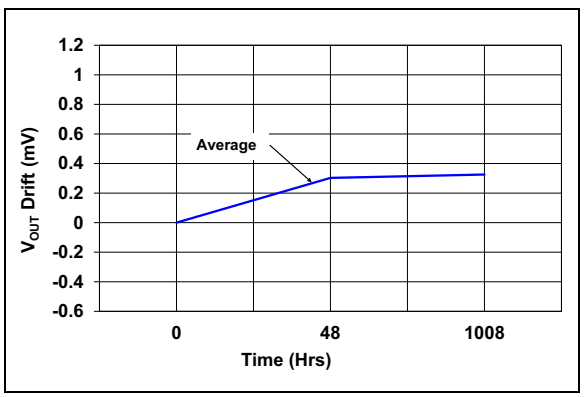


FIGURE 3-14: *V_{OUT} Drift vs. Time, T_A = +25°C, No Load, 800 Units.*

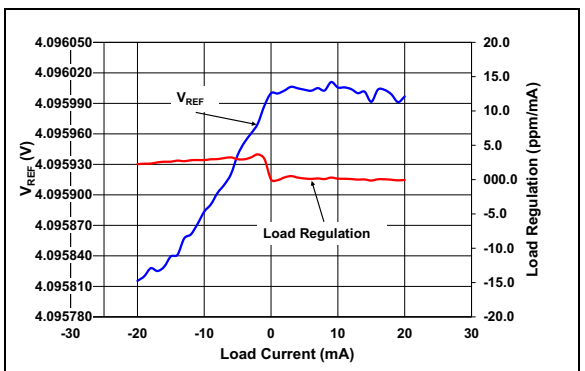


FIGURE 3-17: *MCP1501-40 V_{REF} and Load Regulation vs. Load Current.*

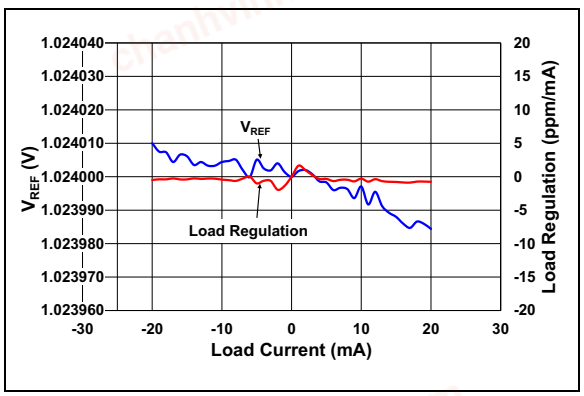


FIGURE 3-15: *MCP1501-10 V_{REF} and Load Regulation vs. Load Current.*

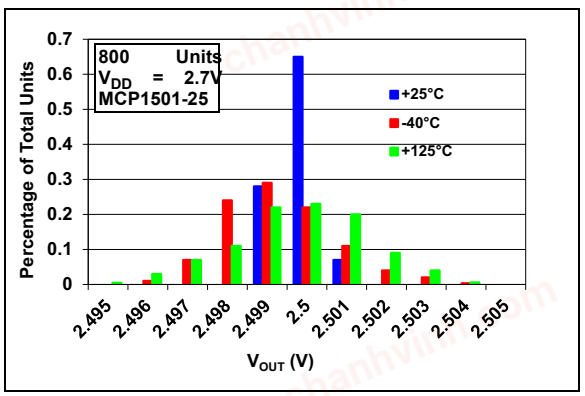


FIGURE 3-18: *MCP1501 Output Voltage Histogram, V_{DD} = 2.7V.*

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

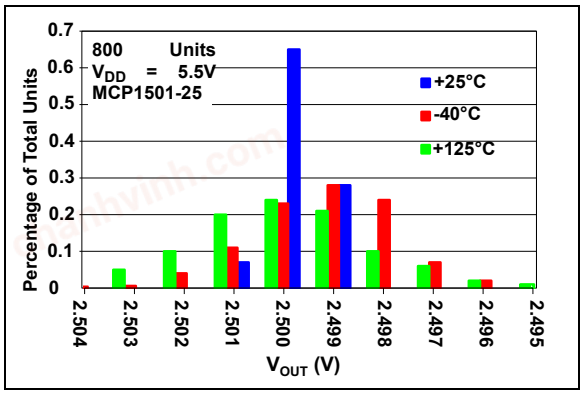


FIGURE 3-19: *MCP1501 Output Voltage Histogram, V_{DD} = 5.5V.*

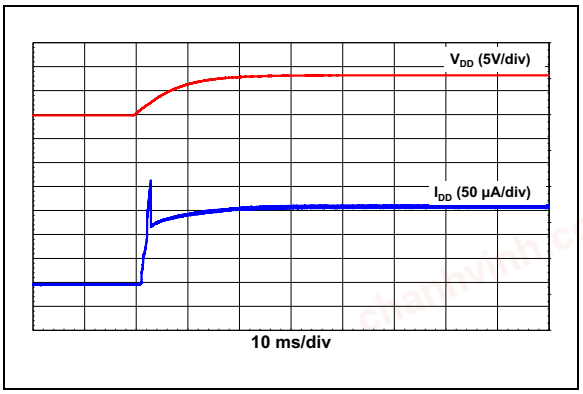


FIGURE 3-22: *I_{DD} Turn On Transient Response.*

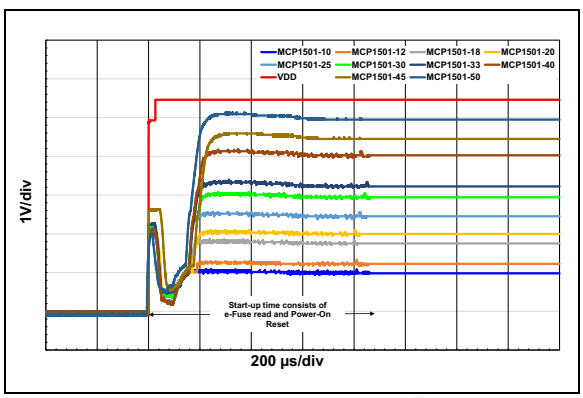


FIGURE 3-20: *Fast Ramp Start-Up at 25°C for All Options.*

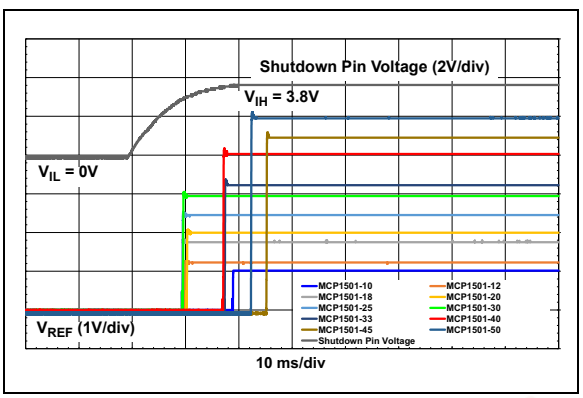


FIGURE 3-23: *Shutdown Low to High Slow Ramp Turn On Transient Response @ 25°C for All Options.*

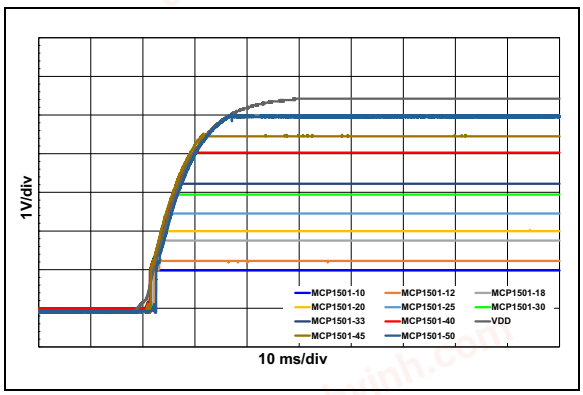


FIGURE 3-21: *Slow Ramp Start-Up at 25°C for All Options.*

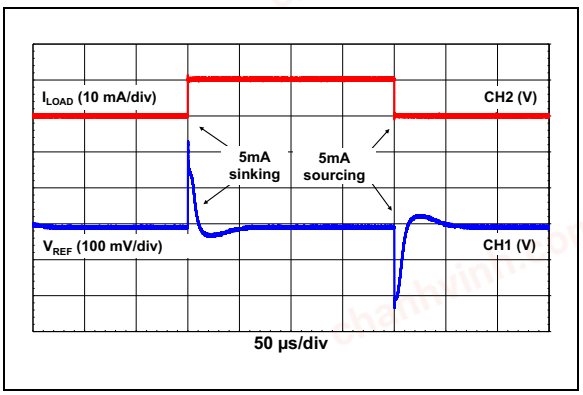


FIGURE 3-24: *Load Regulation Transient Response @ 25°C for All Options.*

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

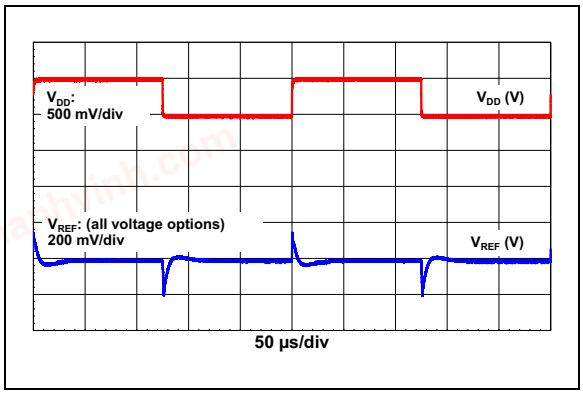


FIGURE 3-25: *Line Regulation Transient Response @ 25°C for All Options.*

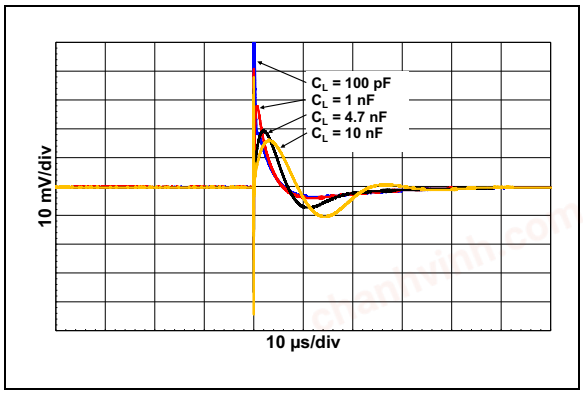


FIGURE 3-28: *MCP1501-40 Transient Response vs. Capacitive Load, V_{DD} = 5V.*

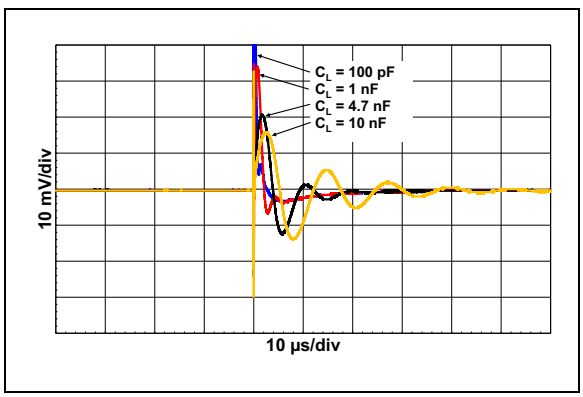


FIGURE 3-26: *MCP1501-10 Transient Response vs. Capacitive Load, V_{DD} = 5V.*

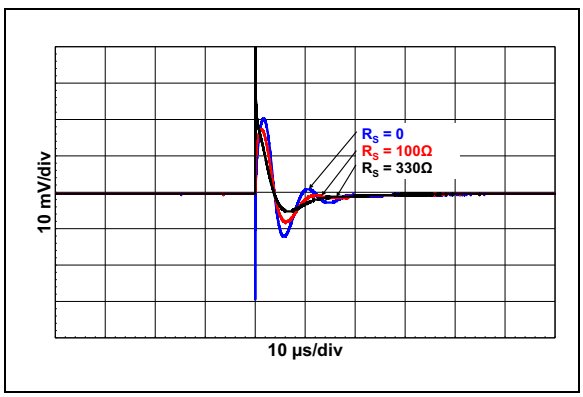


FIGURE 3-29: *MCP1501-10 Transient Response vs. R_S, V_{DD} = 5V, CL = 4.7nF.*

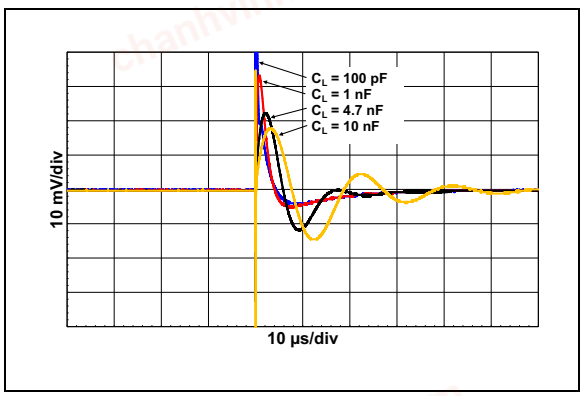


FIGURE 3-27: *MCP1501-20 Transient Response vs. Capacitive Load, V_{DD} = 5V.*

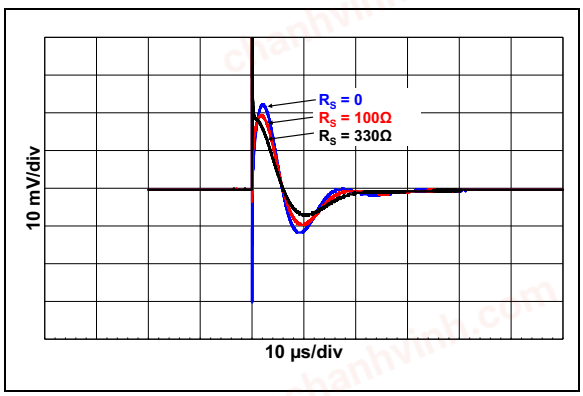


FIGURE 3-30: *MCP1501-20 Transient Response vs. R_S, V_{DD} = 5V, CL = 4.7nF.*

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

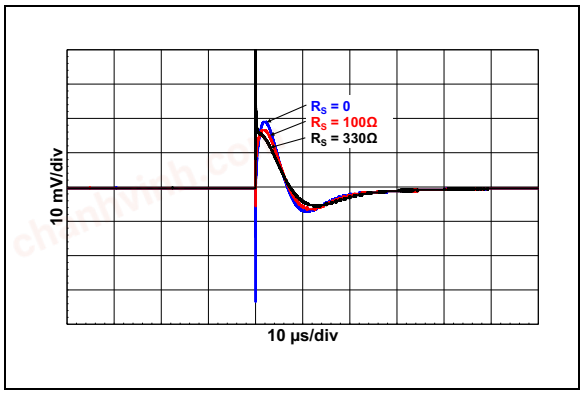


FIGURE 3-31: *MCP1501-40 Transient Response vs. R_S, V_{DD} = 5V, CL = 4.7nF.*

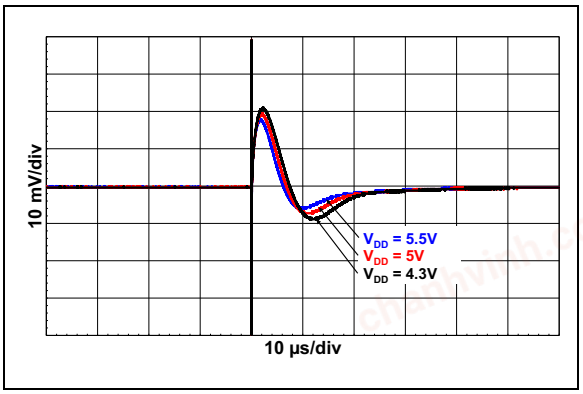


FIGURE 3-34: *MCP1501-40 Transient Response vs. V_{DD}, C_L = 4.7nF.*

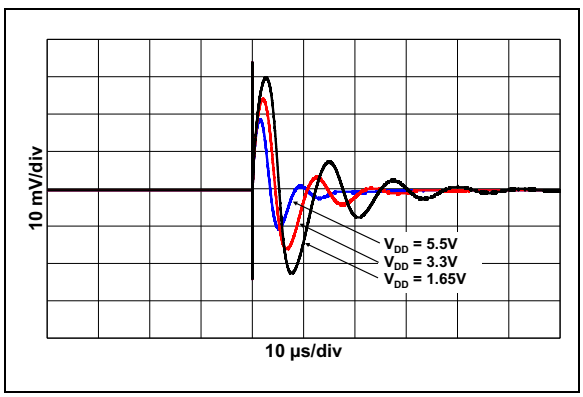


FIGURE 3-32: *MCP1501-10 Transient Response vs. V_{DD}, CL = 4.7nF.*

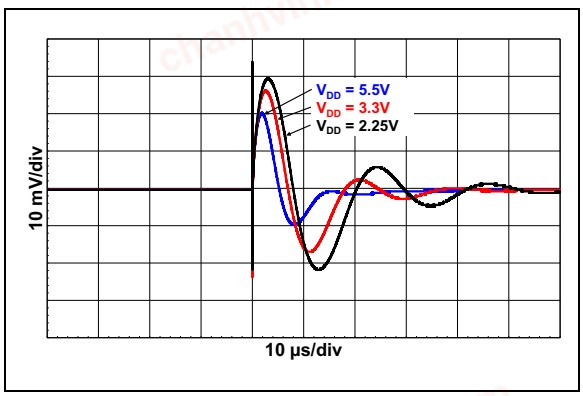


FIGURE 3-33: *MCP1501-20 Transient Response vs. V_{DD}, C_L = 4.7 nF.*

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4.0 THEORY OF OPERATION

The MCP1501 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 detail of the MCP1501. 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.

MCP1501 band gap is based on a second order temperature compensated circuit. This allows the MCP1501 to achieve high initial accuracy and 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 MCP1501 also includes a chopper-based amplifier architecture that ensures excellent low-noise operation, further reduces temperature dependent offsets that would otherwise increase the temperature coefficient of the MCP1501 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 MCP1501.

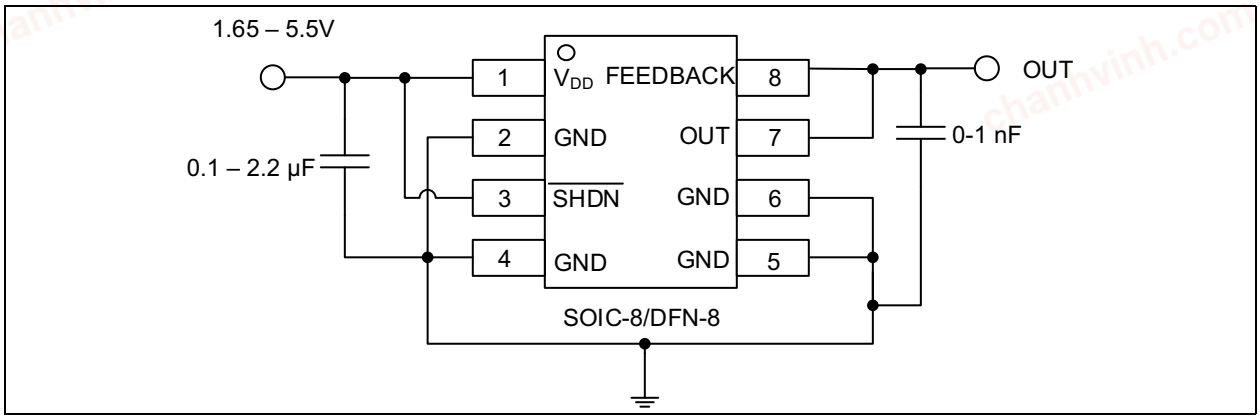


FIGURE 5-1: *Basic Circuit Configuration.*

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, the input voltage is connected to the device at the V_{IN} 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).

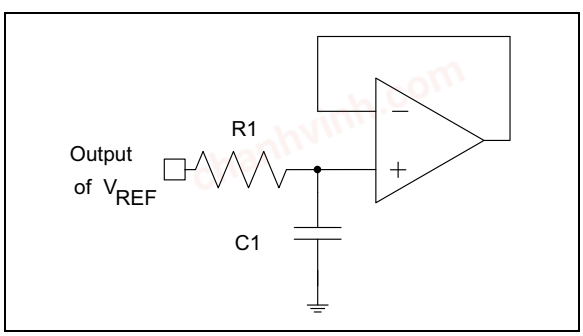


FIGURE 5-2: *Output Noise-Reducing Filter.*

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

EQUATION 5-1:

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

The values that are shown in Figure 5-2 (10 kΩ and 1 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.

5.1.2 LOAD CAPACITOR

The maximum capacitive load without series resistance is 10nF. 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. Devices in the SOT-23-6 package are generally more prone to assembly stress than devices in the WDFN package. 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).

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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 MCP1501 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 MCP1501 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 MCP1501-25 and -4.096V for the MCP1501-40.

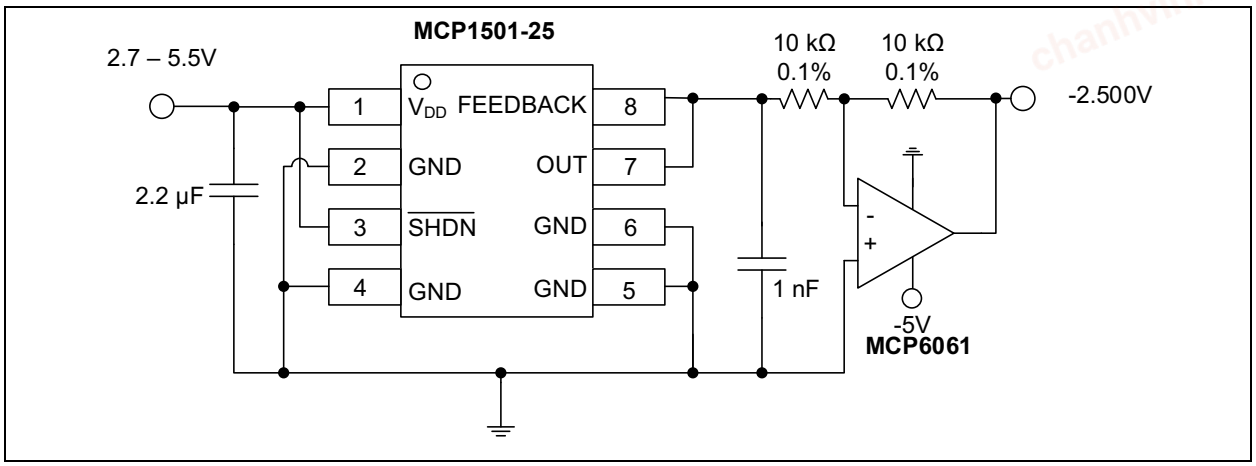


FIGURE 5-3: *Negative Voltage Reference.*

5.2.2 A/D CONVERTER REFERENCE

The MCP1501 product family was carefully designed to provide a precise, low noise voltage reference for the Microchip families of ADCs. The circuit shown in Figure 5-4 shows a MCP1501-25 configured to provide the reference to the MCP3201, a 12-bit ADC.

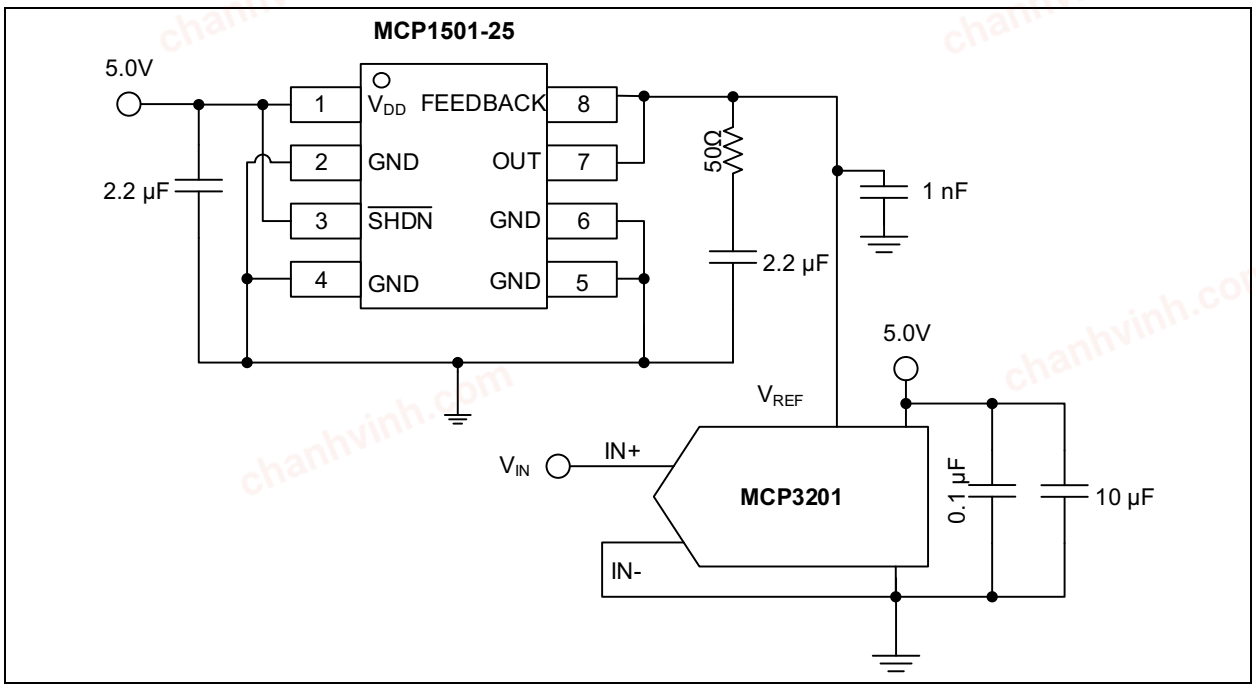


FIGURE 5-4: *ADC Example Circuit.*

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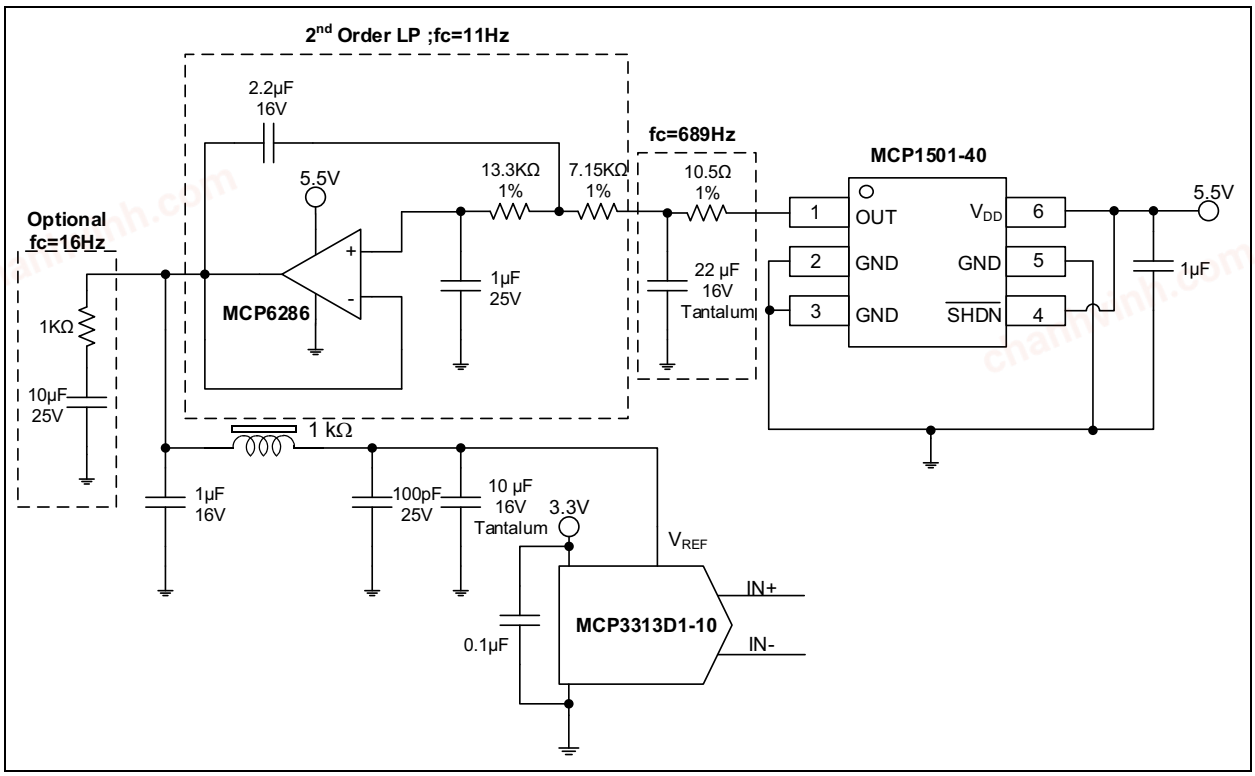


FIGURE 5-5: *SAR ADC Example Circuit.*

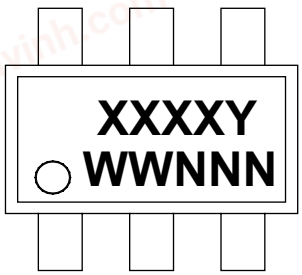
The circuit depicted in Figure 5-5 shows a MCP1501-40 configured to provide the reference to a SAR ADC. Refer to the MCP331X1D 16/14/12-bit, 1 Msps SAR ADC Evaluation Kit User's Guide (DS50002733).

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6.0 PACKAGE INFORMATION

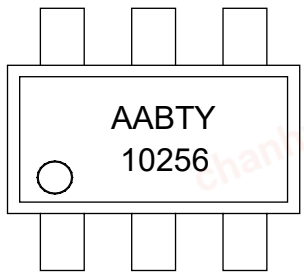
6.1 Package Markings

6-Lead SOT-23

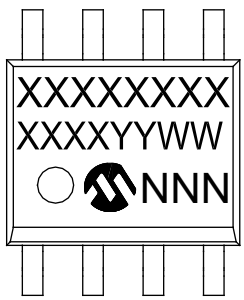


Device	Code
MCP1501T-10E/CHY	AABTY
MCP1501T-12E/CHY	AABUY
MCP1501T-18E/CHY	AABVY
MCP1501T-20E/CHY	AABWY
MCP1501T-25E/CHY	AABXY
MCP1501T-30E/CHY	AABYY
MCP1501T-33E/CHY	AABZY
MCP1501T-40E/CHY	AACAY
MCP1501T-45E/CHY	AAFEY
MCP1501T-50E/CHY	AAFFY

Example

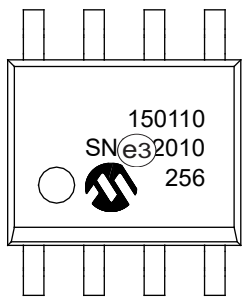


8-Lead SOIC

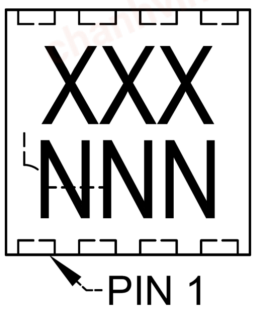


Device	Code
MCP1501T-10E/SN	150110
MCP1501T-12E/SN	150112
MCP1501-18E/SN	150118
MCP1501-20E/SN	150120
MCP1501T-25E/SN	150125
MCP1501T-30E/SN	150130
MCP1501T-33E/SN	150133
MCP1501T-40E/SN	150140

Example

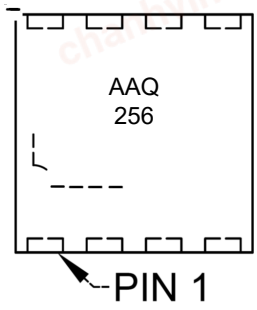


8-Lead WDFN (2 x2 mm)



Device	Code
MCP1501T-10E/RW	AAQ
MCP1501T-12E/RW	AAR
MCP1501-18E/RW	AAS
MCP1501-20E/RW	AAT
MCP1501T-25E/RW	AAU
MCP1501T-30E/RW	AAV
MCP1501T-33E/RW	AAW
MCP1501T-40E/RW	AAX

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.

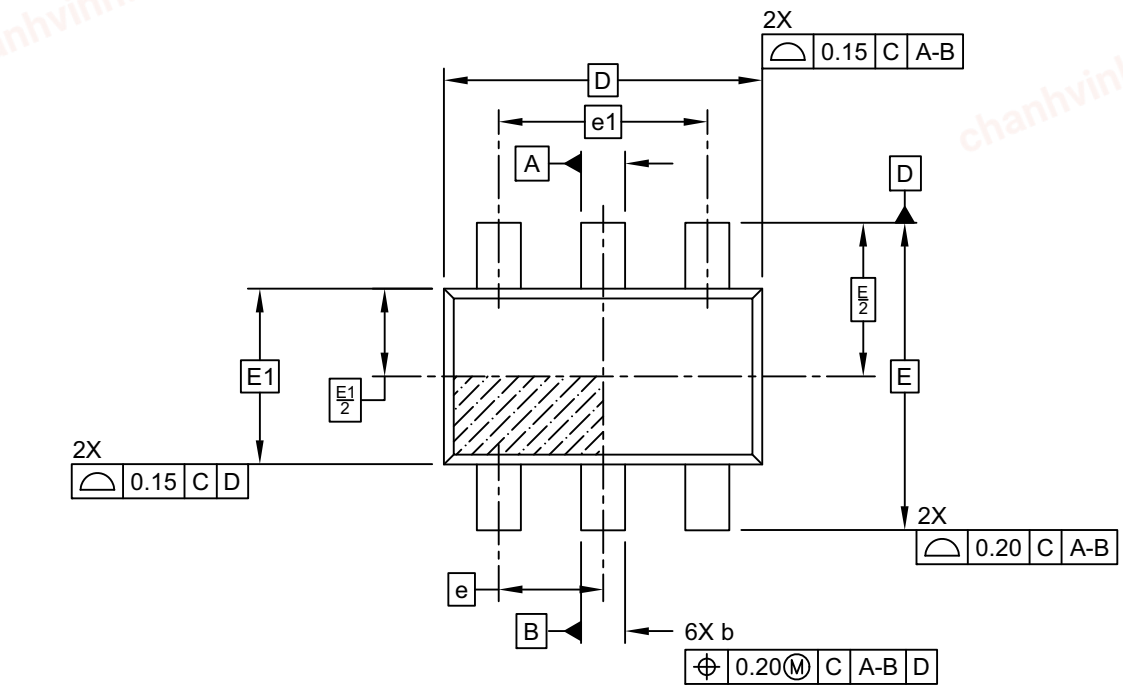
Note: In the event the full Microchip part number cannot be marked on one line, it will be carried over to the next line, thus limiting the number of available characters for customer-specific information.

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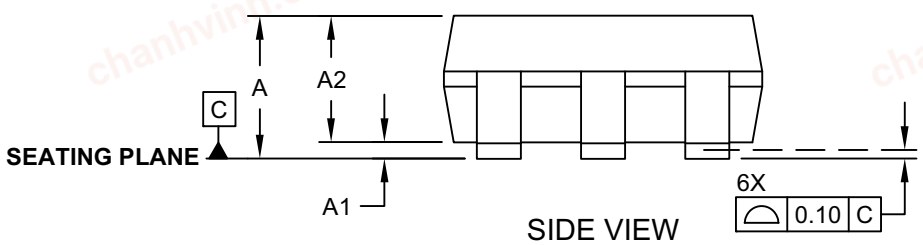
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6-Lead Plastic Small Outline Transistor (CH, CHY) [SOT-23]

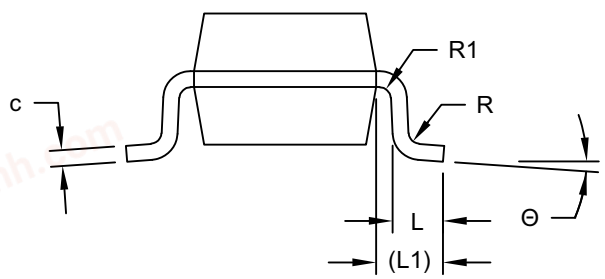
Note: For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



TOP VIEW



SIDE VIEW



END VIEW

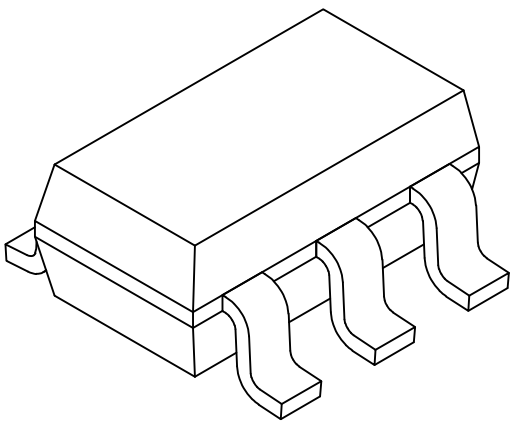
Microchip Technology Drawing C04-028D (CH) Sheet 1 of 2

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6-Lead Plastic Small Outline Transistor (CH, CHY) [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	ϕ	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.

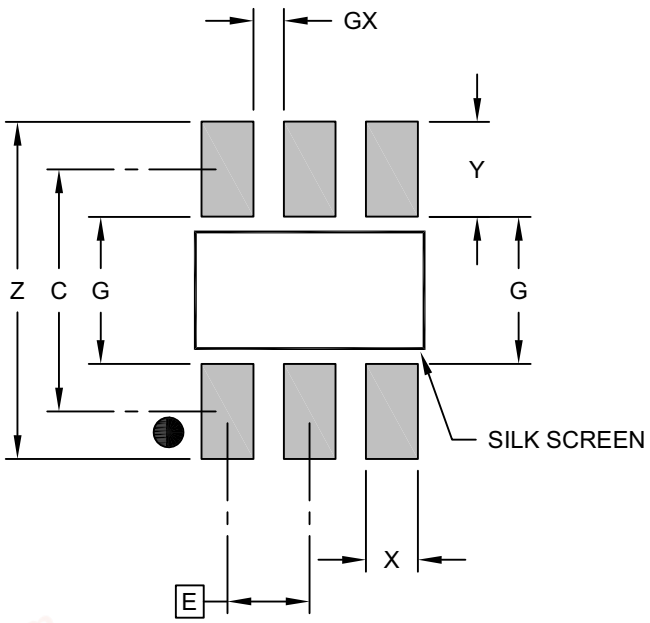
Microchip Technology Drawing C04-028D (CH) Sheet 2 of 2

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6-Lead Plastic Small Outline Transistor (CH, CHY) [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 (X3)	X			0.60
Contact Pad Length (X3)	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

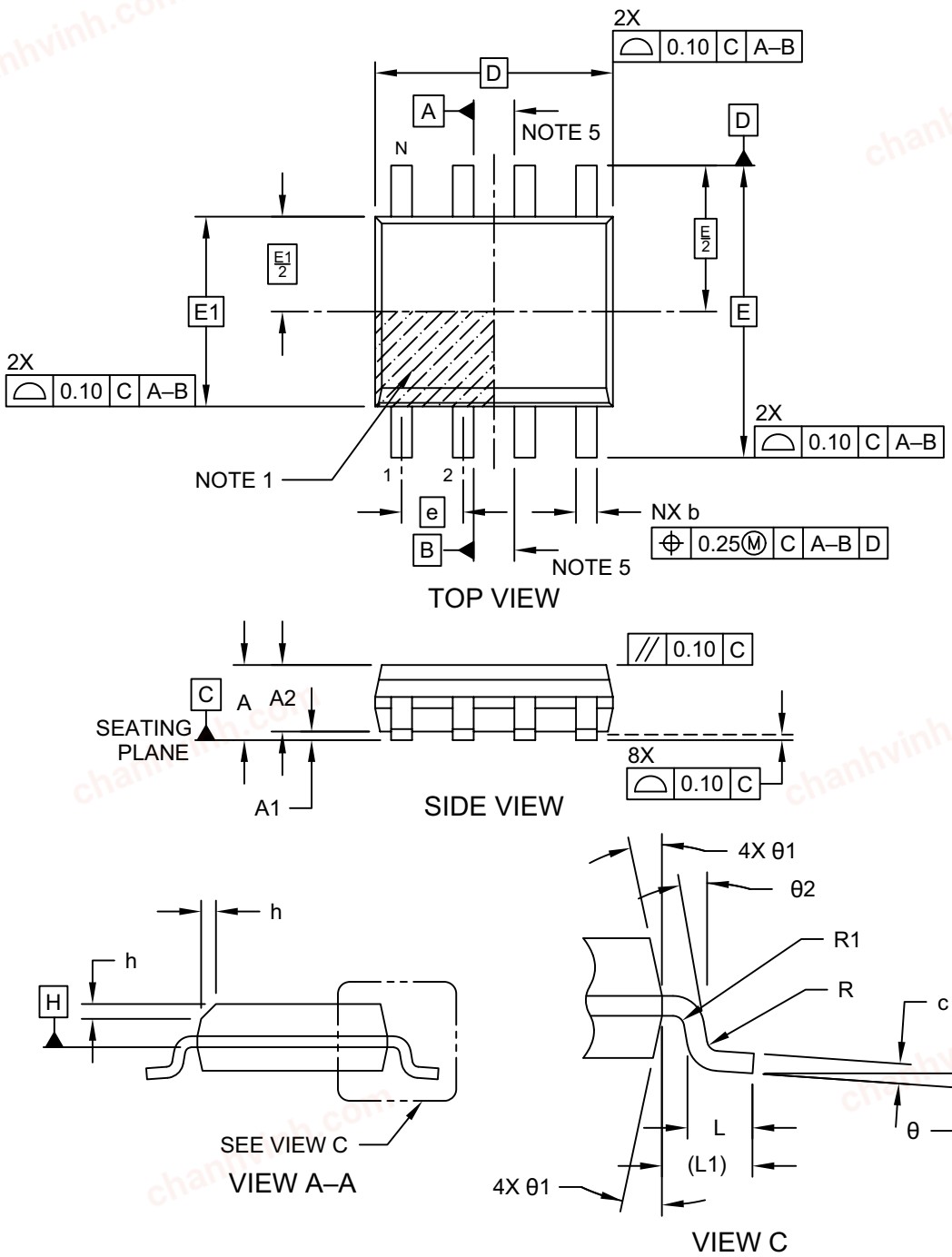
BSC: Basic Dimension. Theoretically exact value shown without tolerances.

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8-Lead Plastic Small Outline (SN) - Narrow, 3.90 mm (.150 In.) Body [SOIC]

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



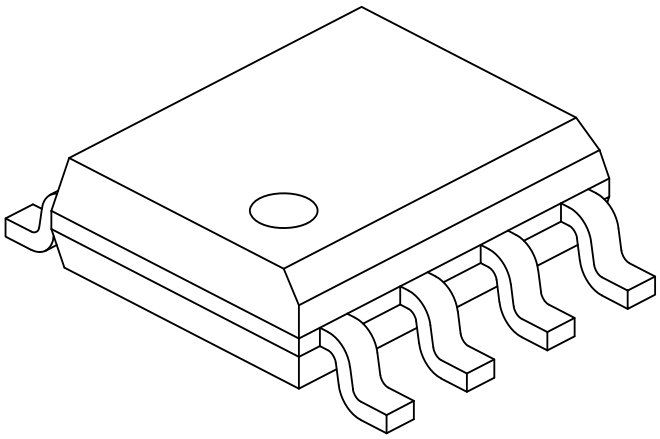
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8-Lead Plastic Small Outline (SN) - Narrow, 3.90 mm (.150 In.) Body [SOIC]

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 Pins	N		8	
Pitch	e		1.27 BSC	
Overall Height	A	–	–	1.75
Molded Package Thickness	A2	1.25	–	-
Standoff §	A1	0.10	–	0.25
Overall Width	E		6.00 BSC	
Molded Package Width	E1		3.90 BSC	
Overall Length	D		4.90 BSC	
Chamfer (Optional)	h	0.25	–	0.50
Foot Length	L	0.40	–	1.27
Footprint	L1		1.04 REF	
Lead Thickness	c	0.17	–	0.25
Lead Width	b	0.31	–	0.51
Lead Bend Radius	R	0.07	–	–
Lead Bend Radius	R1	0.07	–	–
Foot Angle	θ	0°	–	8°
Mold Draft Angle	θ1	5°	–	15°
Lead Angle	θ2	0°	–	–

Notes:

1. Pin 1 visual index feature may vary, but must be located within the hatched area.
2. § Significant Characteristic
3. Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.15mm per side.
4. 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.
5. Datums A & B to be determined at Datum H.

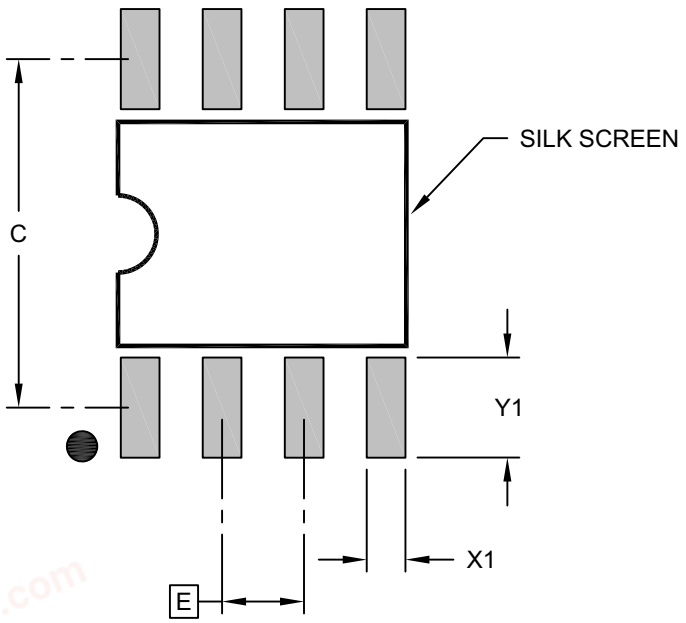
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8-Lead Plastic Small Outline (SN) - Narrow, 3.90 mm (.150 In.) Body [SOIC]

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		1.27 BSC	
Contact Pad Spacing	C		5.40	
Contact Pad Width (X8)	X1			0.60
Contact Pad Length (X8)	Y1			1.55

Notes:

1. Dimensioning and tolerancing per ASME Y14.5M
   BSC: Basic Dimension. Theoretically exact value shown without tolerances.

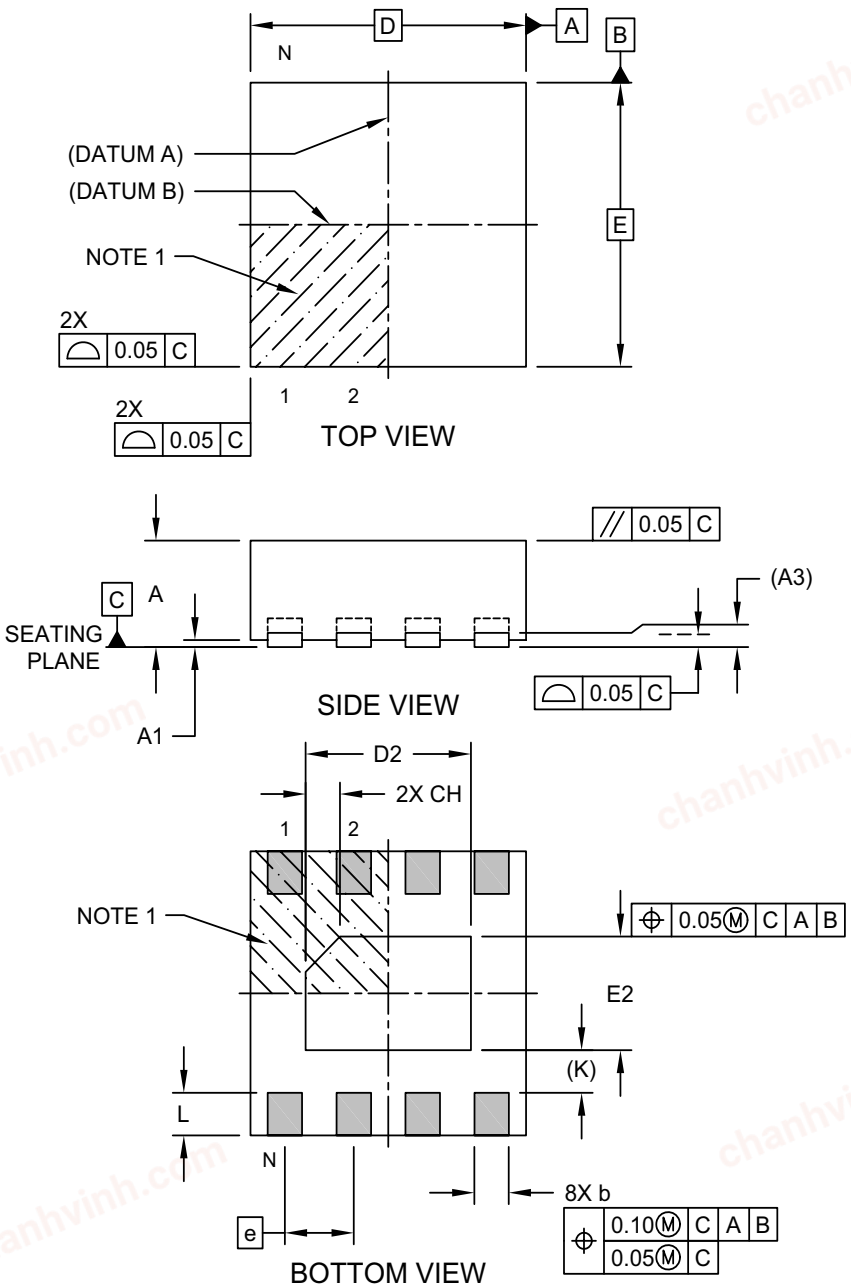
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8-Lead Very, Very Thin Plastic Dual Flat, No Lead Package (RW) - 2x2 mm Body [WDFN]

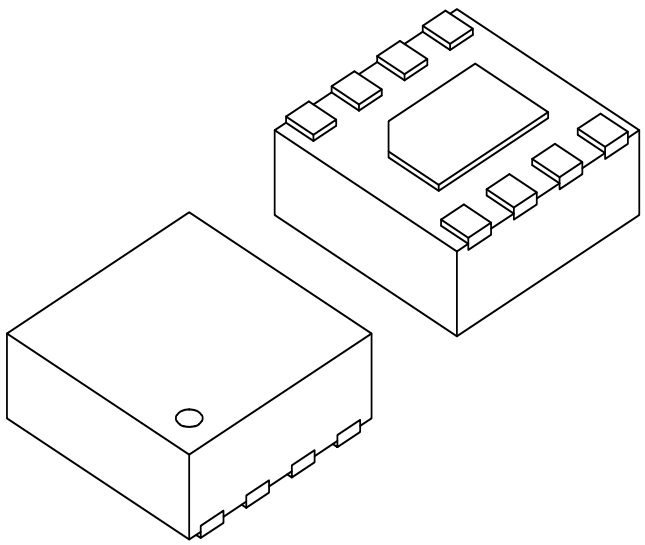
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Microchip Technology Drawing C04-261C Sheet 1 of 2

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Units		MILLIMETERS		
Dimension Limits		MIN	NOM	MAX
Number of Terminals	N		8	
Pitch	e		0.50 BSC	
Overall Height	A	0.70	0.75	0.80
Standoff	A1	0.00	0.02	0.05
Terminal Thickness	A3		0.10 REF	
Overall Width	E		2.00 BSC	
Exposed Pad Width	E2	0.70	0.80	0.90
Overall Length	D		2.00 BSC	
Exposed Pad Length	D2	1.10	1.20	1.30
Exposed Pad Chamfer	CH	-	0.25	-
Terminal Width	b	0.20	0.25	0.30
Terminal Length	L	0.25	0.30	0.35
Terminal-to-Exposed-Pad	K		0.30 REF	

Notes:

1. Pin 1 visual index feature may vary, but must be located within the hatched area.
2. Package is saw singulated
3. 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.

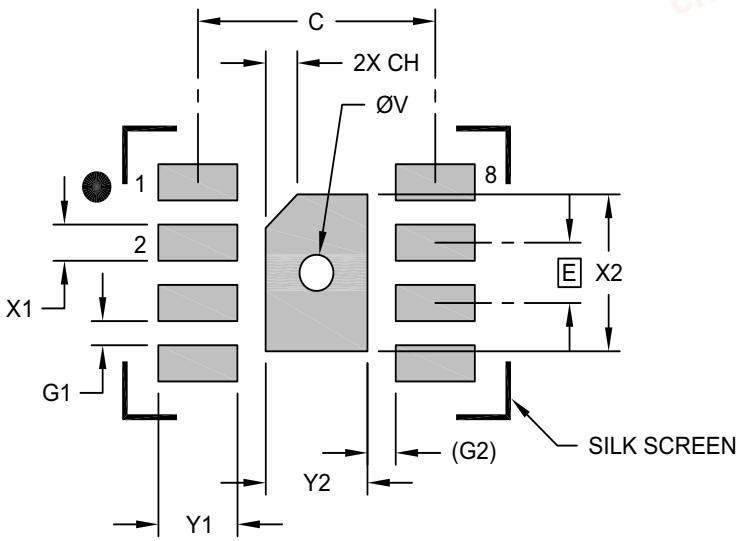
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8-Lead Very, Very Thin Plastic Dual Flat, No Lead Package (RW) - 2x2 mm Body [WDFN]

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		0.50 BSC	
Optional Center Pad Width	Y2			0.90
Optional Center Pad Length	X2			1.30
Contact Pad Spacing	C		2.10	
Center Pad Chamfer	CH		0.28	
Contact Pad Width (X8)	X1			0.30
Contact Pad Length (X8)	Y1			0.70
Contact Pad to Contact Pad (X6)	G1	0.20		
Contact Pad to Center Pad (X8)	G2		0.25 REF	
Thermal Via Diameter	V		0.30	

Notes:

1. Dimensioning and tolerancing per ASME Y14.5M
   BSC: Basic Dimension. Theoretically exact value shown without tolerances.
2. For best soldering results, thermal vias, if used, should be filled or tented to avoid solder loss during reflow process

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APPENDIX A: REVISION HISTORY

Revision H (April 2024)

- Updated Absolute Maximum Ratings(†) section.

Revision G (February 2022)

- Added 4.5V and 5V options throughout the document.

Revision F (March 2021)

The following is the list of modifications:

- Added AEC-Q100 qualification for Automotive applications
- Updated **Section 3.0 "Typical Operating Curves"**
- Updated Features
- Updated General Description
- Updated Block Diagram
- Updated **TABLE 2-1: "DC Characteristics"**.
- Updated **Section 5.1.2, Load Capacitor**.
- Updated Figure 5-4 and Figure 5-5.
- Updated **Section 6.0 "Package Information"**.

Revision E (August 2017)

The following is the list of modifications:

- Updated Features.
- Updated Package Types.
- Updated **Section 2.0, Electrical Characteristics**, Table 2-1.
- Updated Figure 3-8, Figure 3-18 and Figure 3-19.
- Updated Table 1-1.
- Updated Section 1.4, Shutdown Pin (SHDN).
- Updated **Section 5.1.2, Load Capacitor**.
- Corrected Figure 5-3 and Figure 5-4.
- Added Figure 5-5.
- Minor typographical corrections.

Revision D (March 2017)

The following is the list of modifications:

- Updated Table 2-1.
- Updated Equation 2-1, Equation 2-3, Equation 2-4, Equation 2-7, Equation 2-8, Equation 2-9 and Equation 2-11.
- Updated Figure 3-7, Figure 3-18, Figure 3-19, Figure 2-25 and Figure 2-26.
- Updated Figure 5-1 and Figure 5-4.
- Updated **"Product Identification System"** section.
- Minor typographical corrections.

Revision C (May 2016)

The following is the list of modifications:

- Updated **Section 2.0, Electrical Characteristics**, **Section 4.0, Theory of Operation**, **Section 5.0, Application Circuits**.
- Updated Features section, General Description section, **Section 1.1, Buffered VREF Output (OUT)**.
- Updated**"Product Identification System"** section.
- Updated Figure 3-8, Figure 3-18, Figure 3-19, Figure 5-1 and Figure 5-4.
- Updated Equation 2-10 and Equation 2-11.
- Minor typographical corrections.

Revision B (January 2016)

The following is the list of modifications:

- Updated Section 6.0, Package Information.
- Updated **"Product Identification System"** section.
- Minor typographical corrections.

Revision A (December 2015)

Original Release of this Document.

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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:	MCP1501 – 50 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)
	SN	=	8-Lead Plastic Small Outline – Narrow, 3.90 mm Body (SOIC)
	RW	=	8-Lead Very, Very Thin Plastic Dual Flat, No Lead Package – 2 x 2 mm Body (WDFN)
	*Y	=	Nickel palladium gold manufacturing designator. Only available on the SOT-23 package.

Examples:

a) MCP1501T-10E/CHY: 1.024V, 6-lead SOT-23 package, Tape and Reel

b) MCP1501-12E/SN: 1.2V, 8-lead SOIC package

c) MCP1501T-18E/SN: 1.8V, 8-lead SOIC package, Tape and Reel

d) MCP1501T-20E/RW: 2.048V, 8-lead WDFN 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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