National Semiconductor

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SM74601

SOT-23 Precision Micropower Series Voltage Reference

General Description

Ideal for space critical applications, the SM74601 precision voltage reference is available in the SOT-23 surface-mount package. The SM74601's advanced design eliminates the need for an external stabilizing capacitor while ensuring stability with capacitive loads up to 10 µF, thus making the SM74601 easy to use.

Series references provide lower power consumption than shunt references, since they do not have to idle the maximum possible load current under no load conditions. This advantage, the low quiescent current (60 µA), and the low dropout voltage (400 mV) make the SM74601 ideal for battery-powered solutions.

Features

- Renewable Energy Grade
- Output voltage initial accuracy 0.5%
- Low temperature coefficient 100ppm/°C
- Low Supply Current, 60 µA
- Enable pin allowing a 3 µA shutdown mode
- Up to 20 mA output current
- Voltage options 1.8V, 2.048V, 2.5V, 3.0V, 3.3V, 4.096V
- Custom voltage options available (1.8V to 4.096V)
- V_{IN} range of V_{REF} + 400 mV to 5.5V @10 mA
- Stable with low ESR ceramic capacitors
- SOT23-5 Package
- −40°C to 125°C junction temperature range

Applications

- Photovoltaic
- Instrumentation & Process Control
- Test Equipment
- Data Acquisition Systems
- Base Stations
- Servo Systems
- Portable, Battery Powered Equipment
- Automotive & Industrial Electronics
- Precision Regulators
- Battery Chargers
- Communications
- Medical Equipment

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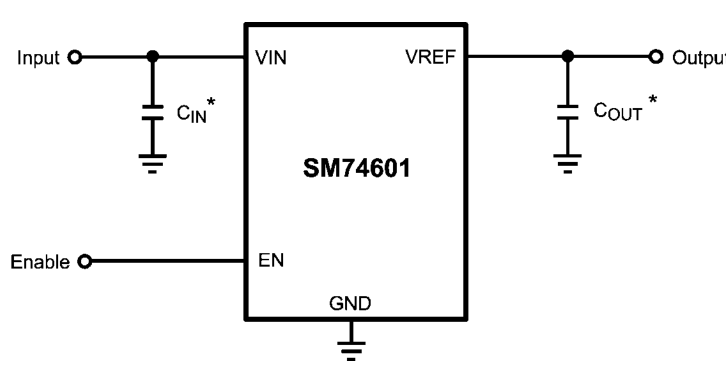
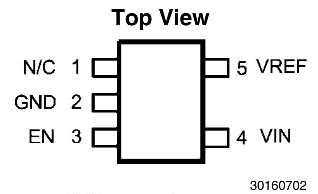
Typical Application Circuit



*Note: The capacitor C_{IN} is required and the capacitor C_{OUT} is optional.

Connection Diagram



SOT23-5 Package
NS Package Number MF05A

Ordering Information

SM74601 Supplied as 250 units, Tape and Reel	SM74601 Supplied as 1000 units, Tape and Reel	SM74601 Supplied as 3000 units, Tape and Reel	NSC Package Drawing	Part Marking	Package Type
SM74601MFE–1.8	SM74601MF–1.8	SM74601MFX–1.8	MF05A	S602	SOT23–5
SM74601MFE–2.0	SM74601MF–2.0	SM74601MFX–2.0		S603	
SM74601MFE–2.5	SM74601MF–2.5	SM74601MFX–2.5		S601	
SM74601MFE–3.0	SM74601MF–3.0	SM74601MFX–3.0		S604	
SM74601MFE–3.3	SM74601MF–3.3	SM74601MFX–3.3		S605	
SM74601MFE–4.1	SM74601MF–4.1	SM74601MFX–4.1		S606	

Pin Descriptions

Pin #	Name	Function
1	N/C	No connect pin, leave floating
2	GND	Ground
3	EN	Enable pin
4	VIN	Input supply
5	VREF	Reference output

Absolute Maximum Ratings (Note 1)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.

Maximum Voltage on any input	-0.3 to 6V
Output short circuit duration	Indefinite
Power Dissipation (T_A = 25°C) (Note 2)	350 mW
Storage Temperature Range	–65°C to 150°C
Lead Temperature (soldering, 10sec)	260°C
Vapor Phase (60 sec)	215°C
Infrared (15sec)	220°C
ESD Susceptibility (Note 3)	
Human Body Model	2 kV

Operating Ratings

Maximum Input Supply Voltage	5.5V
Maximum Enable Input Voltage	V_{IN}
Maximum Load Current	20mA
Junction Temperature Range (T_J)	–40°C to +125°C

Electrical Characteristics

SM74601-1.8 (V_{OUT} = 1.8V)

Limits in standard type are for T_J = 25°C only, and limits in **boldface type** apply over the junction temperature (T_J) range of -40°C to +125°C unless otherwise specified. Minimum and Maximum limits are guaranteed through test, design, or statistical correlation. Typical values represent the most likely parametric norm at T_J = 25°C, and are provided for reference purposes only. Unless otherwise specified V_{IN} = 5V and I_{LOAD} = 0A.

Symbol	Parameter	Conditions	Min (Note 4)	Typ (Note 5)	Max (Note 4)	Unit
V_{REF}	Output Voltage Initial Accuracy					
TCV_{REF}/°C (Note 6)	Temperature Coeffecient				100	ppm/°C
I_Q	Supply Current			60	**100**	µA
I_{Q_SD}	Supply Current in Shutdown	EN = 0V		3	**7**	µA
$\Delta V_{REF}/\Delta V_{IN}$	Line Regulation	V_{REF} + 400 mV ≤ V_{IN} ≤ 5.5V		30		ppm / V
$\Delta V_{REF}/\Delta I_{LOAD}$	Load Regulation	0 mA ≤ I_{LOAD} ≤ 20 mA		25	**120**	ppm / mA
ΔV_{REF}	Long Term Stability (Note 7)	1000 Hrs		50		ppm
	Thermal Hysteresis (Note 8)	-40°C ≤ T_J ≤ +125°C		75		
V_{IN} - V_{REF}	Dropout Voltage (Note 9)	I_{LOAD} = 10 mA		200	**400**	mV
V_N	Output Noise Voltage	0.1 Hz to 10 Hz		170		μV_{PP}
I_{SC}	Short Circuit Current				**75**	mA
V_{IL}	Enable Pin Maximum Low Input Level				**35**	%V
V_{IH}	Enable Pin Minimum High Input Level		**65**			%V

Electrical Characteristics

SM74601-2.0 (V_{OUT} = 2.048V)

Limits in standard type are for T_J = 25°C only, and limits in **boldface type** apply over the junction temperature (T_J) range of -40°C to +125°C unless otherwise specified. Minimum and Maximum limits are guaranteed through test, design, or statistical correlation. Typical values represent the most likely parametric norm at T_J = 25°C, and are provided for reference purposes only. Unless otherwise specified V_{IN} = 5V and I_{LOAD} = 0A.

Symbol	Parameter	Conditions	Min (Note 4)	Typ (Note 5)	Max (Note 4)	Unit
V_{REF}	Output Voltage Initial Accuracy					
TCV_{REF}/°C (Note 6)	Temperature Coeffecient				100	ppm/°C
I_Q	Supply Current			60	**100**	µA
I_{Q_SD}	Supply Current in Shutdown	EN = 0V		3	**7**	µA
$\Delta V_{REF}/\Delta V_{IN}$	Line Regulation	V_{REF} + 400 mV ≤ V_{IN} ≤ 5.5V		30		ppm / V
$\Delta V_{REF}/\Delta I_{LOAD}$	Load Regulation	0 mA ≤ I_{LOAD} ≤ 20 mA		25	**120**	ppm / mA
ΔV_{REF}	Long Term Stability (Note 7)	1000 Hrs		50		ppm
	Thermal Hysteresis (Note 8)	-40°C ≤ T_J ≤ +125°C		75		
V_{IN} - V_{REF}	Dropout Voltage (Note 9)	I_{LOAD} = 10 mA		175	**400**	mV
V_N	Output Noise Voltage	0.1 Hz to 10 Hz		190		μV_{PP}
I_{SC}	Short Circuit Current				**75**	mA
V_{IL}	Enable Pin Maximum Low Input Level				**35**	%V
V_{IH}	Enable Pin Minimum High Input Level		**65**			%V

Electrical Characteristics

SM74601-2.5 (V_{OUT} = 2.5V)

Limits in standard type are for T_J = 25°C only, and limits in **boldface type** apply over the junction temperature (T_J) range of -40°C to +125°C unless otherwise specified. Minimum and Maximum limits are guaranteed through test, design, or statistical correlation. Typical values represent the most likely parametric norm at T_J = 25°C, and are provided for reference purposes only. Unless otherwise specified V_{IN} = 5V and I_{LOAD} = 0A.

Symbol	Parameter	Conditions	Min (Note 4)	Typ (Note 5)	Max (Note 4)	Unit
V_{REF}	Output Voltage Initial Accuracy					
TCV_{REF}/°C (Note 6)	Temperature Coeffecient				100	ppm/°C
I_Q	Supply Current			60	**100**	µA
I_{Q_SD}	Supply Current in Shutdown	EN = 0V		3	**7**	µA
$\Delta V_{REF}/\Delta V_{IN}$	Line Regulation	V_{REF} + 400 mV ≤ V_{IN} ≤ 5.5V		50		ppm / V
$\Delta V_{REF}/\Delta I_{LOAD}$	Load Regulation	0 mA ≤ I_{LOAD} ≤ 20 mA		25	**120**	ppm / mA
ΔV_{REF}	Long Term Stability (Note 7)	1000 Hrs		50		ppm
	Thermal Hysteresis (Note 8)	-40°C ≤ T_J ≤ +125°C		75		
V_{IN} - V_{REF}	Dropout Voltage (Note 9)	I_{LOAD} = 10 mA		175	**400**	mV
V_N	Output Noise Voltage	0.1 Hz to 10 Hz		275		μV_{PP}
I_{SC}	Short Circuit Current				**75**	mA
V_{IL}	Enable Pin Maximum Low Input Level				**35**	%V
V_{IH}	Enable Pin Minimum High Input Level		**65**			%V

Electrical Characteristics

SM74601-3.0 (V_{OUT} = 3.0V)

Limits in standard type are for T_J = 25°C only, and limits in **boldface type** apply over the junction temperature (T_J) range of -40°C to +125°C unless otherwise specified. Minimum and Maximum limits are guaranteed through test, design, or statistical correlation. Typical values represent the most likely parametric norm at T_J = 25°C, and are provided for reference purposes only. Unless otherwise specified V_{IN} = 5V and I_{LOAD} = 0A.

Symbol	Parameter	Conditions	Min (Note 4)	Typ (Note 5)	Max (Note 4)	Unit
V_{REF}	Output Voltage Initial Accuracy					
TCV_{REF}/°C (Note 6)	Temperature Coeffecient				100	ppm/°C
I_Q	Supply Current			60	**100**	µA
I_{Q_SD}	Supply Current in Shutdown	EN = 0V		3	**7**	µA
$\Delta V_{REF}/\Delta V_{IN}$	Line Regulation	V_{REF} + 400 mV ≤ V_{IN} ≤ 5.5V		70		ppm / V
$\Delta V_{REF}/\Delta I_{LOAD}$	Load Regulation	0 mA ≤ I_{LOAD} ≤ 20 mA		25	**120**	ppm / mA
ΔV_{REF}	Long Term Stability (Note 7)	1000 Hrs		50		ppm
	Thermal Hysteresis (Note 8)	-40°C ≤ T_J ≤ +125°C		75		
V_{IN} - V_{REF}	Dropout Voltage (Note 9)	I_{LOAD} = 10 mA		175	**400**	mV
V_N	Output Noise Voltage	0.1 Hz to 10 Hz		285		μV_{PP}
I_{SC}	Short Circuit Current				**75**	mA
V_{IL}	Enable Pin Maximum Low Input Level				**35**	%V
V_{IH}	Enable Pin Minimum High Input Level		**65**			%V

Electrical Characteristics

SM74601-3.3 (V_{OUT} = 3.3V)

Limits in standard type are for T_J = 25°C only, and limits in **boldface type** apply over the junction temperature (T_J) range of -40°C to +125°C unless otherwise specified. Minimum and Maximum limits are guaranteed through test, design, or statistical correlation. Typical values represent the most likely parametric norm at T_J = 25°C, and are provided for reference purposes only. Unless otherwise specified V_{IN} = 5V and I_{LOAD} = 0A.

Symbol	Parameter	Conditions	Min (Note 4)	Typ (Note 5)	Max (Note 4)	Unit
V_{REF}	Output Voltage Initial Accuracy					
TCV_{REF}/°C (Note 6)	Temperature Coeffecient				100	ppm/°C
I_Q	Supply Current			60	**100**	µA
I_{Q_SD}	Supply Current in Shutdown	EN = 0V		3	**7**	µA
$\Delta V_{REF}/\Delta V_{IN}$	Line Regulation	V_{REF} + 400 mV ≤ V_{IN} ≤ 5.5V		85		ppm / V
$\Delta V_{REF}/\Delta I_{LOAD}$	Load Regulation	0 mA ≤ I_{LOAD} ≤ 20 mA		25	**120**	ppm / mA
ΔV_{REF}	Long Term Stability (Note 7)	1000 Hrs		50		ppm
	Thermal Hysteresis (Note 8)	-40°C ≤ T_J ≤ +125°C		75		
V_{IN} - V_{REF}	Dropout Voltage (Note 9)	I_{LOAD} = 10 mA		175	**400**	mV
V_N	Output Noise Voltage	0.1 Hz to 10 Hz		310		μV_{PP}
I_{SC}	Short Circuit Current				**75**	mA
V_{IL}	Enable Pin Maximum Low Input Level				**35**	%V
V_{IH}	Enable Pin Minimum High Input Level		**65**			%V

Electrical Characteristics

SM74601-4.1 (V_{OUT} = 4.096V) Limits in standard type are for T_J = 25°C only, and limits in **boldface type** apply over the junction temperature (T_J) range of -40°C to +125°C unless otherwise specified. Minimum and Maximum limits are guaranteed through test, design, or statistical correlation. Typical values represent the most likely parametric norm at T_J = 25°C, and are provided for reference purposes only. Unless otherwise specified V_{IN} = 5V and I_{LOAD} = 0A.

Symbol	Parameter	Conditions	Min (Note 4)	Typ (Note 5)	Max (Note 4)	Unit
V_{REF}	Output Voltage Initial Accuracy					
TCV_{REF}/°C (Note 6)	Temperature Coeffecient				100	ppm/°C
I_Q	Supply Current			60	**100**	µA
I_{Q_SD}	Supply Current in Shutdown	EN = 0V		3	**7**	µA
$\Delta V_{REF}/\Delta V_{IN}$	Line Regulation	V_{REF} + 400 mV ≤ V_{IN} ≤ 5.5V		100		ppm / V
$\Delta V_{REF}/\Delta I_{LOAD}$	Load Regulation	0 mA ≤ I_{LOAD} ≤ 20 mA		25	**120**	ppm / mA
ΔV_{REF}	Long Term Stability (Note 7)	1000 Hrs		50		ppm
	Thermal Hysteresis (Note 8)	-40°C ≤ T_J ≤ +125°C		75		
V_{IN} - V_{REF}	Dropout Voltage (Note 9)	I_{LOAD} = 10 mA		175	**400**	mV
V_N	Output Noise Voltage	0.1 Hz to 10 Hz		350		μV_{PP}
I_{SC}	Short Circuit Current				**75**	mA
V_{IL}	Enable Pin Maximum Low Input Level				**35**	%V
V_{IH}	Enable Pin Minimum High Input Level		**65**			%V

Note 1: Absolute Maximum Ratings indicate limits beyond which damage may occur to the device. Operating Ratings indicate conditions for which the device is intended to be functional, but do not guarantee specific performance limits. For guaranteed specifications, see Electrical Characteristics.

Note 2: Without PCB copper enhancements. The maximum power dissipation must be de-rated at elevated temperatures and is limited by T_{JMAX} (maximum junction temperature), θ_{J-A} (junction to ambient thermal resistance) and T_A (ambient temperature). The maximum power dissipation at any temperature is: $P_{DissMAX} = (T_{JMAX} - T_A) / \theta_{J-A}$ up to the value listed in the Absolute Maximum Ratings. θ_{J-A} for SOT23-5 package is 220°C/W, T_{JMAX} = 125°C.

Note 3: The human body model is a 100 pF capacitor discharged through a 1.5 kΩ resistor into each pin.

Note 4: Limits are 100% production tested at 25°C. Limits over the operating temperature range are guaranteed through correlation using Statistical Quality Control.

Note 5: Typical numbers are at 25°C and represent the most likely parametric norm.

Note 6: Temperature coefficient is measured by the "Box" method; i.e., the maximum ΔV_{REF} is divided by the maximum ΔT.

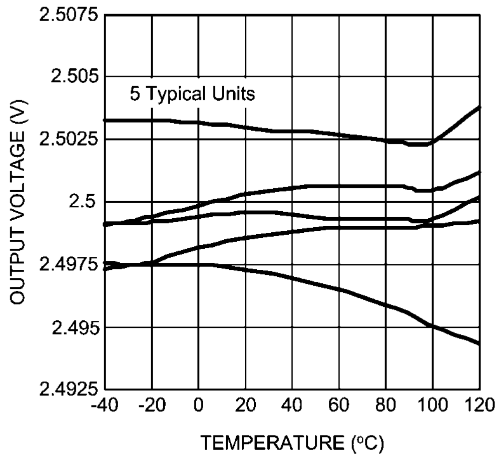
Note 7: Long term stability is V_{REF} @25°C measured during 1000 hrs.

Note 8: Thermal hysteresis is defined as the change in +25°C output voltage before and after cycling the device from (-40°C to 125°C).

Note 9: Dropout voltage is defined as the minimum input to output differential at which the output voltage drops by 0.5% below the value measured with a 5V input.

Typical Performance Characteristics for 2.5V

Output Voltage vs Temperature



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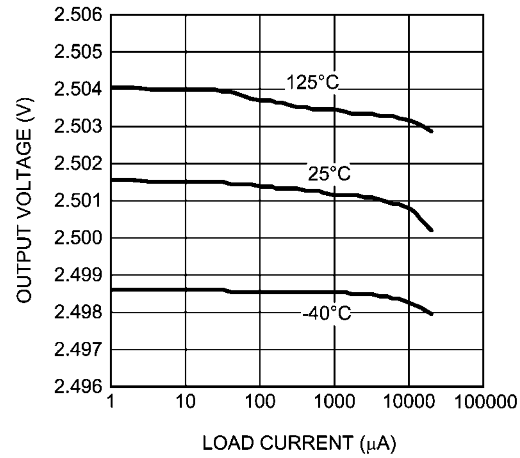
Load Regulation



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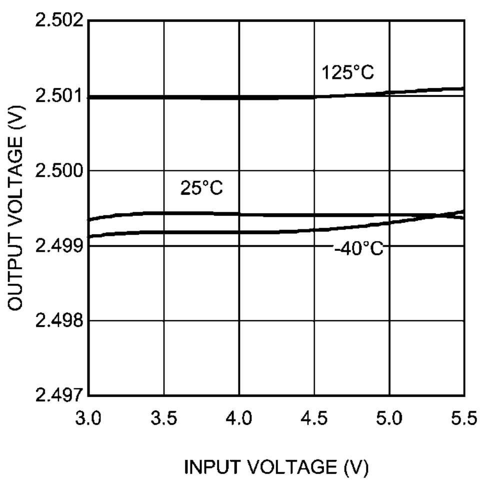
Line Regulation



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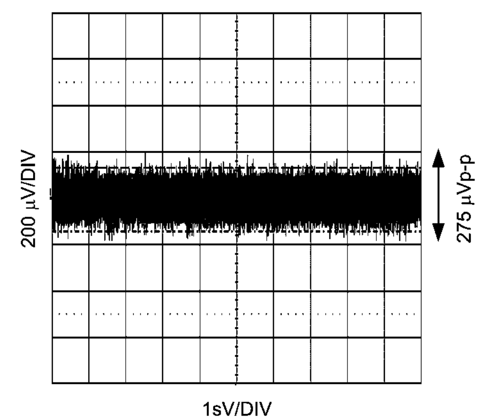
0.1 - 10 Hz Noise



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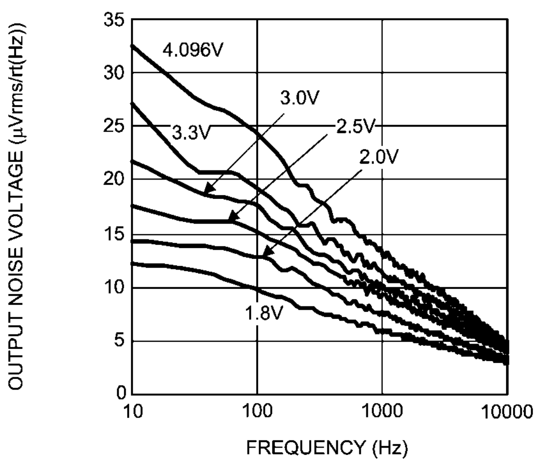
Output Voltage Noise Spectrum



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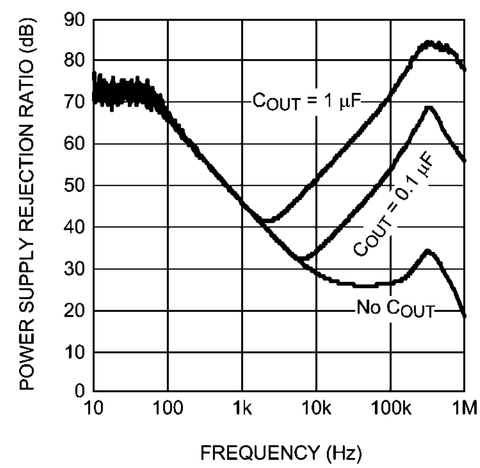
Power Supply Rejection Ratio vs Frequency



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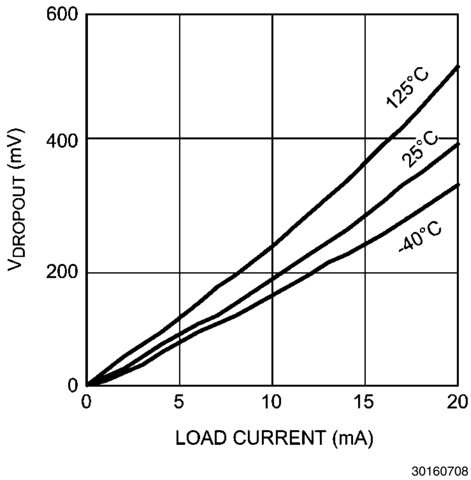
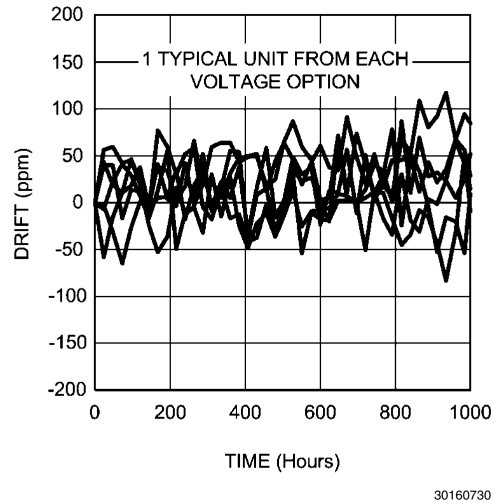
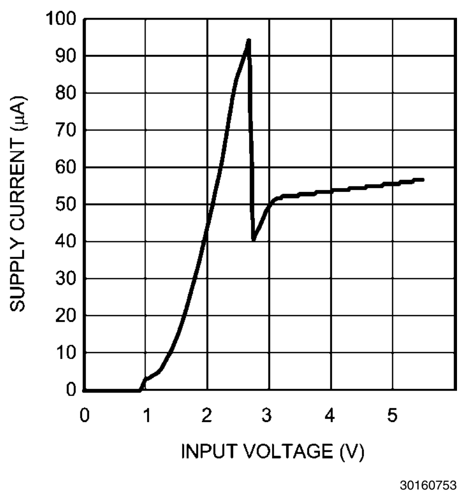
Dropout vs Load to 0.5% Accuracy



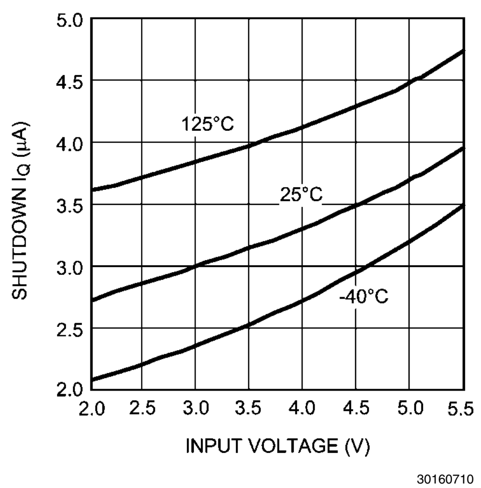
Typical Long Term Stability



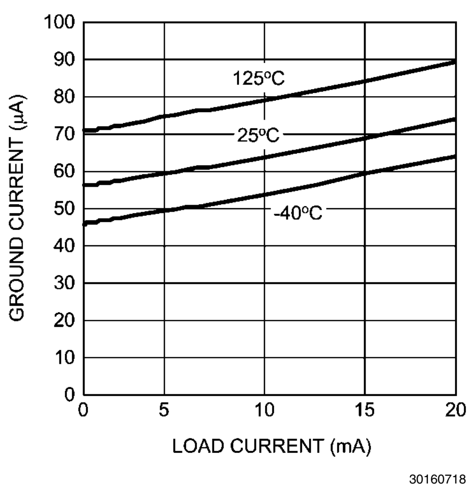
Supply Current vs Input Voltage



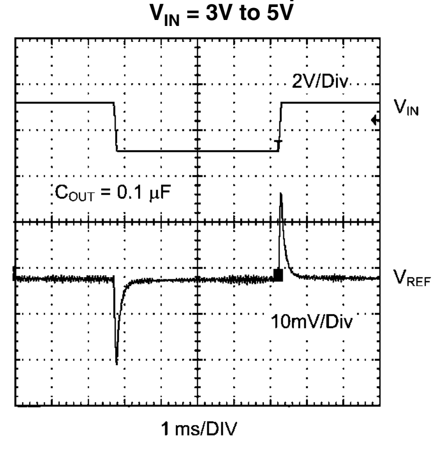
Shutdown I_Q vs Input Voltage



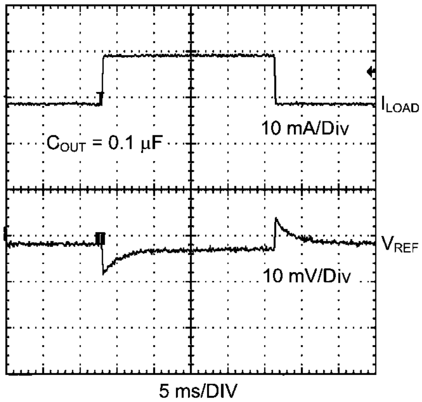
Ground Current vs Load Current



Line Transient Response
V_{IN} = 3V to 5V



Load Transient Response
I_{LOAD} = 0 to 10mA



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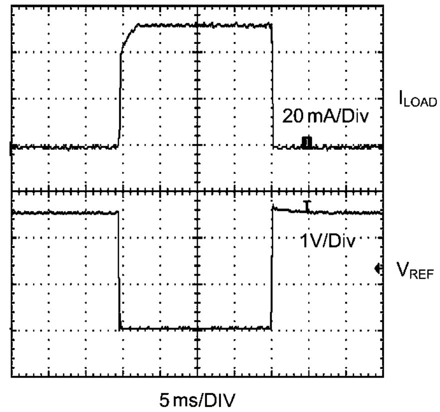
Short-Circuit Protection and Recovery



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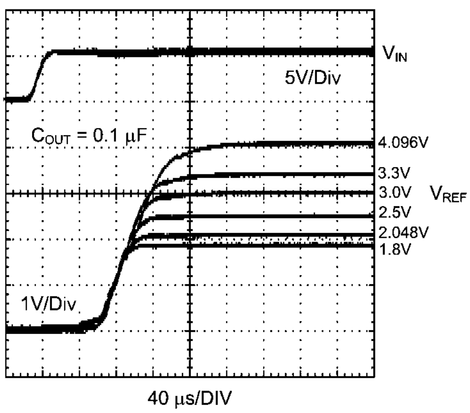
Start-Up Response



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Application Information

THEORY OF OPERATION

The foundation of any voltage reference is the band-gap circuit. While the reference in the SM74601 is developed from the gate-source voltage of transistors in the IC, principles of the band-gap circuit are easily understood using a bipolar example. For a detailed analysis of the bipolar band-gap circuit, please refer to Application Note AN-56.

SUPPLY AND ENABLE VOLTAGES

To ensure proper operation, V_{EN} and V_{IN} must be within a specified range. An acceptable range of input voltages is

$$V_{IN} > V_{REF} + 400\text{ mV } (I_{LOAD} \leq 10\text{ mA})$$

The enable pin uses an internal pull-up current source ($I_{PULL\_UP} \cong 2\ \mu A$) that may be left floating or triggered by an external source. If the part is not enabled by an external source, it may be connected to V_{IN}. An acceptable range of enable voltages is given by the enable transfer characteristics. See the Electrical Characteristics section and Enable Transfer Characteristics figure for more detail. Note, the part will not operate correctly for $V_{EN} > V_{IN}$.

COMPONENT SELECTION

A small ceramic (X5R or X7R) capacitor on the input must be used to ensure stable operation. The value of C_{IN} must be sized according to the output capacitor value. The value of C_{IN} must satisfy the relationship $C_{IN} \geq C_{OUT}$. When no output capacitor is used, C_{IN} must have a minimum value of 0.1 µF. Noise on the power-supply input may affect the output noise. Larger input capacitor values (typically 4.7 µF to 22 µF) may help reduce noise on the output and significantly reduce overshoot during startup. Use of an additional optional bypass capacitor between the input and ground may help further reduce noise on the output. With an input capacitor, the SM74601 will drive any combination of resistance and capacitance up to V_{REF}/20 mA and 10 µF respectively.

The SM74601 is designed to operate with or without an output capacitor and is stable with capacitive loads up to 10 µF. Connecting a capacitor between the output and ground will significantly improve the load transient response when switching from a light load to a heavy load. The output capacitor should not be made arbitrarily large because it will effect the turn-on time as well as line and load transients.

While a variety of capacitor chemistry types may be used, it is typically advisable to use low esr ceramic capacitors. Such capacitors provide a low impedance to high frequency signals, effectively bypassing them to ground. Bypass capacitors should be mounted close to the part. Mounting bypass capacitors close to the part will help reduce the parasitic trace components thereby improving performance.

SHORT CIRCUITED OUTPUT

The SM74601 features indefinite short circuit protection. This protection limits the output current to 75 mA when the output is shorted to ground.

TURN ON TIME

Turn on time is defined as the time taken for the output voltage to rise to 90% of the preset value. The turn on time depends on the load. The turn on time is typically 33.2 µs when driving a 1µF load and 78.8 µs when driving a 10 µF load. Some users may experience an extended turn on time (up to 10 ms) under brown out conditions and low temperatures (-40°C).

THERMAL HYSTERESIS

Thermal hysteresis is defined as the change in output voltage at 25ºC after some deviation from 25ºC. This is to say that thermal hysteresis is the difference in output voltage between two points in a given temperature profile. An illustrative temperature profile is shown in *Figure 1*.

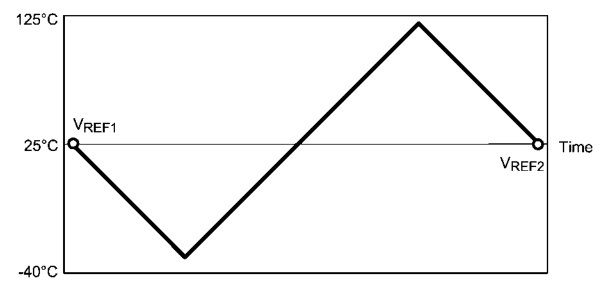

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FIGURE 1. Illustrative Temperature Profile

This may be expressed analytically as the following:

$$V_{HYS} = \frac{|V_{REF1} - V_{REF2}|}{V_{REF}} \times 10^3\ \text{mV}$$

Where

V_{HYS} = Thermal hysteresis expressed in ppm

V_{REF} = Nominal preset output voltage

V_{REF1} = V_{REF} before temperature fluctuation

V_{REF2} = V_{REF} after temperature fluctuation.

The SM74601 features a low thermal hysteresis of 190 µV from -40°C to 125°C.

TEMPERATURE COEFFICIENT

Temperature drift is defined as the maximum deviation in output voltage over the operating temperature range. This deviation over temperature may be illustrated as shown in *Figure 2*.

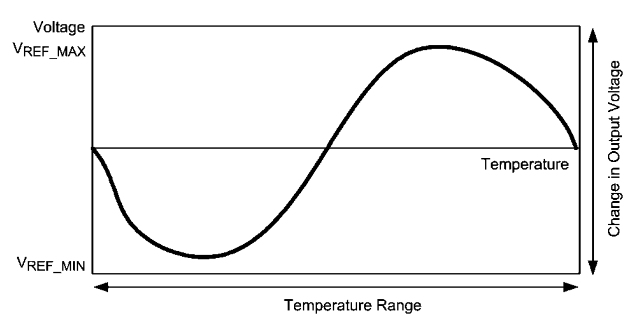

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FIGURE 2. Illustrative Temperature Coefficient Profile

Temperature coefficient may be expressed analytically as the following:

$$T_D = \frac{(V_{REF\_MAX} - V_{REF\_MIN})}{V_{REF} \times \Delta T} \times 10^6\ \text{ppm}$$

T_D = Temperature drift

V_{REF} = Nominal preset output voltage

V_{REF_MIN} = Minimum output voltage over operating temperature range

V_{REF_MAX} = Maximum output voltage over operating temperature range

ΔT = Operating temperature range.

The SM74601 features a low temperature drift of 100 ppm (max), from -40°C to 125°C.

LONG TERM STABILITY

Long-term stability refers to the fluctuation in output voltage over a long period of time (1000 hours). The SM74601 features a typical long-term stability of 50 ppm over 1000 hours. The measurements are made using 5 units of each voltage option, at a nominal input voltage (5V), with no load, at room temperature.

EXPRESSION OF ELECTRICAL CHARACTERISTICS

Electrical characteristics are typically expressed in mV, ppm, or a percentage of the nominal value. Depending on the application, one expression may be more useful than the other. To convert one quantity to the other one may apply the following:

ppm to mV error in output voltage:

$$\frac{V_{REF} \times ppm_{ERROR}}{10^3} = V_{ERROR}$$

Where:

V_{REF} is in volts (V) and V_{ERROR} is in milli-volts (mV).

Bit error (1 bit) to voltage error (mV):

$$\frac{V_{REF}}{2^n} \times 10^3 = V_{ERROR}$$

V_{REF} is in volts (V), V_{ERROR} is in milli-volts (mV), and n is the number of bits.

mV to ppm error in output voltage:

$$\frac{V_{ERROR}}{V_{REF}} \times 10^3 = ppm_{ERROR}$$

Where:

V_{REF} is in volts (V) and V_{ERROR} is in milli-volts (mV).

Voltage error (mV) to percentage error (percent):

$$\frac{V_{ERROR}}{V_{REF}} \times 0.1 = Percent\_Error$$

Where:

V_{REF} is in volts (V) and V_{ERROR} is in milli-volts (mV).

PRINTED CIRCUIT BOARD and LAYOUT CONSIDERATIONS

To minimize the mechanical stress due to PC board mounting that can cause the output voltage to shift from its initial value, mount the reference on a low flex area of the PC board, such as near the edge or a corner.

The part may be isolated mechanically by cutting a U shape slot on the PCB for mounting the device. This approach also provides some thermal isolation from the rest of the circuit.

Bypass capacitors must be mounted close to the part. Mounting bypass capacitors close to the part will reduce the parasitic trace components thereby improving performance.

Typical Application Circuits

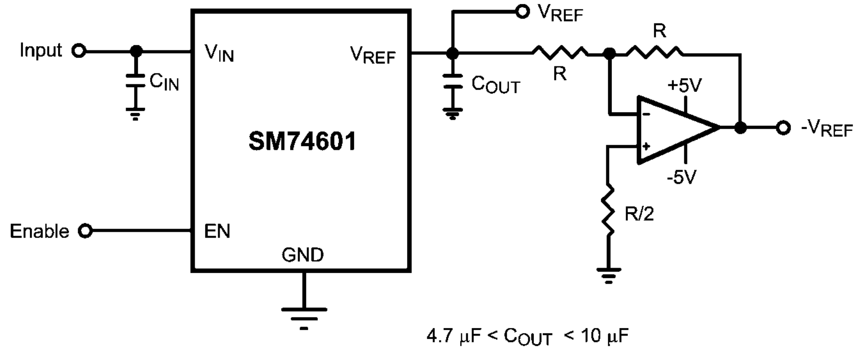

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FIGURE 3. Voltage Reference with Complimentary Output

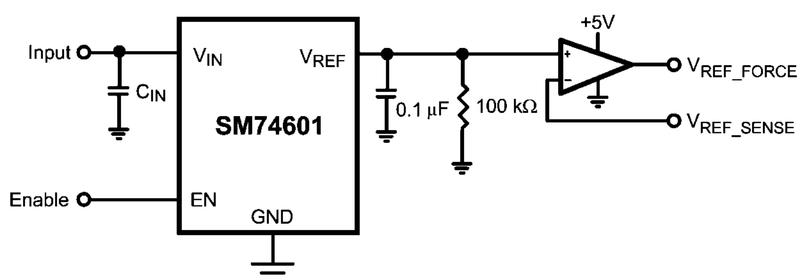

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FIGURE 4. Precision Voltage Reference with Force and Sense Output

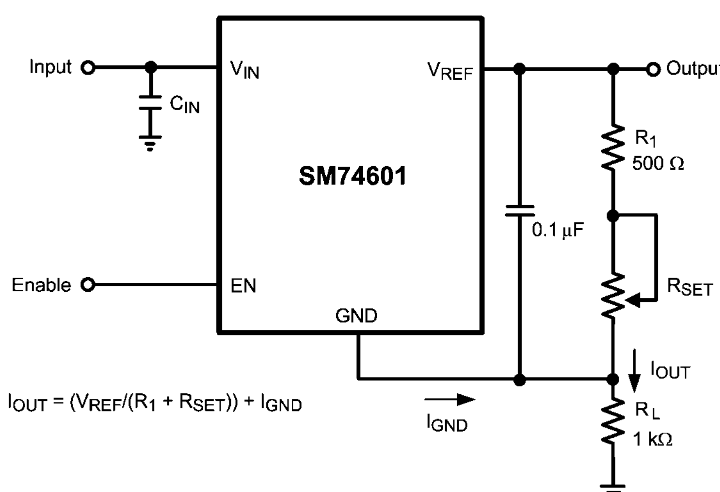

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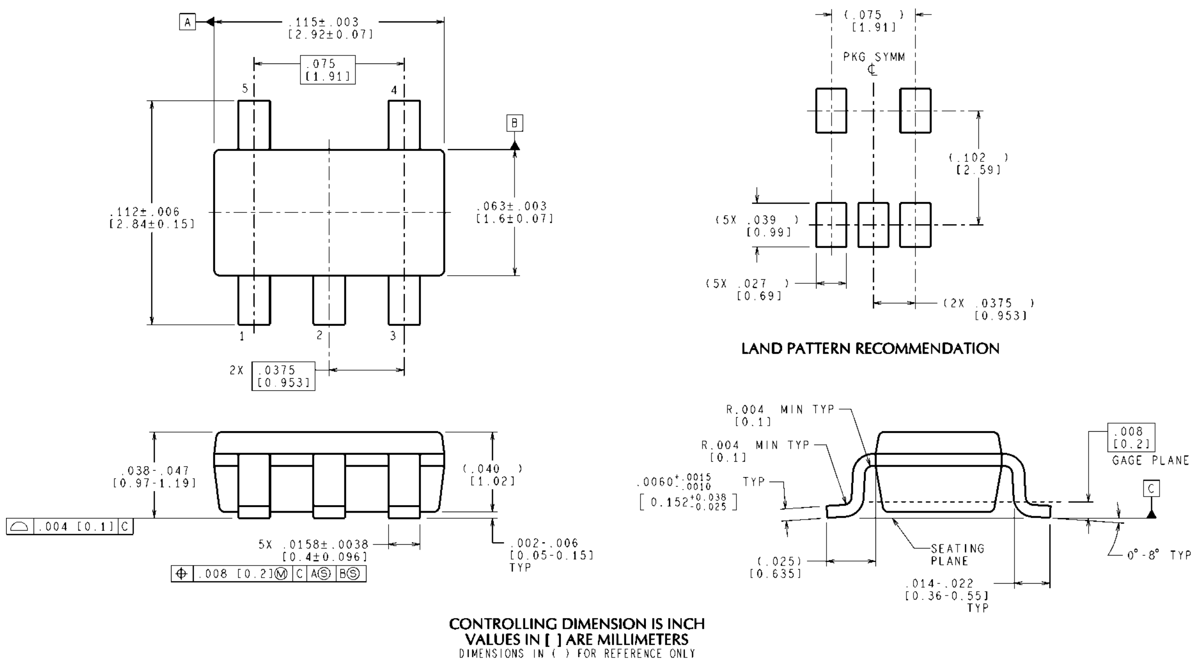
FIGURE 5. Programmable Current Source

Physical Dimensions inches (millimeters) unless otherwise noted



SOT23-5 Package
NS Package Number MF05A

Notes

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