MC33761

Product Preview

Ultra Low-Noise Low Dropout Voltage Regulator with 1V ON/OFF Control

ON Semiconductor

Formerly a Division of Motorola

http://onsemi.com

The MC33761 is an Low DropOut (LDO) regulator featuring excellent noise performances. Thanks to its innovative concept, the circuit reaches an incredible 40µVRMS noise level ***without*** an external bypass capacitor. Housed in a small SOT–23 5 leads–like package, it represents the ideal designer's choice when space and noise are at premium.

The absence of external bandgap capacitor unleashes the response time to a wake–up signal and makes it stay within 40µs (in repetitive mode), pushing the MC33761 as a natural candidate in portable applications.

The MC33761 also hosts a novel architecture which prevents excessive undershoots when the regulator is the seat of fast transient bursts, as in any bursting systems.

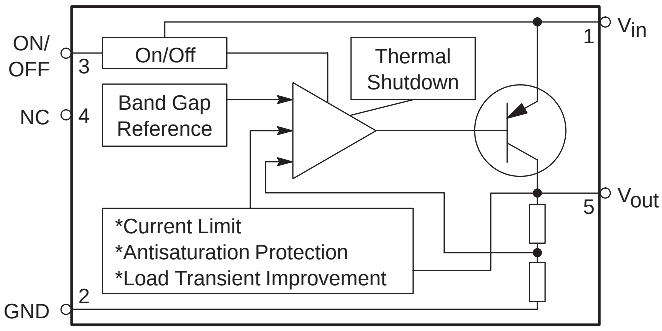
Finally, with a static line regulation better than –75dB, it naturally shields the downstream electronics against choppy lines.

Features

- Ultra low–noise: 150nV/√Hz @ 100Hz, 40µVRMS 100Hz – 100kHz typical, Iout = 60mA, Co=1µF
- Fast response time from OFF to ON: 40µs typical at a 200Hz repetition rate
- Ready for 1V platforms: ON with a 900mVhigh level
- Nominal output current of 80mA with a 100mA peak capability
- Typical dropout of 90mV @ 30mA, 160mV @ 80mA
- Ripple rejection: 70dB @ 1kHz
- 1.5% output precision @ 25°C
- Thermal shutdown
- Vout available from 2.5V to 5.0V

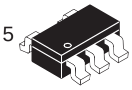
Applications

- Noise sensitive circuits: VCOs RF stages etc.
- Bursting systems (TDMA phones)
- All battery operated devices



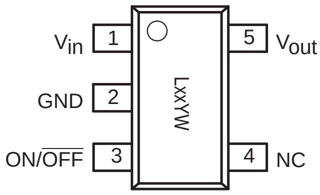
Simplified Block Diagram

This document contains information on a product under development. ON Semiconductor reserves the right to change or discontinue this product without notice.



TSOP–5
SN SUFFIX
CASE 483

PIN CONNECTIONS AND MARKING DIAGRAM



xx = Version
YW = Date Code
(Top View)

ORDERING INFORMATION

See detailed ordering and shipping information in the package dimensions section on page 11 of this data sheet.

PIN FUNCTION DESCRIPTIONS

Pin #	Pin Name	Function	Description
1	V_{in}	Powers the IC	A positive voltage up to 12V can be applied upon this pin.
2	GND	The IC's ground	
3	ON/$\overline{OFF}$	Shuts or wakes–up the IC	A 900mV level on this pin is sufficient to start the IC. A 150mV shuts it down.
4	NC	None	It makes no arm to connect the pin to a known potential, like in a pin–to–pin replacement case.
5	V_{out}	Delivers the output voltage	This pin requires a 1μF output capacitor to be stable.

MAXIMUM RATINGS

Rating	Pin #	Symbol	Value		Unit
			Min	Max	
Power Supply Voltage	1	V_{in}	—	12	V
ESD Capability, HBM Model	All Pins			1	kV
ESD Capability, Machine Model	All Pins			200	V
Maximum Power Dissipation NW Suffix, Plastic Package Thermal Resistance Junction–to–Air		P_D $R_{\theta J-A}$		Internally Limited 210	W °C/W
Operating Ambient Temperature Maximum Junction Temperature (1) Maximum Operating Junction Temperature (2)		T_A T_{Jmax} T_J		–40 to +85 150 125	°C °C °C
Storage Temperature Range		T_{stg}		–60 to +150	°C

(1) Internally Limited by Shutdown.
(2) Specifications are guaranteed below this value.

ELECTRICAL CHARACTERISTICS

(For Typical Values T_A = 25°C, for Min/Max values T_A = –40°C to +85°C, Max T_J = 125°C unless otherwise noted)

Characteristics	Pin #	Symbol	Min	Typ	Max	Unit
Logic Control Specifications						
Input Voltage Range	3	$V_{ON/\overline{OFF}}$	0		V_{in}	V
ON/$\overline{OFF}$ Input Resistance (all versions)	3	$R_{ON/\overline{OFF}}$		250		kΩ
ON/OFF Control Voltages (3) Logic Zero, OFF State, I_O = 50 mA Logic One, ON State, I_O = 50 mA	3	$V_{ON/\overline{OFF}}$	 900		 150	mV
Currents Parameters						
Current Consumption in OFF State (all versions) OFF Mode Current: $V_{in} = V_{out}$ + 1 V, I_O = 0, V_{OFF} = 150 mV		IQ_{OFF}		0.1	2	μA
Current Consumption in ON State (all versions) ON Mode Current: $V_{in} = V_{out}$ + 1 V, I_O = 0, V_{ON} = 3.5 V		IQ_{ON}		180		μA
Current Consumption in ON State (all versions), ON Mode Saturation Current: $V_{in} = V_{out}$ – 0.5 V, No Output Load		IQ_{SAT}		800		μA
Current Limit $V_{in} = Vout_{nom}$ + 1 V, Output is brought to $Vout_{nom}$ – 0.3 V (all versions)		I_{MAX}	100	180		mA

(3) Voltage Slope should be Greater than 2 mV/μs

ELECTRICAL CHARACTERISTICS

(For Typical Values T_A = 25°C, for Min/Max values T_A = –40°C to +85°C, Max T_J = 125°C unless otherwise noted)

Characteristics	Pin #	Symbol	Min	Typ	Max	Unit
Output Voltages						
V_{out} + 1 V < V_{in} < 6 V, T_A = 25°C, 1 mA < I_{out} < 80 mA 2.5 V	5	V_{out}	2.462	2.5	2.537	V
2.8 V	5	V_{out}	2.758	2.8	2.842	V
3.0 V	5	V_{out}	2.955	3.0	3.045	V
3.3 V	5	V_{out}	3.250	3.3	3.349	V
3.6 V	5	V_{out}	3.546	3.6	3.654	V
Other Voltages up to 5V Available in 50mV Increments Steps	5	V_{out}	–1.5	X	+1.5	%
V_{out} + 1V < V_{in} < 6V, T_A = –40°C to +85°C, 1mA < I_{out} < 80mA 2.5 V	5	V_{out}	2.425	2.5	2.575	V
2.8 V	5	V_{out}	2.716	2.8	2.884	V
3.0 V	5	V_{out}	2.91	3.0	3.090	V
3.3 V	5	V_{out}	3.201	3.3	3.399	V
3.6 V	5	V_{out}	3.492	3.6	3.708	V
Other Voltages up to 5V Available in 50mV Increments Steps	5	V_{out}	–3	X	+3	%
Line and Load Regulation, Dropout Voltages						
Line Regulation (all versions) V_{out} + 1 V < V_{in} < 12 V, I_{out} = 80 mA	5/1	Reg_{line}			20	mV
Load Regulation (all versions) V_{in} = V_{out} + 1 V, C_{out} = 1 μF, I_{out} = 1 to 80 mA	5	Reg_{load}			40	mV
Dropout Voltage (all versions) (3) I_{out} = 30 mA I_{out} = 60 mA I_{out} = 80 mA	 5 5 5	 $V_{in}–V_{out}$ $V_{in}–V_{out}$ $V_{in}–V_{out}$		 90 140 160	 150 200 250	mV
Dynamic Parameters						
Ripple Rejection (all versions) V_{in} = V_{out} + 1 V + 1 kHz 100 mVpp Sinusoidal Signal	5/1	Ripple		–70		dB
Output Noise Density @ 1 kHz	5			150		nV/√Hz
RMS Output Noise Voltage (all versions) C_{out} = 1 μF, I_{out} = 50 mA, F = 100 Hz to 1 MHz	5	Noise		35		μV
Output Rise Time (all versions) C_{out} = 1 μF, I_{out} = 50 mA, 10% of Rising ON Signal to 90% of Nominal V_{out}	5	t_{rise}		40		μs
Thermal Shutdown						
Thermal Shutdown (all versions)					125	°C

(3) V_{out} is brought to V_{out} – 100 mV

DEFINITIONS

Load Regulation

The change in output voltage for a change in output current at a constant chip temperature.

Dropout Voltage

The input/output differential at which the regulator output no longer maintains regulation against further reductions in input voltage. Measured when the output drops 100mV below its nominal value (which is measured at 1V differential value). The dropout level is affected by the chip temperature, load current and minimum input supply requirements.

Output Noise Voltage

This is the integrated value of the output noise over a specified frequency range. Input voltage and output current are kept constant during the measurement. Results are expressed in μVRMS.

Maximum Power Dissipation

The maximum total dissipation for which the regulator will operate within its specs.

Quiescent Current

The quiescent current is the current which flows through the ground when the LDO operates without a load on its output: internal IC operation, bias etc. When the LDO becomes loaded, this term is called the Ground current. It is actually the difference between the input current (measured through the LDO input pin) and the output current.

Line Regulation

The change in output voltage for a change in input voltage. The measurement is made under conditions of low dissipation or by using pulse technique such that the average chip temperature is not significantly affected. One usually distinguishes *static line regulation* or *DC line regulation* (a DC step in the input voltage generates a corresponding step in the output voltage) from *ripple rejection* or *audio susceptibility* where the input is combined with a frequency generator to sweep from a few hertz up to a defined boundary while the output amplitude is monitored.

Thermal Protection

Internal thermal shutdown circuitry is provided to protect the integrated circuit in the event that the maximum junction temperature is exceeded. When activated at typically 125°C, the regulator turns off. This feature is provided to prevent catastrophic failures from accidental overheating.

Maximum Package Power Dissipation

The maximum power package power dissipation is the power dissipation level at which the junction temperature reaches its maximum operating value, i.e. 125°C. Depending on the ambient temperature, it is possible to calculate the maximum power dissipation and thus the maximum available output current.

Characterization Curves

All curves taken with $V_{in} = V_{out} + 1$ V, $V_{out} = 2.8$ V, $C_{out} = 1$ µF

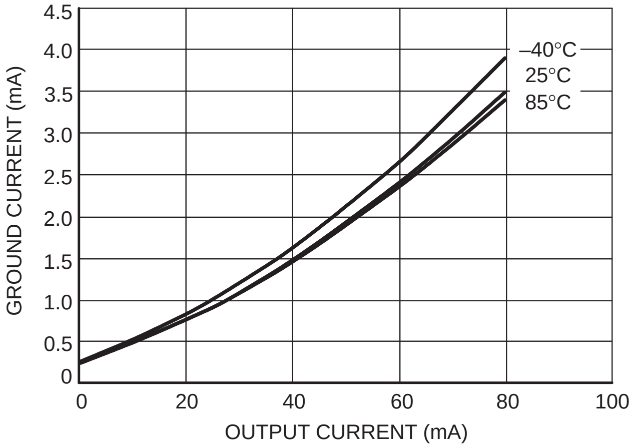


Figure 1. Ground Current versus Output Current

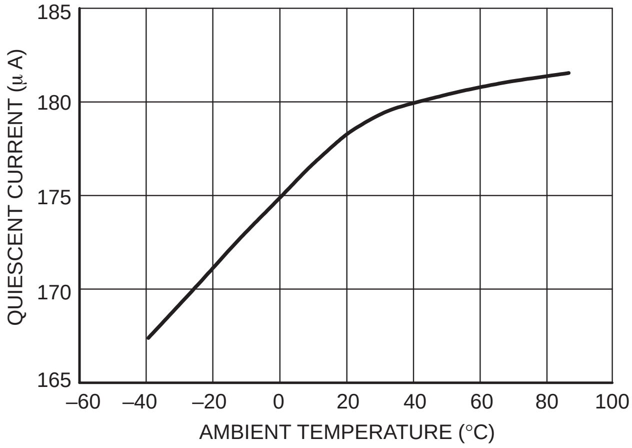


Figure 2. Quiescent Current versus Temperature

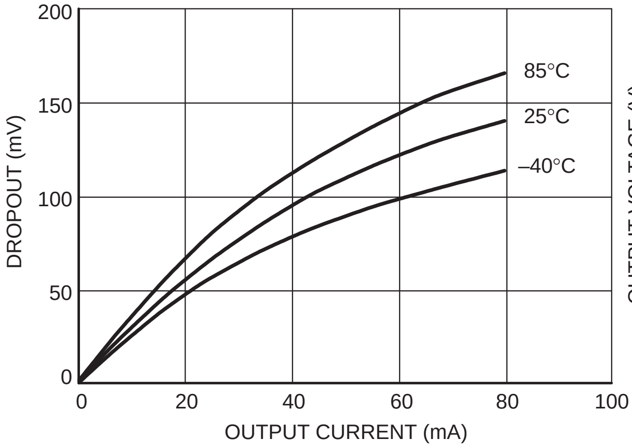


Figure 3. Dropout versus Output Current

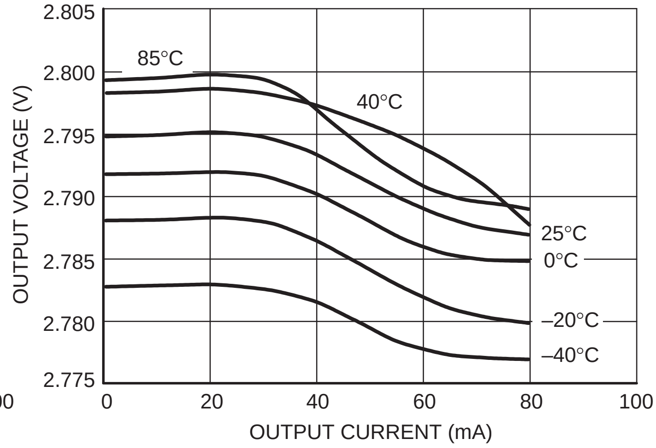


Figure 4. Output Voltage versus Output Current

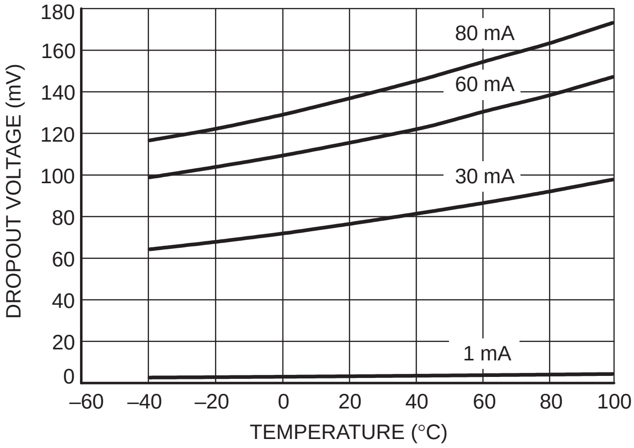


Figure 5. Dropout versus Temperature

APPLICATION HINTS

Input Decoupling

As with any regulator, it is necessary to reduce the dynamic impedance of the supply rail that feeds the component. A 1µF capacitor either ceramic or tantalum is recommended and should be connected close to the MC33761 package. Higher values will correspondingly improve the overall line transient response.

Output Decoupling

Thanks to a novel concept, the MC33761 is a stable component and does not require any specific Equivalent Series Resistance (ESR) neither a minimum output current. Capacitors exhibiting ESRs ranging from a few mΩ up to 3Ω can thus safely be used. The minimum decoupling value is 1µF and can be augmented to fulfill stringent load transient requirements. The regulator accepts ceramic chip capacitors as well as tantalum devices.

Noise Decoupling

Unlike other LDOs, the MC33761 is a true low—noise regulator. Without the need of an external bypass capacitor, it typically reaches the incredible level of 40µVRMS overall noise between 100 Hz and 100 kHz. To give maximum insight on noise specifications, ON Semiconductor includes spectral density graphics. The classical bypass capacitor impacts the start—up phase of standard LDOs. However, thanks to its low—noise architecture, the MC33761 operates without a bypass element and thus offers a typical 40µs start—up phase.

Protections

The MC33761 hosts several protections, giving natural ruggedness and reliability to the products implementing the component. The output current is internally limited to a maximum value of 180 mA *typical* while temperature shutdown occurs if the die heats up beyond 125°C. These values let you assess the maximum differential voltage the device can sustain at a given output current before its protections come into play.

The maximum dissipation the package can handle is given by:

$$P_{max} = \frac{T_{Jmax} - T_A}{R_{\theta JA}}$$

If T_{Jmax} is limited to 125°C, then the MC33761 can dissipate up to 470mW @ 25°C. The power dissipated by the MC33761 can be calculated from the following formula:

$$Ptot = \left(V_{in} \times I_{gnd}(I_{out})\right) + \left(V_{in} - V_{out}\right) \times I_{out}$$

or

$$Vin_{max} = \frac{Ptot + V_{out} \times I_{out}}{I_{gnd} + I_{out}}$$

If a 80mA output current is needed, the ground current is extracted from the data–sheet curves: 4mA @ 80mA. For a MC33761SNT1–28 (2.8 V) delivering 80mA and operating at 25°C, the maximum input voltage will then be 8.3V.

Typical Applications

The following picture portrays the typical application of the MC33761.

Figure 6.

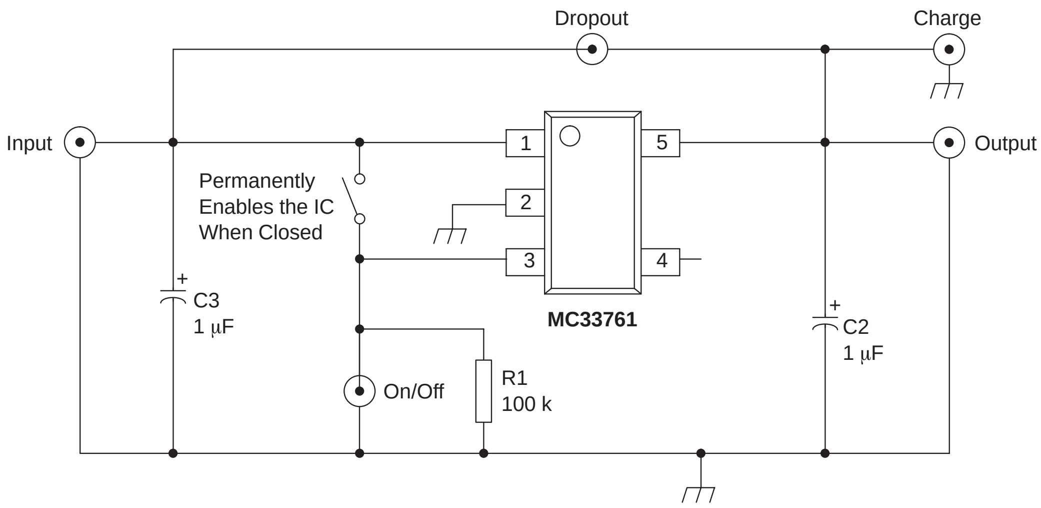
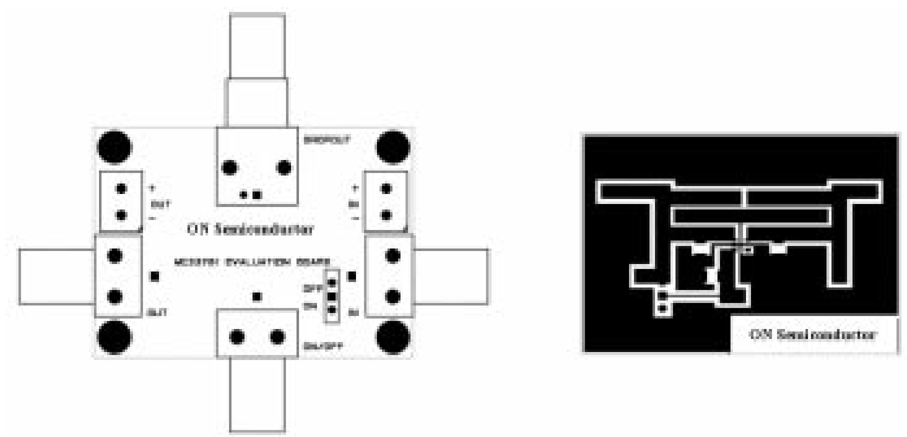


Figure 7. A Typical Application Schematic

As for any low noise designs, particular care has to be taken when tackling Printed Circuit Board (PCB) layout. The figure below gives an example of a layout where stray inductances/capacitances are minimized. This layout is the basis for the MC33761 performance evaluation board. The BNC connectors give the user an easy and quick evaluation mean.



Understanding the Load Transient Improvement

The MC33761 features a novel architecture which allows the user to easily implement the regulator in burst systems where the time between two current shots is kept very small.

The quality of the transient response time is related to many parameters, among which the closed–loop bandwidth with the corresponding phase margin plays an important role. However, other characteristics also come into play like the series pass transistor saturation. When a current perturbation suddenly appears on the output, e.g. a load increase, the error amplifier reacts and actively biases the PNP transistor. During this reaction time, the LDO is in open–loop and the output impedance is rather high. As a result, the voltage brutally drops until the error amplifier effectively closes the loop and corrects the output error. When the load disappears, the opposite phenomenon takes place with a positive overshoot. The problem appears when this overshoot decays down to the LDO steady–state value. During this decreasing phase, the LDO stops the PNP bias and one can consider the LDO asleep (**figure 8**). If by misfortune a current shot appears, the reaction time is incredibly lengthened and a strong undershoot takes place. This reaction is clearly not acceptable for line sensitive devices, such as VCOs or other Radio–Frequency parts. This problem is dramatically exacerbated when the output current drops to zero rather than a few mA. In this later case, the internal feedback network is the only discharge path, accordingly lengthening the output voltage decay period (**figure 9**).

The MC33761 cures this problem by implementing a clever design where the LDO detects the presence of the overshoot and forces the system to go back to steady–state as soon as possible, ready for the next shot. **Figure 10** and **11** show how it positively improves the response time and decreases the negative peak voltage.

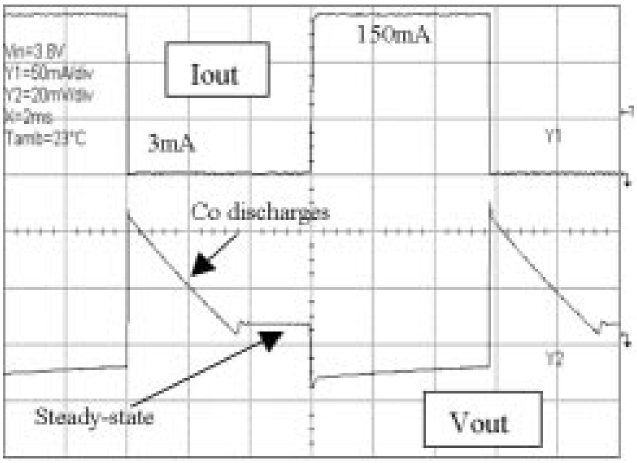


Figure 8. A standard LDO behavior when the load current disappears

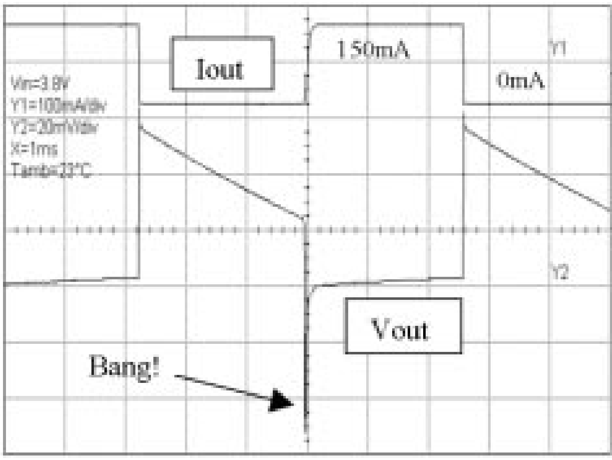


Figure 9. A standard LDO behavior when the load current appears in the decay zone

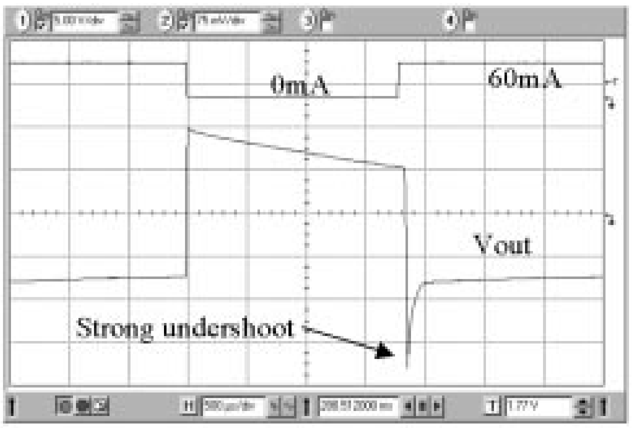


Figure 10. Without load transient improvement

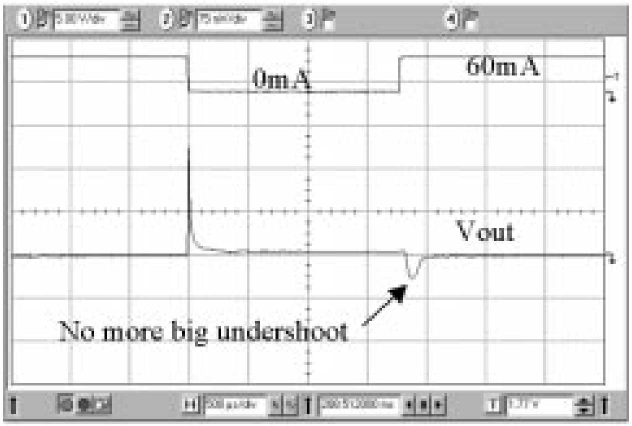


Figure 11. MC33761 with load transient improvement

MC33761 has a fast start–up phase

Thanks to the lack of bypass capacitor the MC33761 is able to supply its downstream circuitry as soon as the OFF to ON signal appears. In a standard LDO, the charging time of the external bypass capacitor hampers the response time. A simple solution consists in suppressing this bypass element but, unfortunately, the noise rises to an unacceptable level. MC33761 offers the best of both worlds since it no longer includes a bypass capacitor and starts in less than 40µs typically (Repetitive at 200Hz). It also ensures a low–noise level of 40µVRMS 100Hz–100kHz. The following picture details the typical 33761 startup phase.

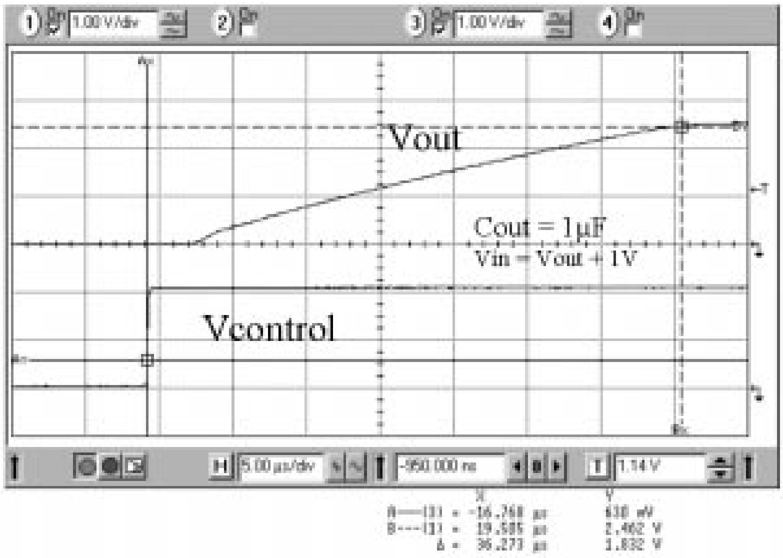


Figure 12. Repetitive start–up waveforms

TYPICAL TRANSIENT RESPONSES

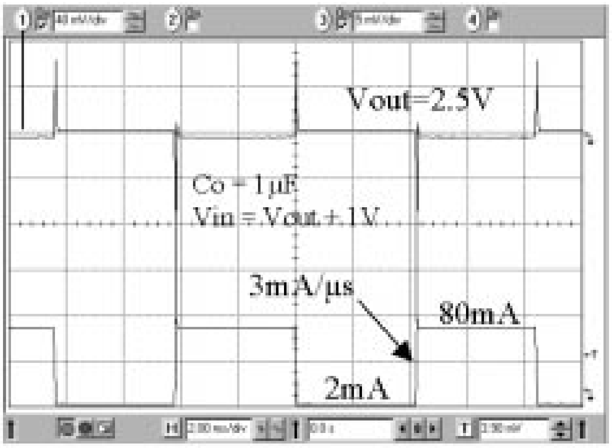


Figure 13. Output is pulsed from 2mA to 80mA

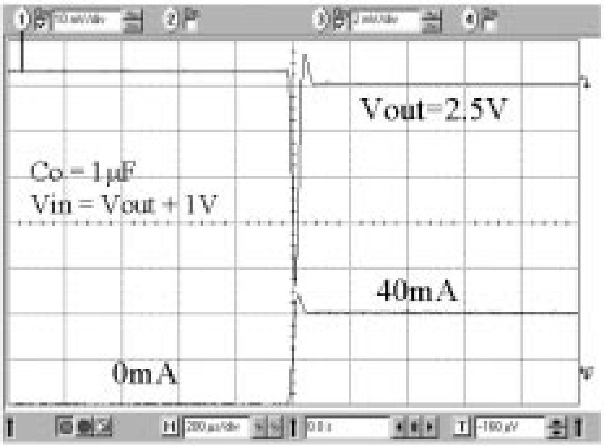


Figure 14. Discharge effects from 0 to 40mA

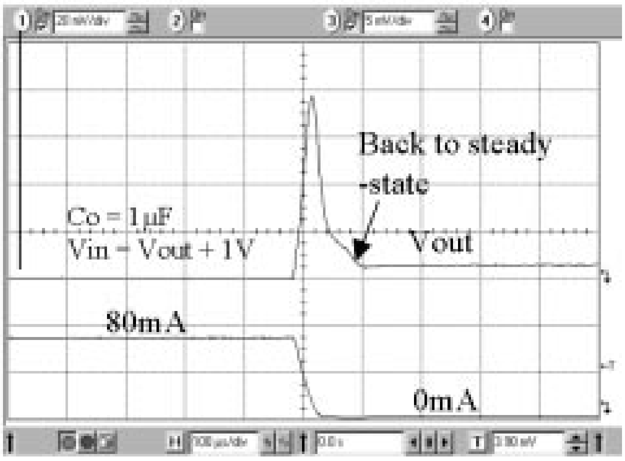


Figure 15. Load transient improvement effect

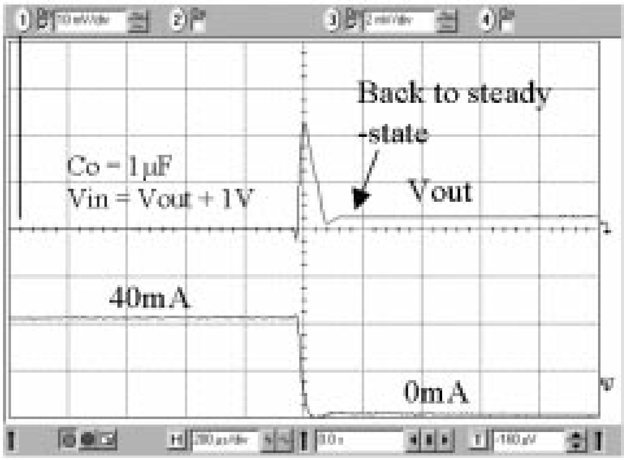


Figure 16. Load transient improvement effect

TYPICAL TRANSIENT RESPONSES

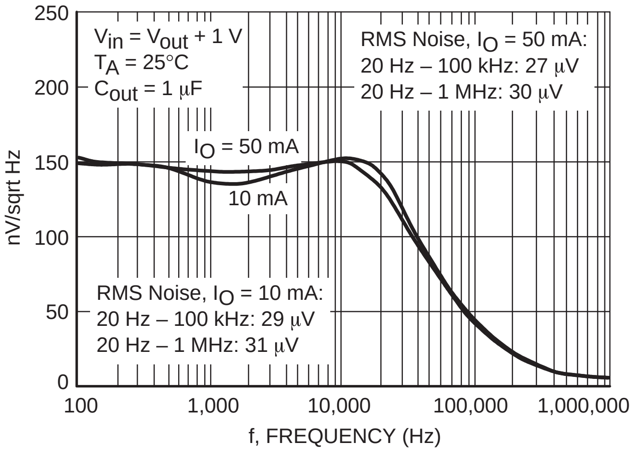


Figure 17. MC33761 Typical Noise Density Performance

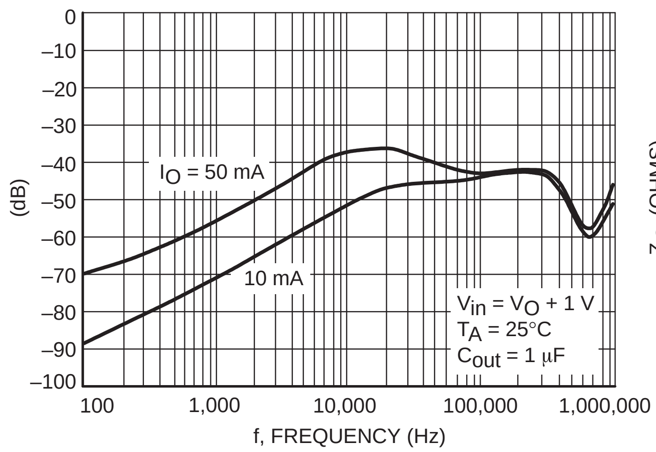


Figure 18. MC33761 Typical Ripple Rejection Performance

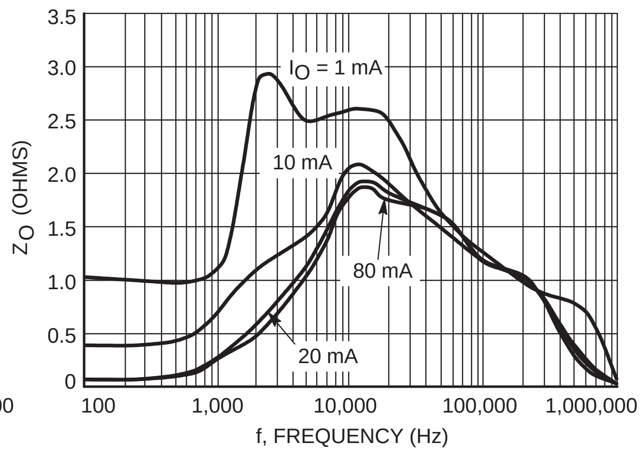


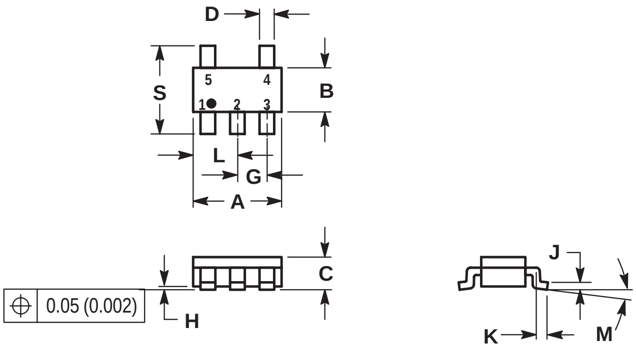
Figure 19. Typical Output Impedance plot $C_{out} = 1\mu F$, $V_{in} = V_{out} + 1$

ORDERING INFORMATION

Device	Voltage Output	Package	Shipping
MC33761SNT1–25	2.5V	TSOP–5	3000 Units / Tape & Reel
MC33761SNT1–28	2.8V	TSOP–5	3000 Units / Tape & Reel
MC33761SNT1–30	3.0V	TSOP–5	3000 Units / Tape & Reel

PACKAGE DIMENSIONS

TSOP–5
SN SUFFIX
PLASTIC PACKAGE
CASE 483–01
ISSUE A



NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: MILLIMETER.
3. MAXIMUM LEAD THICKNESS INCLUDES LEAD FINISH THICKNESS. MINIMUM LEAD THICKNESS IS THE MINIMUM THICKNESS OF BASE MATERIAL.

	MILLIMETERS		INCHES	
DIM	MIN	MAX	MIN	MAX
A	2.90	3.10	0.1142	0.1220
B	1.30	1.70	0.0512	0.0669
C	0.90	1.10	0.0354	0.0433
D	0.25	0.50	0.0098	0.0197
G	0.85	1.00	0.0335	0.0413
H	0.013	0.100	0.0005	0.0040
J	0.10	0.26	0.0040	0.0102
K	0.20	0.60	0.0079	0.0236
L	1.25	1.55	0.0493	0.0610
M	0°	10°	0°	10°
S	2.50	3.00	0.0985	0.1181

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