600mA, High PSRR, Fast Response LDO Regulators

FEATURES

- 2.5V to 5.5V Input Voltage Range
- Up to 600mA output current (Typical) with V_{IN}-V_{OUT} ≤ 1.8V@T_A = 25°C
- 600mV @600mA Dropout Voltage
- Excellent Transient Response
- Stable with 1µF Ceramic Output Capacitor
- 60dB PSRR at 1kHz
- Low 75µA Quiescent Current
- Low Shutdown Current: <1µA
- Output Accuracy: ±2%
- Adjustable Output Voltage: 0.8V~5V
- Current Limit Protection
- Thermal Shutdown
- Output Auto-Discharge in Shutdown
- RoHS Compliant and 100% Lead (Fb)-Free Halogen-Free

GENERAL DESCRIPTION

The TMI6050 is a 600mA, low-dropout (LDO) linear regulator with fast transient response and high PSRR. It offers high output accuracy, low dropout voltage and low quiescent current as well as fast start-up time. This regulator is based on a CMOS process.

The TMI6050 is designed to work with low-ESR ceramic capacitors, reducing the amount of the PCB area necessary for power applications. Only a 1µF ceramic output capacitor can make the device stable over the whole load range current (0mA to 600mA).

The output voltage of TMI6050 output adjustable version can be set by an external resistor divider. When the FB pin is connected to an external resistor divider, its output can be adjusted from 0.8V to 5V. Other key features include over-current protection and thermal shutdown. The TMI6050 is packaged in SOT23-5 packages.

APPLICATIONS

- Cellular Phones
- Bluetooth portable radios and Accessories
- Battery-Powered Equipment
- Laptop, Palmtops, Notebook Computer
- PDAs
- Digital still Camera and Video Recorders

TYPICAL APPILCATION

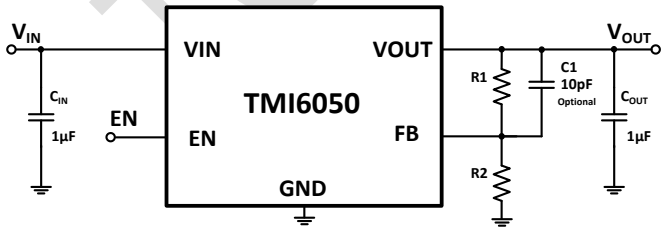


Figure 1. TMI6050 adjustable output Circuit

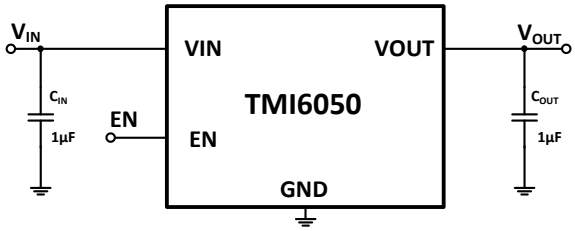


Figure 2. TMI6050 fixed output Circuit

BLOCK DIAGRAM

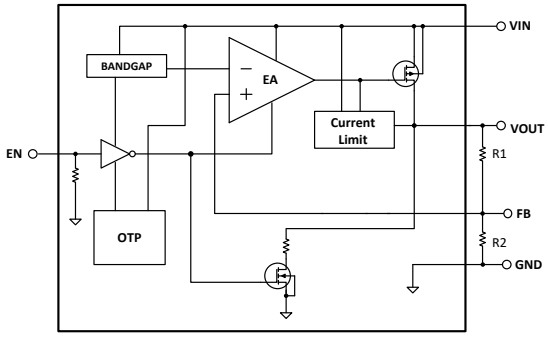


Figure 3. TMI6050 adjustable function block

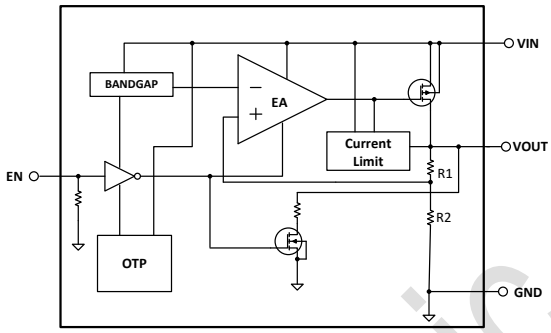


Figure 4. TMI6050 fixed function block

ABSOLUTE MAXIMUM RATINGS

Description	Value	Unit
VIN, EN Input Voltage Range	-0.3~6	V
All other pins Voltage Range	-0.3 to (V_{IN}+0.3)	V
Junction Temperature	160	°C
Storage Temperature Range	-65~150	°C
Junction-to-ambient Thermal Resistance (Note1)	120	°C/W
Junction-to-ambient Thermal Resistance (Note2)	220	°C/W
Junction-to-case(top) Thermal Resistance (Note1)	62	°C/W
Lead Temperature Soldering, 10sec	260	°C

Note 1: Measured on 3cm x 5cm 2-layers FR-4 Board, 1oz copper.

Note 2: Measured on 2cm x 2cm 2-layers small FR-4 Board, 1oz copper, no via holes on GND copper.

ESD RATINGS

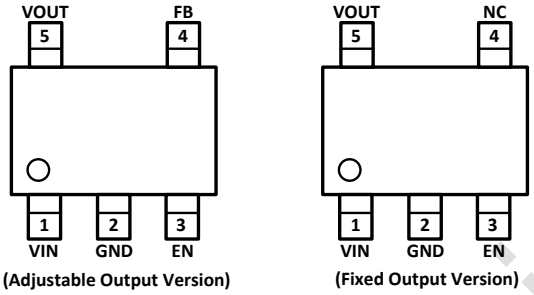
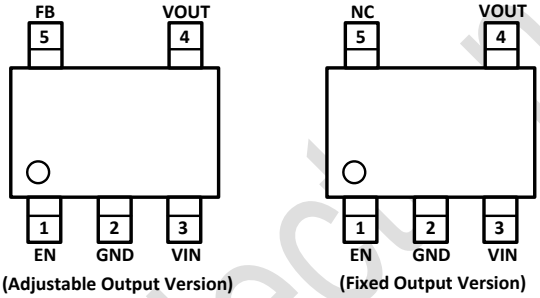
Items	Description	Value	Unit
V_{ESD_HBM}	Human Body Model for all pins	±2000	V
V_{ESD_CDM}	Charged Device Model for all pins	±2000	V

ESDA/JEDEC specification JS-002

RECOMMEND OPERATING CONDITIONS

Items	Description	Min	Max	Unit
Voltage Range	IN	2.5	5.5	V
T_J	Operation Junction Temperature	-40	125	°C

PIN CONFIGURATION

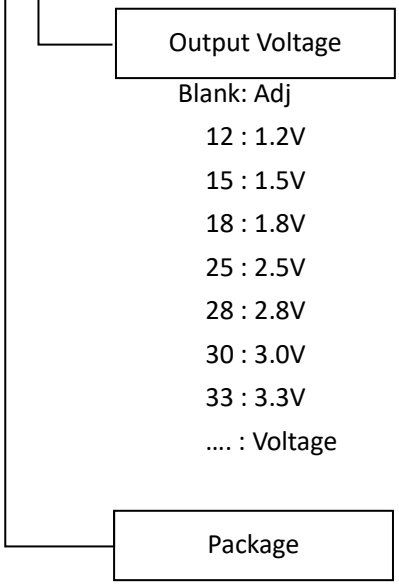
Package Type	Pin Configurations
TMI6050 / SOT23-5	
TMI6050B / SOT23-5	

PIN FUNCTIONS

TMI6050	TMI6050B	Name	Function
1	3	VIN	Input Supply of the LDO.
2	2	GND	Signal Ground.
3	1	EN	Enable Pin. Connect this pin to ground or less than EN falling threshold to disable the device, connect EN to above EN rising threshold to enable the device. This pin should not be floated.
4	5	NC/FB	Feedback Pin for adjustable output version. NC for fixed output version.
5	4	VOUT	Output of the LDO

ORDER INFORMATION

TMI6050X-XX



Top Mark: TXXXXX (TXX: Device Code, XXX: Inside code)

Part Number	Package	Top Mark	Quantity/ Reel
TMI6050	SOT23-5	TEAXXX	3000
TMI6050-12	SOT23-5	TEBXXX	3000
TMI6050-15	SOT23-5	TEHXXX	3000
TMI6050-18	SOT23-5	TECXXX	3000
TMI6050-25	SOT23-5	TEDXXX	3000
TMI6050-28	SOT23-5	TEEXXX	3000
TMI6050-30	SOT23-5	TEFXXX	3000
TMI6050-33	SOT23-5	TEGXXX	3000
TMI6050B	SOT23-5	TGAXXX	3000
TMI6050B-12	SOT23-5	TGBXXX	3000
TMI6050B-15	SOT23-5	TGHXXX	3000
TMI6050B-18	SOT23-5	TGCXXX	3000
TMI6050B-25	SOT23-5	TGDXXX	3000
TMI6050B-28	SOT23-5	TGEXXX	3000
TMI6050B-30	SOT23-5	TGFXXX	3000
TMI6050B-33	SOT23-5	TGGXXX	3000

TMI6050 and TMI6050B devices are Pb-free and RoHS compliant.

ELECTRICAL CHARACTERISTICS

T_A=25℃, V_{IN}=V_{OUT}+1V, or V_{IN}=2.5V for V_{OUT}<1.5V unless otherwise specified.

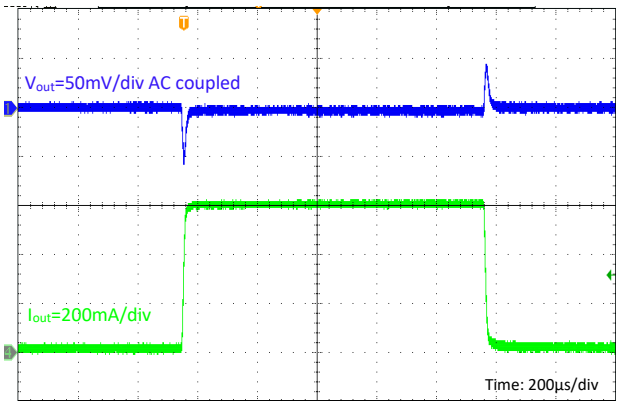
Symbol	Parameter	conditions	Min	Typ	Max	Unit
Input Voltage						
V_{IN}	Input Voltage Range		2.5		5.5	V
I_Q	Quiescent Current	V_{EN}=2.5V, I_{OUT}=0mA		75	90	μA
I_{SHDN}	Shutdown Current	V_{EN}=0V		0.1	1	μA
PSRR	Power Supply Ripple Rejection	V_{IN}=Vnom+1V_{P-P}, f=1kHz, I_{LOAD}=10mA		60		dB
Enable						
V_{ENH}	Enable Rising Threshold	V_{IN}=5.0V, V_{OUT}=2.5V	0.7	0.9	1.1	V
		V_{IN}=3.3V, V_{OUT}=2.5V	0.5	0.8	1.0	V
V_{EN_HYS}	EN Hysteresis			0.08		V
I_{EN}	EN Input Current	V_{IN}=3.5V, V_{EN}=3.5V or 0V	-1	0.2	1	μA
T_{ST}	Start-up Time	V_{IN}=3.5V, V_{OUT}=2.5V	20	40	100	μs
Output Voltage						
V_{OUT}	Output Voltage Accuracy	V_{IN}=V_{OUT}+1V, I_{OUT}=10mA	-2		+2	%
		V_{IN}=V_{OUT}+1V, I_{OUT}=10mA, T_A=-40°C to +85°C	-3		+3	%
V_{FB}	FB Pin Voltage		0.786	0.8	0.816	V
V_{LNR}	Output Line Regulation	V_{OUT}+0.5V<V_{IN}<5.5V, I_{OUT}=10mA		0.01	0.1	%/V
V_{LDR}	Output Load Regulation	2mA<I_{OUT}<600mA, V_{IN}=V_{NOM}+1.0V			12	mV
V_{DROP}	Dropout Voltage (Note 3)	I_{OUT}=600mA		600	700	mV
I_{OUTMAX}	Maximum Output Current	V_{IN}=V_{OUT}+1V	600			mA
Protection						
I_{limit}	Current Limit		650	800		mA
I_{short}	Output Short Current Limit	V_{FB} or V_{OUT} = 0V		150		mA
R_{AD}	Resistance of Auto-Discharge			130		Ω
T_{SD}	Thermal Shutdown Temperature	No Load, V_{IN}=V_{EN}=5V		160		°C
T_{SDHYS}	Thermal Shutdown Hysteresis	No Load, V_{IN}=V_{EN}=5V		20		°C

Note 3: Dropout is defined as V_{IN}-V_{OUT} when V_{OUT} is 2% below the value of V_{OUT} for V_{IN}=V_{OUT}+0.3V.

TYPICAL PERFORMANCE CHARACTERISTICS

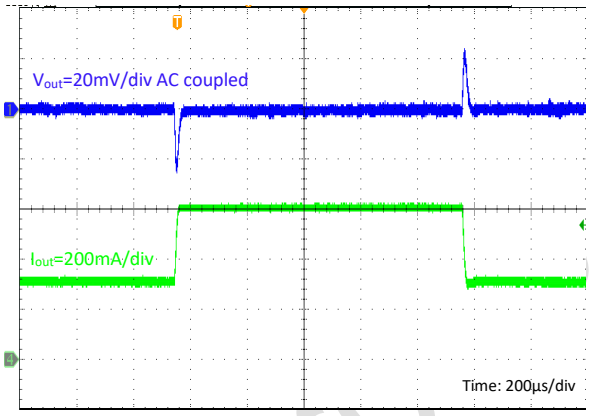
Load Transient

Vin=4V, Vo=3.3V, Io=10mA to 600mA



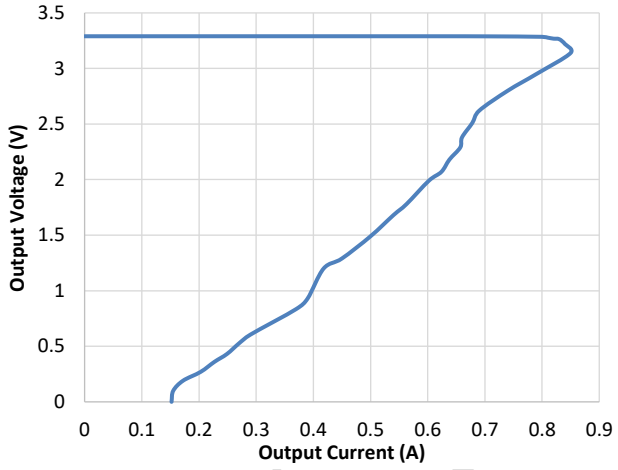
Load Transient

Vin=4V, Vo=3.3V, Io=300mA to 600mA



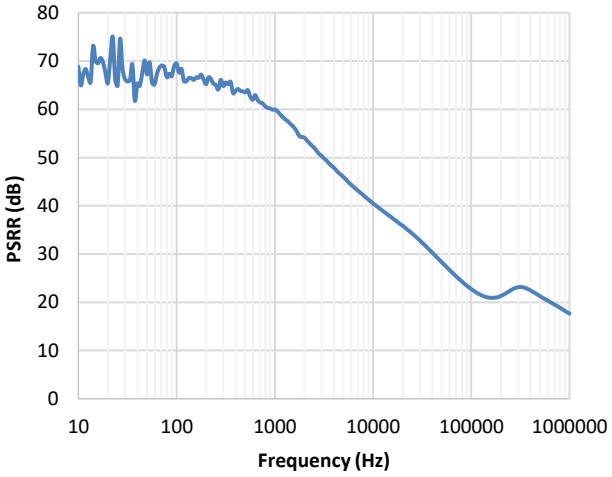
Over Current Protection

Vin=5V, Vo=3.3V, Ta=25°C



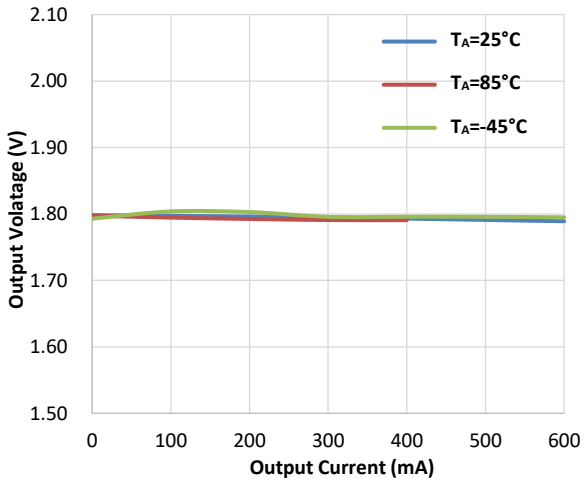
PSRR vs Frequency

Vin=5V, Vo=3.3V, Io=10mA, Ta=25°C



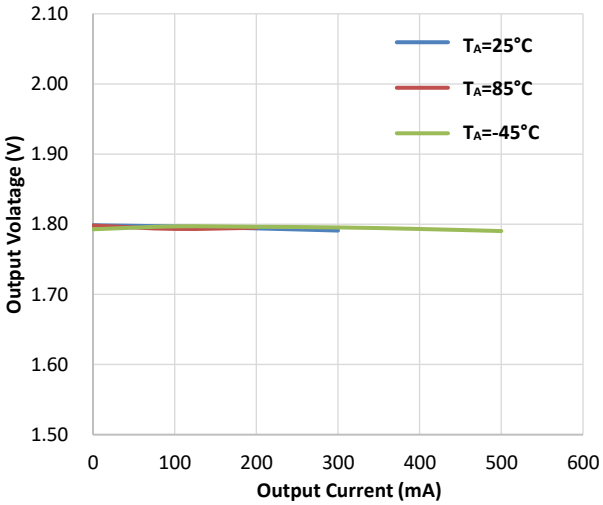
Load Regulation

Vin=3.3V, Vo=1.8V



Load Regulation

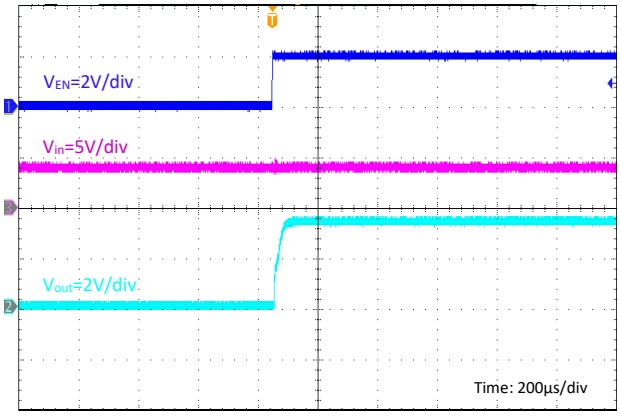
Vin=5V, Vo=1.8V



TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

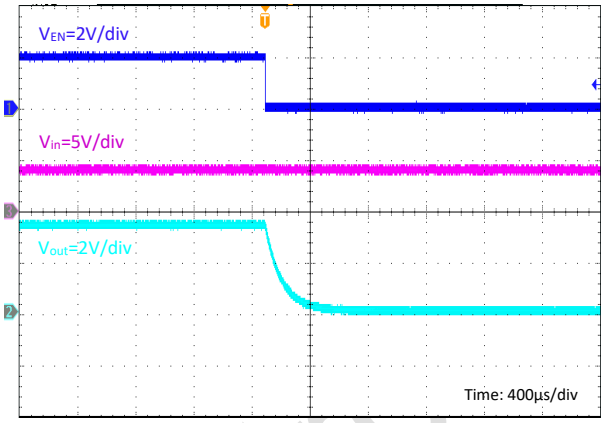
EN Power on

TMI6050, Vin=4V, Vo=3.3V, Io=0A



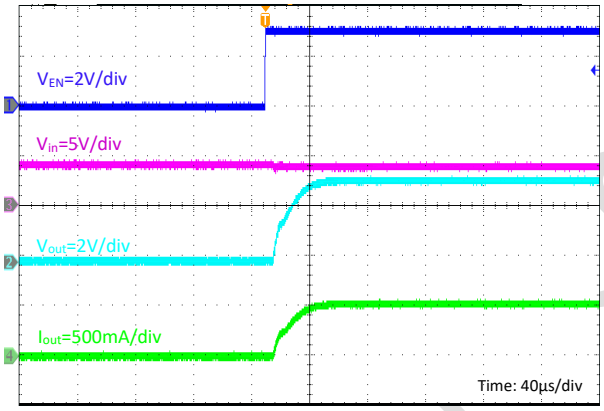
EN Power Off

TMI6050, Vin=4V, Vo=3.3V, Io=0A



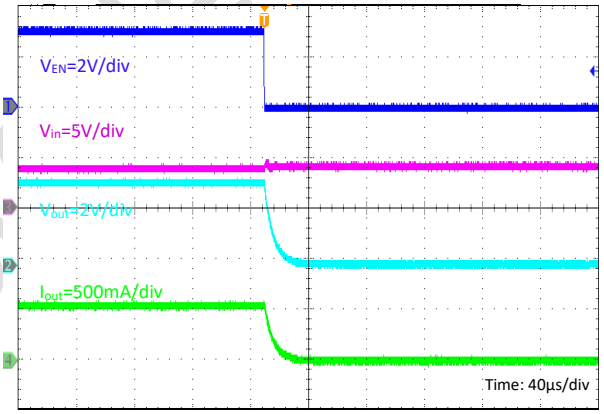
EN Power on

TMI6050, Vin=4V, Vo=3.3V, Io=600mA



EN Power Off

TMI6050, Vin=4V, Vo=3.3V, Io=600mA



Detailed Function Description

The TMI6050 is a high output current, low dropout linear regulator with fast transient response and high PSRR. It offers high output accuracy, low quiescent current and fast start-up time. It is designed to work with low-ESR ceramic capacitor, reducing the amount of the PCB area. Only a 1μF effective capacitance ceramic output capacitor can make the device stable over the whole load range.

As shown in the function block diagram, the TMI6050 is composed of the bandgap reference voltage, the error amplifier, P-channel MOSFET pass transistor, external resistor divider and some additional protection circuits. The reference voltage, connected to the cathode terminal of the error amplifier, compares with the feedback voltage to regulate the output voltage to make it constant over the whole load current range. If the feedback voltage is lower than the reference voltage, the pass transistor gate is pulled lower to increase its conductivity. This allows more current to flow to the output and increase the output voltage. If the feedback voltage is higher than the reference voltage, the pass transistor gate is pulled higher to decrease its conductivity. This allows less current to flow to the output and decrease the output voltage. The feedback point is the output of the external resistor divider connected to the V_{OUT} pin.

Enable/Shutdown

The TMI6050 is disabled when the EN pin is connected to ground or the voltage less than EN falling threshold, and the quiescent current is less than 1μA. Connect EN pin to higher EN rising threshold voltage to enable the device. This pin cannot be floated.

Output Auto Discharge

When the regulator is disabled, an internal 130Ω resister is connected between VOUT and GND to discharge output capacitor C_{OUT}.

Current Limit

The TMI6050 includes a current limit circuit to monitor the gate voltage of the pass transistor to limit the output current. When the output current is higher than the over-current limit, the circuit will clamp the gate voltage of the pass transistor to limit the output current. The typical output current limit is 800mA.

Adjustable Output Voltage

TMI6050 has a wide output voltage range. The output voltage is programmed by an external resistor divider as shown in Figure 1. The output can be calculated be by the following equation:

$$V_{OUT}=(1+\frac{R_1}{R_2})\times V_{REF} \quad \text{(Equation.1)}$$

Where V_{REF} is the internal reference voltage, which is 0.8V in TMI6050.

Short Circuit Protection

When V_{OUT} pin is short-circuit to GND, short circuit protection will be triggered and clamp the output current to approximately 150mA. This feature protects the regulator from over current condition and damage due to overheating.

Thermal Shutdown

The TMI6050 monitors internal temperature. When the junction temperature exceeds 160°C, the over temperature protection (OTP) circuit turn off the pass transistor until the device is cooled down by 30°C. Then the pass transistor resumes. For continue operation, do not exceed absolute maximum junction temperature.

Application Information

External capacitor

The TMI6050 requires external capacitor for stability. It is specifically designed to work with low-ESR capacitors requiring minimum PCB area. Place the external capacitors as close as possible to the device.

Input capacitor

A 1μF or higher capacitance value ceramic capacitor is required between the VIN pin and the GND pin. Place it as close as possible to the device. There are no requirements for the ESR on the input capacitor, but the tolerance and temperature coefficient must be capacitance is 1μF over the whole operating temperature range. The ceramic capacitor with 1μF or larger rating capacitance, X5R or X7R type dielectrics and 0402 or larger size is recommended as input capacitor.

Output capacitor

An output capacitor (C_{OUT}) is needed to improve transient response and maintain stability. The TMI6050 is stable with very small ceramic output capacitors. A 1μF to 10μF capacitor is suitable for the most TMI6050 applications. X5R or X7R type dielectrics and 0402 or larger size is recommended as output capacitor

Feedforward capacitor

As to adjustable output version TMI6050, a feedforward capacitor (C_{FB}) paralleling with high side feedback resistor R1 could help to increase response performance and enhance stability.

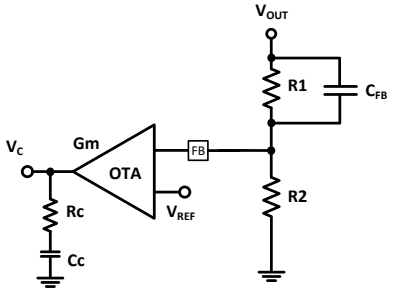


Figure 5. Application Circuits of Feedforward Capacitor C_{FB}

As shown in above figure 5, the effect of feedback dividers and feedforward capacitor (C_{FB}) can be expressed:

$$\frac{\Delta v_{FB}}{\Delta v_{out}} = \left(\frac{R2}{R1+R2}\right) \cdot \frac{1+s \cdot R1 \cdot C_{FB}}{1+s \cdot (R1//R2) C_{FB}} = \frac{V_{REF}}{V_{OUT}} \cdot \frac{1+s \cdot R1 \cdot C_{FB}}{1+s \cdot (R1//R2) C_{FB}}$$

If there is no C_{FB}, the Gain of divider is fixed as V_{REF}/V_{OUT}. C_{FB} introduces a pole and a zero, so the gain and phase of feedback network is changed in high frequency. The below figure 6 shows the loop bode plots of TMI6050 2.5V output with R1=5.1kΩ, R2=2.4kΩ, C_{FB} =2.2nF, C_{OUT}=1μF for example. With C_{FB} =2.2nF, the

cross frequency of control loop increases from 30kHz to 200kHz, while the phase margins of control loop are almost same and the phase margins of two application condition are both larger than 90 deg.

The feedforward capacitor also has effect on output soft start up. During output voltage start up process, the voltage of C_{FB} is charging from 0V to V_{OUT}-V_{REF}. It is help to smooth the sloop rate of output voltage.

For most application, the recommended feedforward capacitance of is C_{FB} from 1nF to 4.7nF and the recommended divider resistance is 1kΩ to 100kΩ for appropriate additional compensation zero and pole.

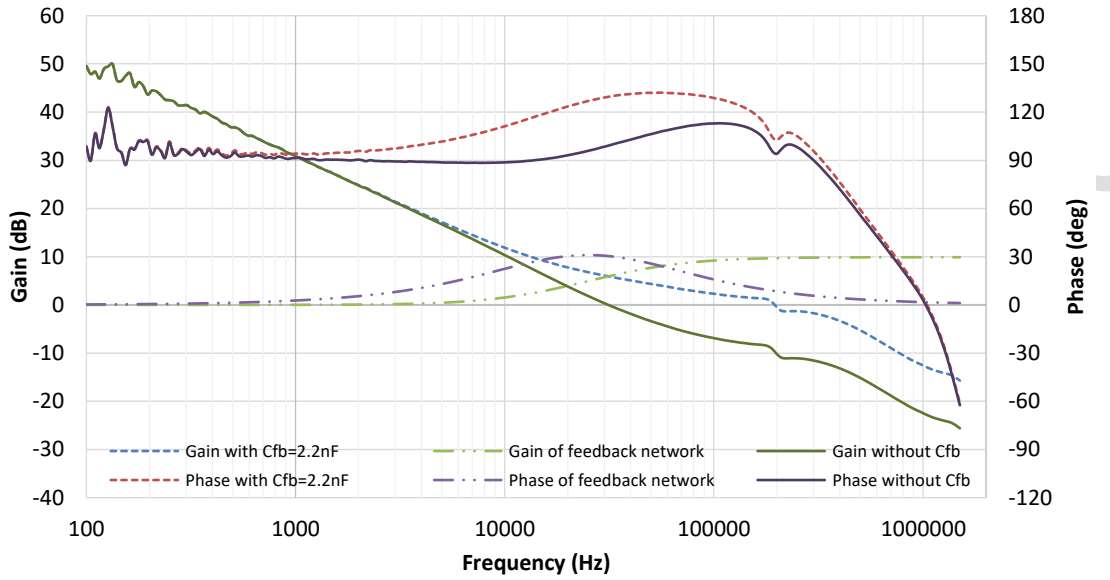


Figure 6. Loop Bode Plots of TMI6050 Adjustable Version with 2.5V Output

Maximum Output Current

The maximum output current of TMI6050 depends on the application conditions. LDO power dissipation PD equals to voltage drop between V_{IN} and V_{OUT} multiplying by output current. The maximum power dissipation of TMI6050 depends maximum operation junction temperature, ambient temperature and thermal resistance θ_{JA} as shown in below equation:

$$P_D=\frac{T_{J\_MAX}-T_A}{\theta_{JA}}$$

Where T_{J_MAX} is 160°C and θ_{JA} is 120°C/W measured on DEMO board with 3cm x 5cm 2-layer PCB, so the maximum power dissipation at T_A=25°C is about 1080mW. The curve of maximum output current with voltage drop between VIN and VOUT is shown in below figure.

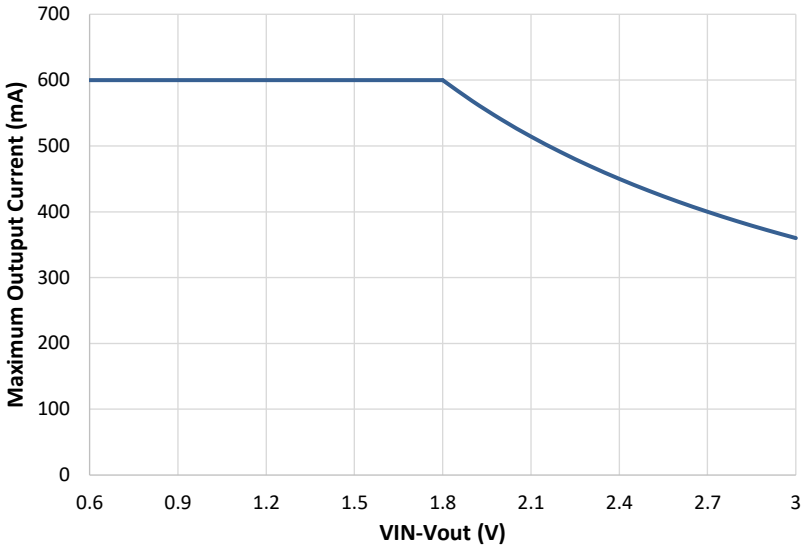
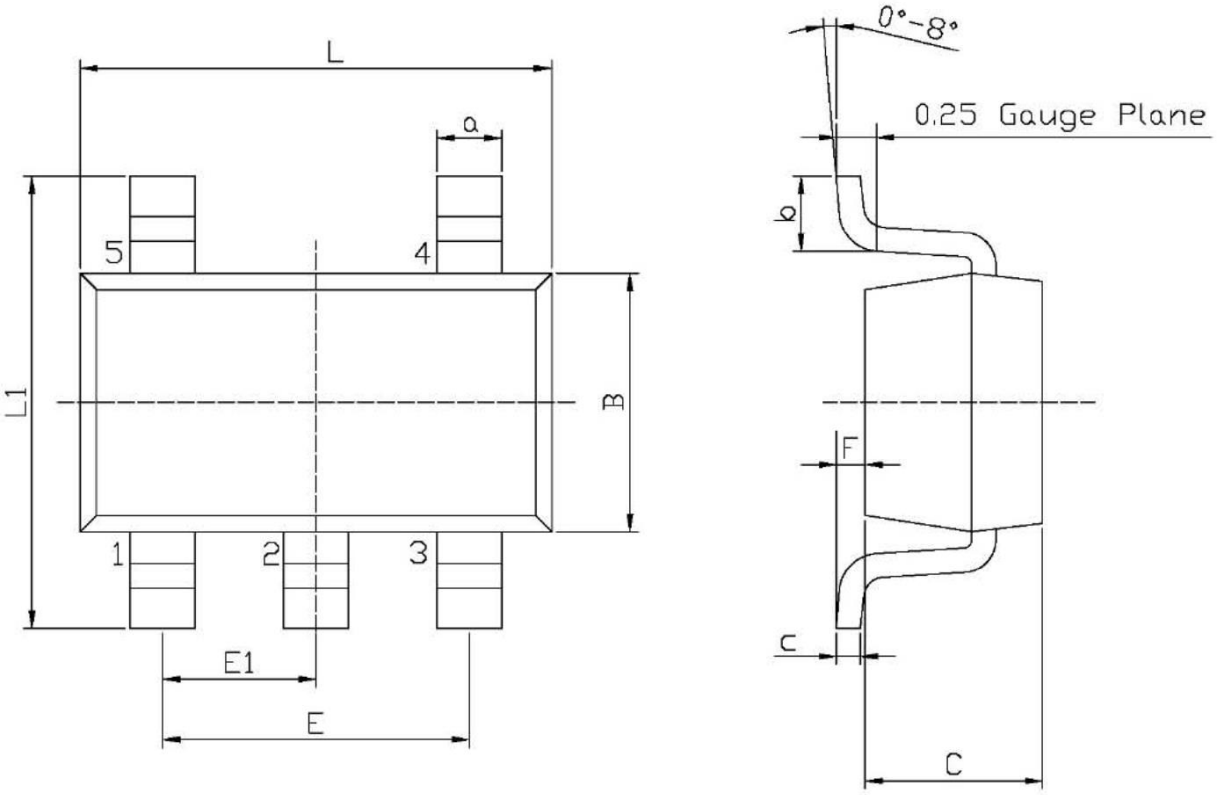


Figure 7. curve of maximum output current vs. V_{IN}-V_{OUT}

With ambient temperature rising, the maximum output current and maximum power dissipation drops down.

PACKAGE INFORMATION

SOT23-5



Unit: mm

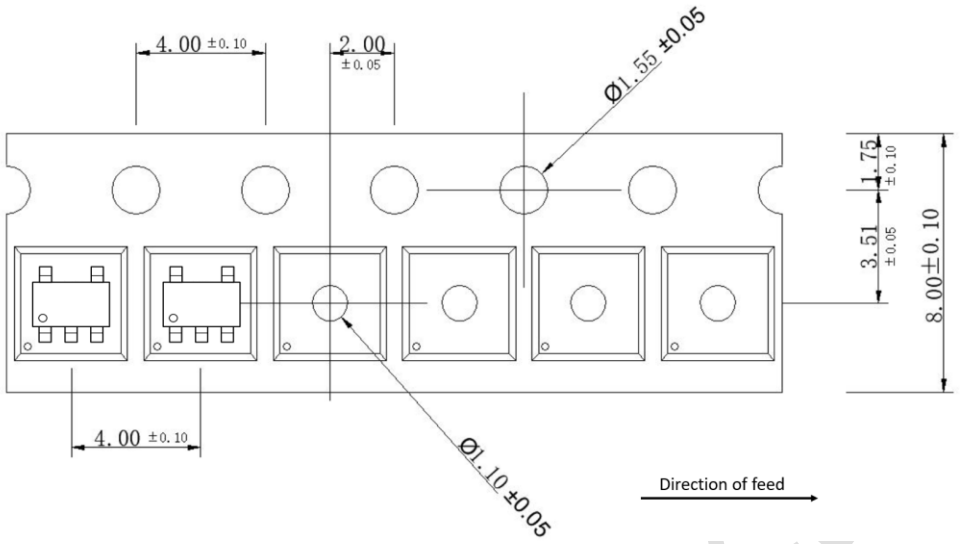
Symbol	Dimensions In Millimeters			Symbol	Dimensions In Millimeters		
	Min	Typ	Max		Min	Typ	Max
L	2.82	2.92	3.02	E1	0.85	0.95	1.05
B	1.50	1.60	1.70	a	0.35	0.425	0.50
C	0.90	1.10	1.30	c	0.10	0.15	0.20
L1	2.60	2.80	3.00	b	0.35	0.45	0.55
E	1.80	1.90	2.00	F	0	0.075	0.15

Note:

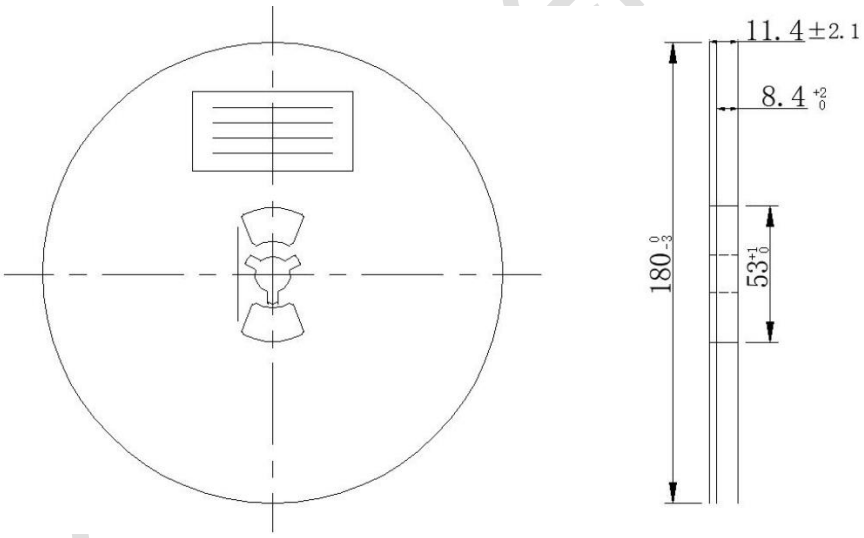
1) All dimensions are in millimeters.
2) Package length does not include mold flash, protrusion or gate burr.
3) Package width does not include inter lead flash or protrusion.
4) Lead popularity (bottom of leads after forming) shall be 0.10 millimeters max.
5) Pin 1 is lower left pin when reading top mark from left to right.

TAPE AND REEL INFORMATION

TAPE DIMENSIONS:



REEL DIMENSIONS:



Note:

1) All Dimensions are in Millimeter
2) Quantity of Units per Reel is 3000
3) MSL level is level 3.