

# 600mA, High PSRR, Fast Response LDO Regulators

## FEATURES

- 2.5V to 5.5V Input Voltage Range
- Up to 600mA output current (Typical) with  $V_{IN}-V_{OUT} \leq 1.8V$  @  $T_A = 25^\circ C$
- 600mV @600mA Dropout Voltage
- Excellent Transient Response
- Stable with 1 $\mu$ F Ceramic Output Capacitor
- 60dB PSRR at 1kHz
- Low 75 $\mu$ A Quiescent Current
- Low Shutdown Current: <1 $\mu$ A
- Output Accuracy:  $\pm 2\%$
- 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 1 $\mu$ F 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 APPLICATION

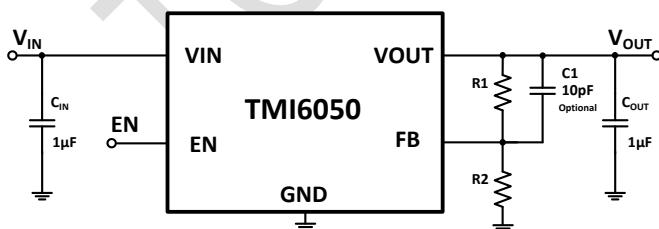


Figure 1. TMI6050 adjustable output Circuit

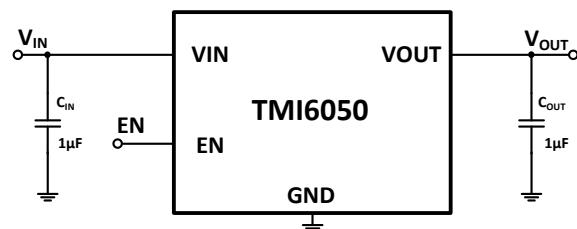


Figure 2. TMI6050 fixed output Circuit

## BLOCK DIAGRAM

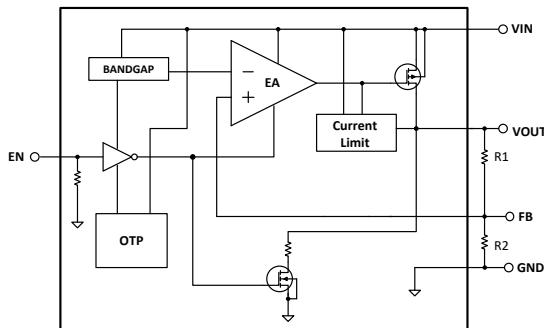


Figure 3. TMI6050 adjustable function block

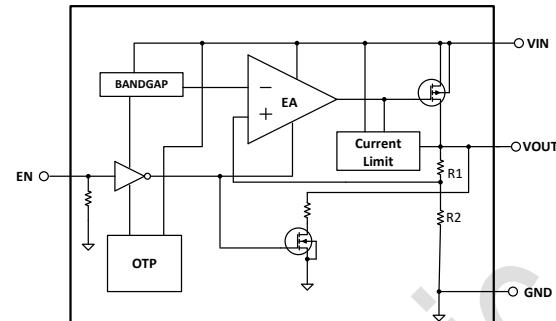


Figure 4. TMI6050 fixed function block

## ABSOLUTE MAXIMUM RATINGS

Description	Value	Unit
VIN, EN Input Voltage Range	-0.3~6	V
All other pins Voltage Range	-0.3 to (VIN+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

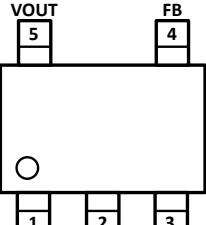
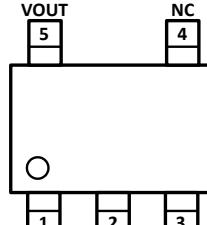
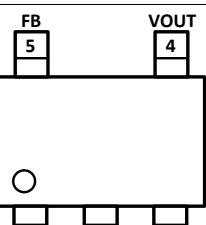
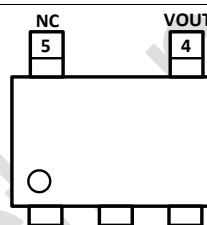
Items	Description	Value	Unit
$V_{ESD\_HBM}$	Human Body Model for all pins	$\pm 2000$	V
$V_{ESD\_CDM}$	Charged Device Model for all pins	$\pm 2000$	V

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

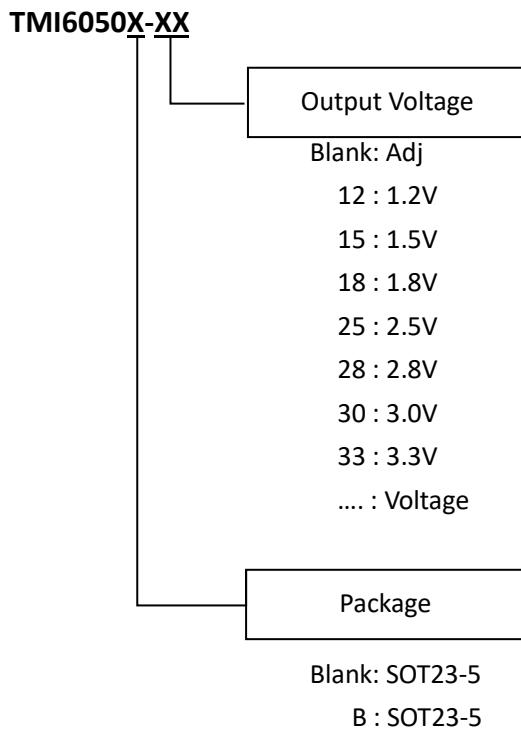
## PIN CONFIGURATION

Package Type	Pin Configurations	
TMI6050 / SOT23-5	 (Adjustable Output Version)	 (Fixed Output Version)
TMI6050B / SOT23-5	 (Adjustable Output Version)	 (Fixed Output Version)

## 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 0.4V to disable the device, connect EN to 1.05V or above 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



**Top Mark: TXXXX (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

$T_A=25^\circ\text{C}$ ,  $V_{IN}=V_{OUT}+1\text{V}$ , or  $V_{IN}=2.5\text{V}$  for  $V_{OUT}<1.5\text{V}$  unless otherwise specified.

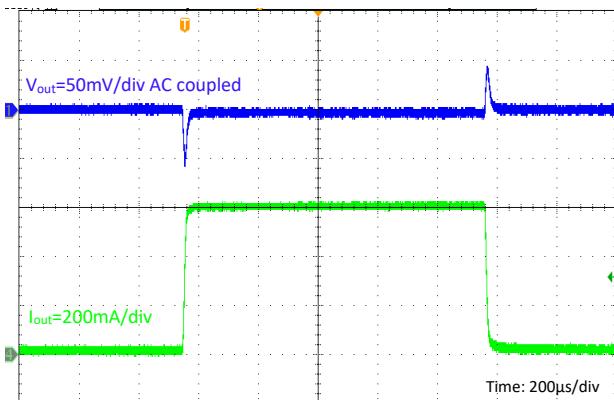
Symbol	Parameter	conditions	Min	Typ	Max	Unit
<b>Input Voltage</b>						
$V_{IN}$	Input Voltage Range		2.5		5.5	V
$I_Q$	Quiescent Current	$V_{EN}=2.5\text{V}$ , $I_{OUT}=0\text{mA}$		75	90	$\mu\text{A}$
$I_{SHDN}$	Shutdown Current	$V_{EN}=0\text{V}$		0.1	1	$\mu\text{A}$
PSRR	Power Supply Ripple Rejection	$V_{IN}=V_{NOM}+1\text{V}_{P-P}$ , $f=1\text{kHz}$ , $I_{LOAD}=10\text{mA}$		60		dB
<b>Enable</b>						
$V_{ENH}$	Enable Input High Voltage	All temperature range	1.05			V
$V_{ENL}$	Enable Input Low Voltage	All temperature range			0.4	V
$I_{EN}$	EN Input Current	$V_{IN}=3.5\text{V}$ , $V_{EN}=3.5\text{V}$ or $0\text{V}$	-1	0.2	1	$\mu\text{A}$
$T_{ST}$	Start-up Time	$V_{IN}=3.5\text{V}$ , $V_{OUT}=2.5\text{V}$		40		$\mu\text{s}$
<b>Output Voltage</b>						
$V_{OUT}$	Output Voltage Accuracy	$V_{IN}=V_{OUT}+1\text{V}$ , $I_{OUT}=10\text{mA}$	-2		+2	%
		$V_{IN}=V_{OUT}+1\text{V}$ , $I_{OUT}=10\text{mA}$ , $T_A=-40^\circ\text{C}$ to $+85^\circ\text{C}$	-3		+3	%
$V_{FB}$	FB Pin Voltage		0.786	0.8	0.816	V
$V_{LNR}$	Output Line Regulation	$V_{OUT}+0.5\text{V} < V_{IN} < 5.5\text{V}$ , $I_{OUT}=10\text{mA}$		0.01	0.1	%/V
$V_{LDR}$	Output Load Regulation	$2\text{mA} < I_{OUT} < 600\text{mA}$ , $V_{IN}=V_{NOM}+1.0\text{V}$			12	mV
$V_{DROP}$	Dropout Voltage (Note 3)	$I_{OUT}=600\text{mA}$		600	700	mV
$I_{OUTMAX}$	Maximum Output Current	$V_{IN}=V_{OUT}+1\text{V}$	600			mA
<b>Protection</b>						
$I_{limit}$	Current Limit		650	800		mA
$I_{short}$	Output Short Current Limit	$V_{FB}$ or $V_{OUT}=0\text{V}$		150		mA
$R_{AD}$	Resistance of Auto-Discharge			130		$\Omega$
$T_{SD}$	Thermal Shutdown Temperature	No Load, $V_{IN}=V_{EN}=5\text{V}$		160		$^\circ\text{C}$
$T_{SDHYS}$	Thermal Shutdown Hysteresis	No Load, $V_{IN}=V_{EN}=5\text{V}$		20		$^\circ\text{C}$

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

## TYPICAL PERFORMANCE CHARACTERISTICS

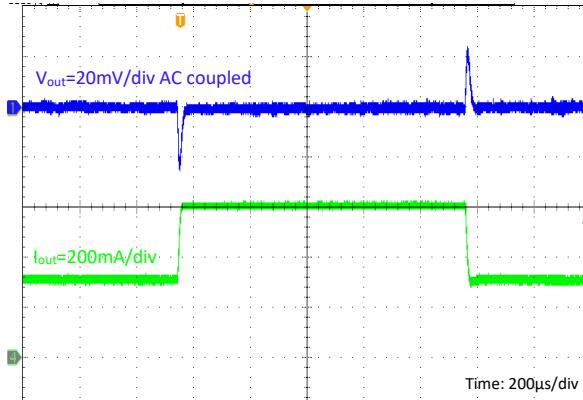
### Load Transient

V<sub>in</sub>=4V, V<sub>o</sub>=3.3V, I<sub>o</sub>=10mA to 600mA



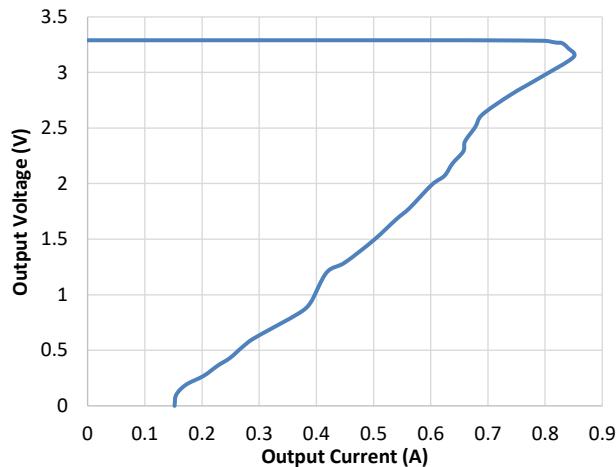
### Load Transient

V<sub>in</sub>=4V, V<sub>o</sub>=3.3V, I<sub>o</sub>=300mA to 600mA



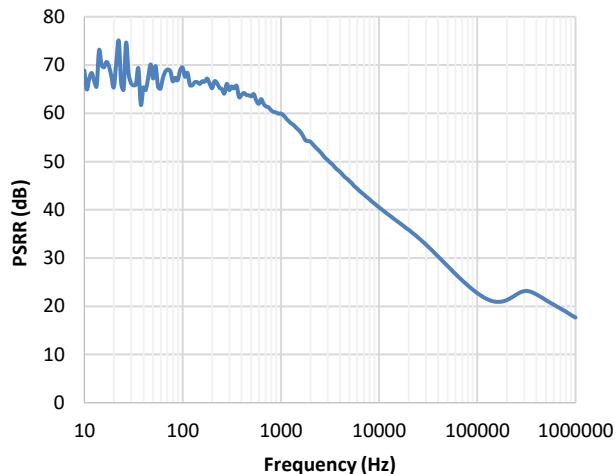
### Over Current Protection

V<sub>in</sub>=5V, V<sub>o</sub>=3.3V, T<sub>a</sub>=25°C



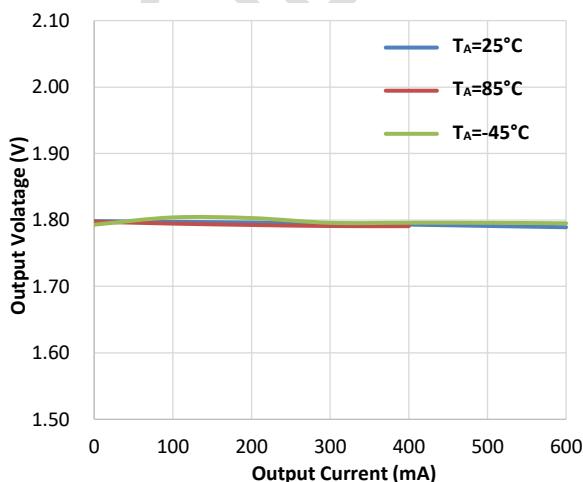
### PSRR vs Frequency

V<sub>in</sub>=5V, V<sub>o</sub>=3.3V, I<sub>o</sub>=10mA, T<sub>a</sub>=25°C



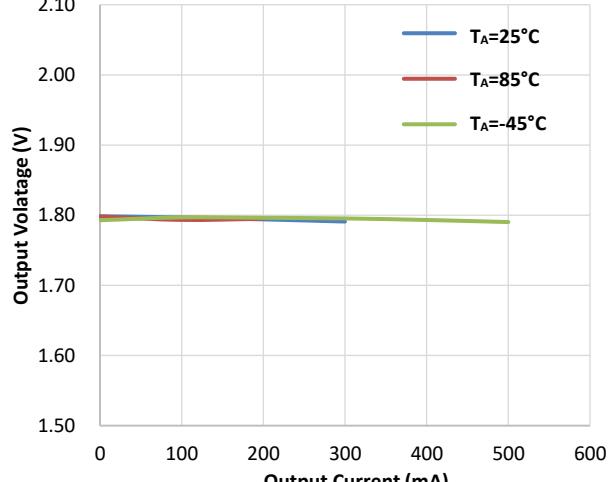
### Load Regulation

V<sub>in</sub>=3.3V, V<sub>o</sub>=1.8V



### Load Regulation

V<sub>in</sub>=5V, V<sub>o</sub>=1.8V



## 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 1 $\mu$ F 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<sub>OUT</sub> pin.

### Enable/Shutdown

The TMI6050 is disabled when the EN pin is connected to ground or the voltage less than 0.4V, and the quiescent current is less than 1 $\mu$ A. Connect EN pin to 1.05V or higher voltage to enable the device. This pin cannot be floated.

### Output Auto Discharge

When the regulator is disabled, an internal 130 $\Omega$  resister is connected between V<sub>OUT</sub> and GND to discharge output capacitor C<sub>OUT</sub>.

### 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:

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

Where V<sub>REF</sub> is the internal reference voltage, which is 0.8V in TMI6050.

### Short Circuit Protection

When V<sub>OUT</sub> 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.

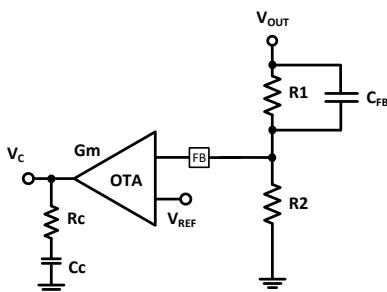


Figure 5. Application Circuits of Feedforward Capacitor  $C_{FB}$

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

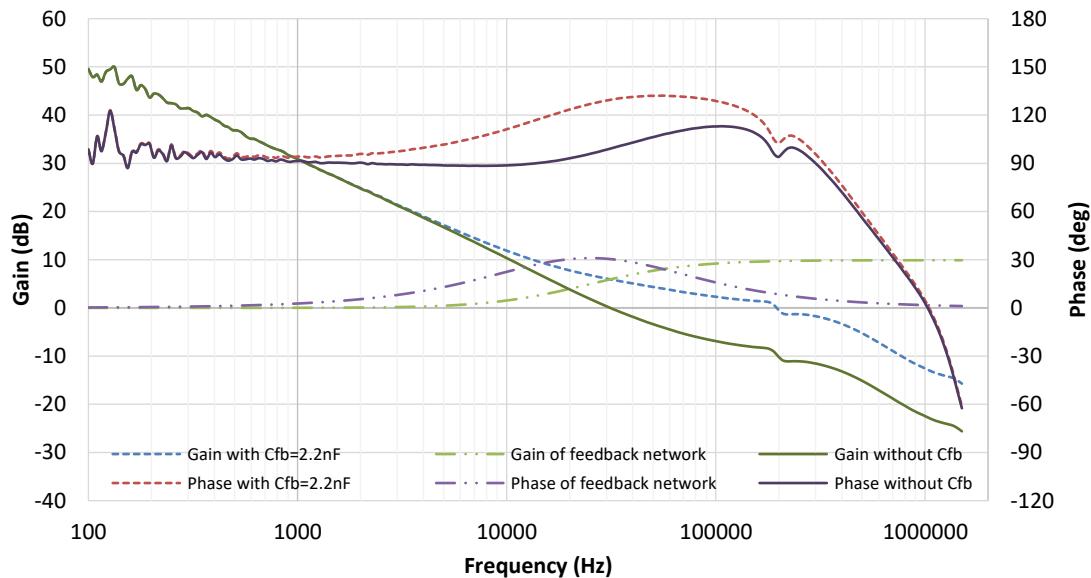
$$\frac{\Delta V_{FB}}{\Delta V_{out}} = \left( \frac{R2}{R1+R2} \right) \cdot \frac{1+s \cdot R1 \cdot C_{FB}}{1+s \cdot (R1//R2)C_{FB}} = \frac{V_{REF}}{V_{OUT}} \cdot \frac{1+s \cdot R1 \cdot C_{FB}}{1+s \cdot (R1//R2)C_{FB}}$$

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  $R1=5.1k\Omega$ ,  $R2=2.4k\Omega$ ,  $C_{FB}=2.2nF$ ,  $C_{OUT}=1\mu F$  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 slope 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 1k $\Omega$  to 100k $\Omega$  for appropriate additional compensation zero and pole.



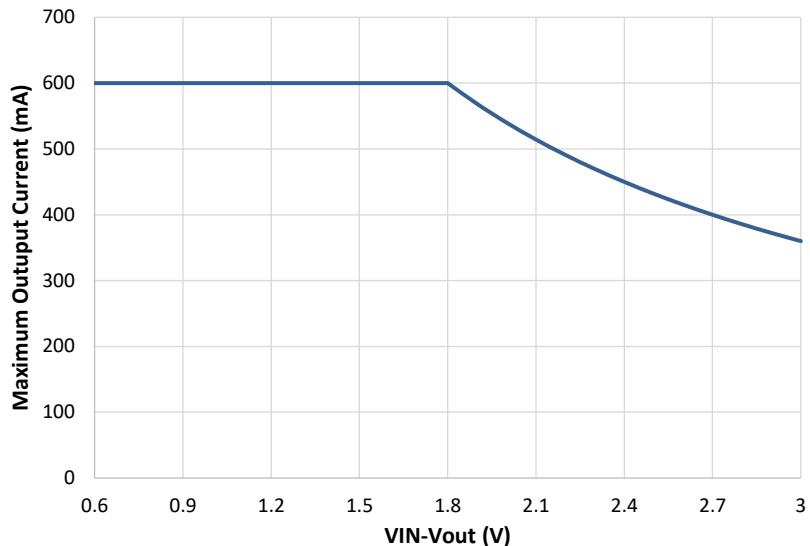
**Figure 6. Loop Bode Plots of TMI6050 Adjustable Version with 2.5V Output**

### Maximum Output Current

The maximum output current of TMI6050 depends on the application conditions. LDO power dissipation  $P_D$  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  $\theta_{JA}$  as shown in below equation:

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

Where  $T_{J\_MAX}$  is 160°C and  $\theta_{JA}$  is 120°C/W measured on DEMO board with 3cm x 5cm 2-layer PCB, so the maximum power dissipation at  $T_A=25^\circ\text{C}$  is about 1080mW. The curve of maximum output current with voltage drop between  $V_{IN}$  and  $V_{OUT}$  is shown in below figure.

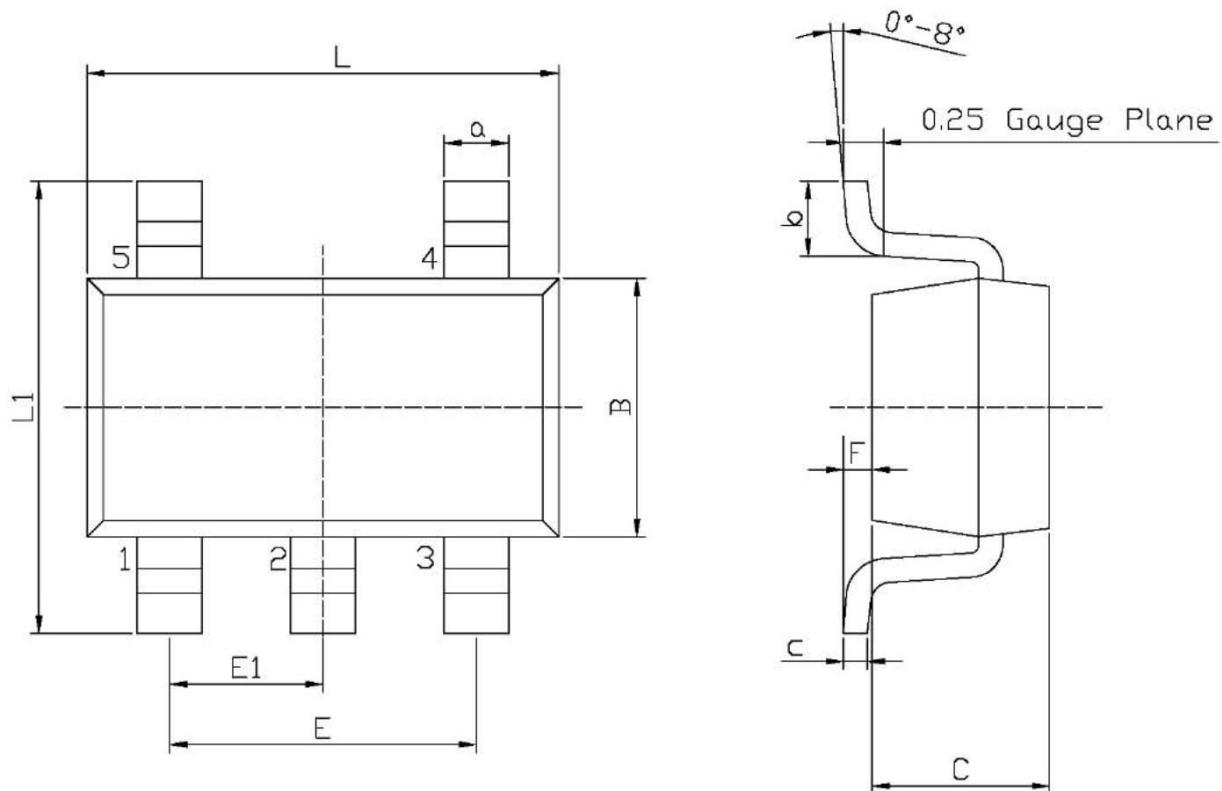


**Figure 7. curve of maximum output current vs. V<sub>IN</sub>-V<sub>OUT</sub>**

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

## PACKAGE INFORMATION

SOT23-5



Unit: mm

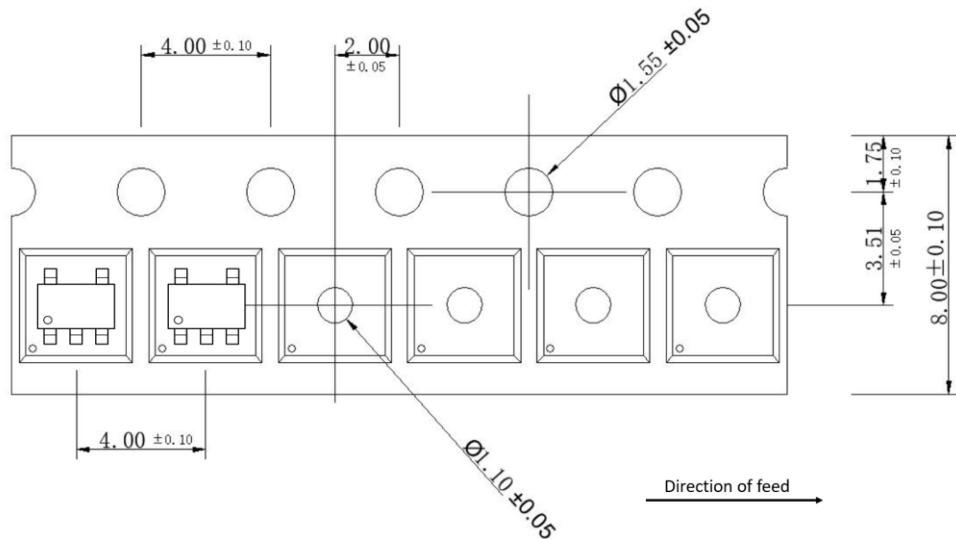
Symbol	Dimensions In Millimeters			Symbol	Dimensions In Millimeters		
	Min	Typ	Max		Min	Typ	Max
L	2.82	2.92	3.02	E1	0.85	0.95	1.05
B	1.50	1.60	1.70	a	0.35	0.425	0.50
C	0.90	1.10	1.30	c	0.10	0.15	0.20
L1	2.60	2.80	3.00	b	0.35	0.45	0.55
E	1.80	1.90	2.00	F	0	0.075	0.15

### Note:

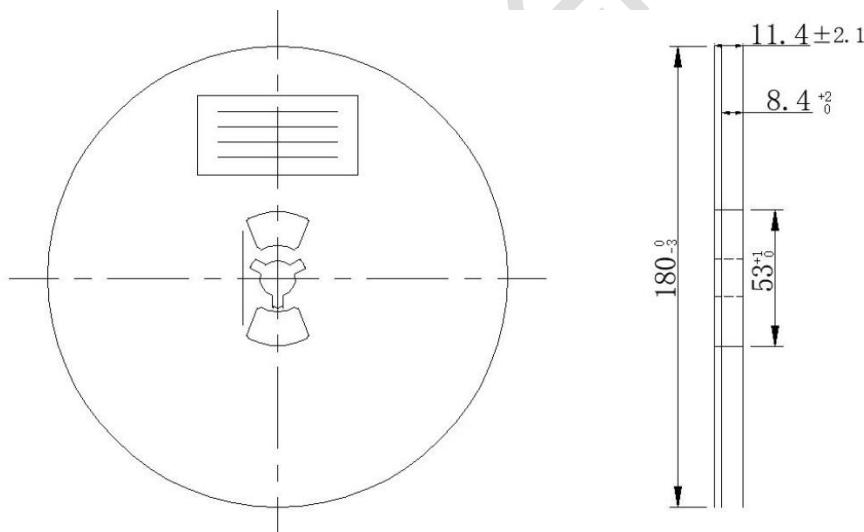
- 1) All dimensions are in millimeters.
- 2) Package length does not include mold flash, protrusion or gate burr.
- 3) Package width does not include inter lead flash or protrusion.
- 4) Lead popularity (bottom of leads after forming) shall be 0.10 millimeters max.
- 5) Pin 1 is lower left pin when reading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