600KHz, 18V, 3A Synchronous COT Step-Down Converter

Features

- 70mΩ/35mΩ Low RDS(ON) Internal FETs
- High Efficiency Synchronous-Mode Operation
- 4.5V to 18V Input Voltage Range
- Output Voltage From:
  0.8V (HCR3153M)
  0.6V (HCR3153S)
  0.765V (HCR3153T)
- 600KHz Switch Frequency
- Up to 3A, 3.5A@1.2V Output Current
- COT Control to achieve fast transient responses
- Power Save Mode at Light Load
- Integrated internal compensation
- Stable with Low ESR Ceramic Output Capacitors
- Over Current Protection With Hiccup-Mode
- Thermal Shutdown
- Inrush Current Limit and Soft Start
- Build in Input Over Voltage Protection(OVP)

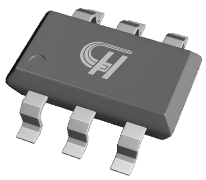
Applications

- Digital Set Top Boxes
- Flat Panel Television & Monitors
- Notebook Computer
- Wireless and DSL Modems

General Description

The HCR3153M/S/T is a high efficiency 600KHz Constant on-Time(COT) control mode synchronous step-down DC-DC converter capable of delivering up to 3A current. HCR3153M/S/T integrates main switch and syschronous switch with very low $R_{DS(ON)}$ to minimize the conduction loss. Low output voltage ripple and small external inductor and capacitor size are achieved with 600KHz switching frequency.It adopts the COT architecture to achieve fast transient responses for high voltage step down applications.

The HCR3153M/S/T requires a minimum number of readily available standard external components and is available in a TSOP-6 (SOT23-6L) ROHS compliant package.



TSOP-6 (SOT23-6L)

Figure 1. Package Type of HCR3153M/S/T

Pin Configuration

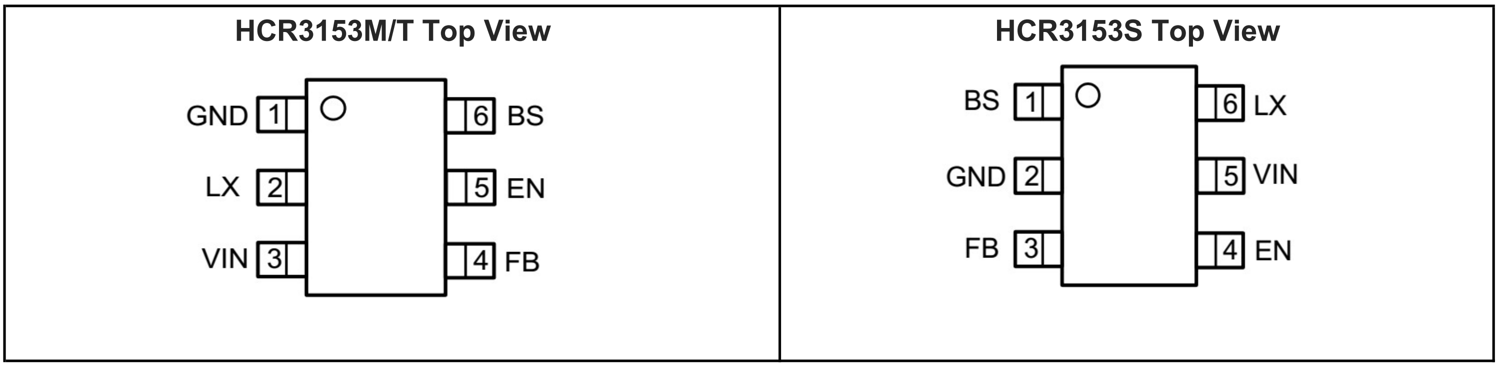
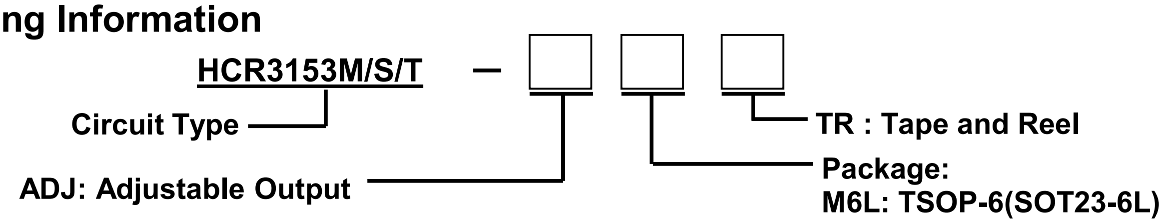


Figure 2. Pin Configuration of TSOP-6 (SOT23-6L) (Top View)

Pin Function Table

HCR3153M/T	HCR3153S	Pin Name	Function
1	2	GND	Ground Pin
2	6	LX	Power Switch Output. It is the switch node connection to inductor. This pin connects to the drains of the internal P-ch and N-ch MOSFET switches.
3	5	VIN	Power Supply input pin.
4	3	FB	Output Voltage Feedback input. Connect FB to the center point of the external resistor divider.
5	4	EN	Drive EN pin to a logic-high to enable the IC. Drive EN pin to a logic-Low to disable the IC and enter micro-power shutdown mode. Don't floating EN.
6	1	BS	Bootstrap. A capacitor connected between LX and BS pins is required to form a floating supply across the high-side switch driver.

Ordering Information



Ordering Code

Part Number	Marking ID note2	Temperature Junction Range	Package	Quantity per Reel
HCR3153M-ADJM6LTR	TM3XXX	-40'C to +125'C	TSOP-6 (SOT23-6L)	3000pcs/TR
HCR3153S-ADJM6LTR	TS3XXX	-40'C to +125'C	TSOP-6 (SOT23-6L)	3000pcs/TR
HCR3153T-ADJM6LTR	TT3XXX	-40'C to +125'C	TSOP-6 (SOT23-6L)	3000pcs/TR

note 2. the TM3/TT3/TS3 is device code. The XXX is inside code.

Absolute Maximum Ratings Note 1

Parameter	Symbol	Value	Unit
Input Supply Voltage Range	V_{IN}	-0.3 to +20.0	V
LX Voltage Range	V_{LX}	-0.3 to +20.0	V
EN Voltage Range	V_{EN}	-0.3 to +20.0	V
FB Voltage Range	V_{FB}	-0.3 to +6.0	V
BS Voltage Range	V_{BS}	-0.6 to +23.0	V
Power Dissipation	P_O	1000	mW
Thermal Resistance Junction to Ambient	$R_{\theta JA}$	100	'C/W
Thermal Resistance Junction to Case	$R_{\theta JC}$	56	'C/W
Storage Temperature Range	T_{STG}	-65 to +150	'C
Operating Junction Temperature	T_J	-40 to +125	'C
Lead Temperature (Soldering, 10s)	T_{LEAD}	260	'C
Human Body Model for all pins	V_{ESD_HBM}	±2000	V
Charge Device Model for all pins	V_{ESD_CDM}	±2000	V

Note 1: Stresses beyond those listed under"Absolute maximum Ratings" may damage the device.

2: The device is not guaranteed to function outside the recommended operating conditions.

Recommended Operating Conditions

Parameter	Symbol	Test Condition	Min	Type	Max	Unit
Input Voltage Range	V_{IN}	-	4.5	-	+18	V
Operating Junction Temperature Range	T_J	-	-40	-	+125	'C

Electrical Characteristics

(VIN=12V, VOUT=3.3V, TA=25'C, unless otherwise noted.)

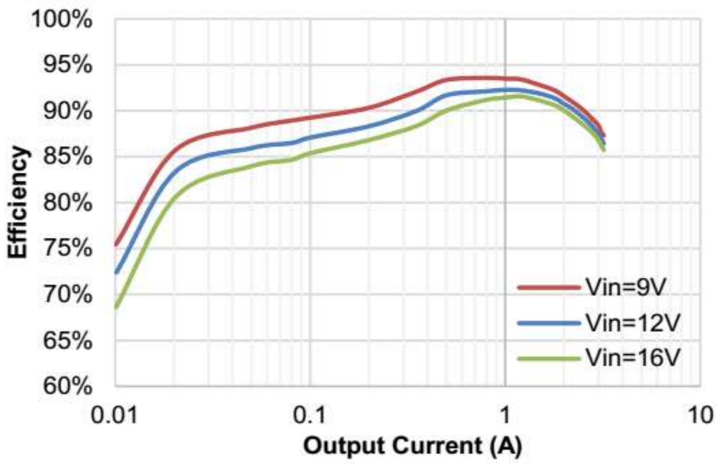
Parameter	Symbol	Test Condition	Min	Type	Max	Unit
Input Voltage Range	V_{IN}		4.5	-	18	V
Input OVP Threshold	V_{OVP}		18.7	19.3	19.8	V
UVLO Rising Threshold	V_{UVLO}		4.0	4.2	4.35	V
UVLO Hysteresis	V_{UVLOH}		0.4	0.45	0.5	V
Quiescent Current	I_Q	V_{EN}=2.0V, V_{FB}=V_{REF}X105%	-	300	-	uA
Shutdown Current	I_{SHDN}	V_{IN}=12V, V_{EN}=0V	-	5	10	uA
Regulated Feedback Voltage (HCR3153M)	V_{REF1}	T_A=25'C, 4.5V<V_{IN}<18V	0.784	0.800	0.816	V
Regulated Feedback Voltage (HCR3153S)	V_{REF2}	T_A=25'C, 4.5V<V_{IN}<18V	0.588	0.600	0.612	V
Regulated Feedback Voltage (HCR3153T)	V_{REF3}	T_A=25'C, 4.5V<V_{IN}<18V	0.750	0.765	0.780	V
High-Side Switch On Resistance	$R_{DS(ON)1}$		-	70	-	mΩ
Low-Side Switch On Resistance	$R_{DS(ON)2}$		-	35	-	mΩ
High-Side Switch Leakage Current	I_{LX_LC}	V_{EN}=0V, V_{LX}=0V	1	-	10	uA
Switch Valley Current Limit	I_{LIM}	Minimum Duty Cycle	3.7	4.0	4.5	A
On-Time	T_{ON}	V_{IN}=12V,V_{OUT}=1.2V, I_{OUT}=1A	132	166	200	nS
Oscillation Frequency	F_{OSC}		500	600	700	KHz
Maximum Duty Cycle	η		-	90	-	%
Minimum On-Time	T_{ON}		70	80	100	nS
Soft Start Time	T_{start}		0.7	1.0	1.3	mS
Hiccup on Time	T_{HOT}		-	1.2	-	mS
Hiccup Time Before Restart	T_{HTBR}		-	3.6	-	mS
EN Rising Threshold	V_{EN-R}		0.85	0.95	1.05	V
EN Falling Threshold	V_{EN-F}		0.75	0.85	0.95	V
EN Hysteresis	V_{EN_Hy}		-	100	-	mV
Thermal Shutdown Threshold [note3]	T_{SHDN}		-	165	-	'C
Thermal Shutdown Hysteresis[note3]	T_{HYTS}		-	30	-	'C

Note 3. Guaranteed by design.

Typical Performance Characteristics

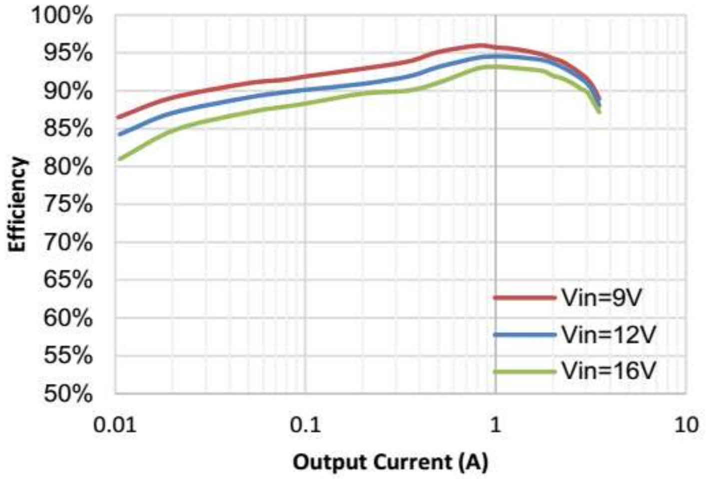
Efficiency

V_{OUT} =3.3V, L=4.7μH, DCR=30mΩ



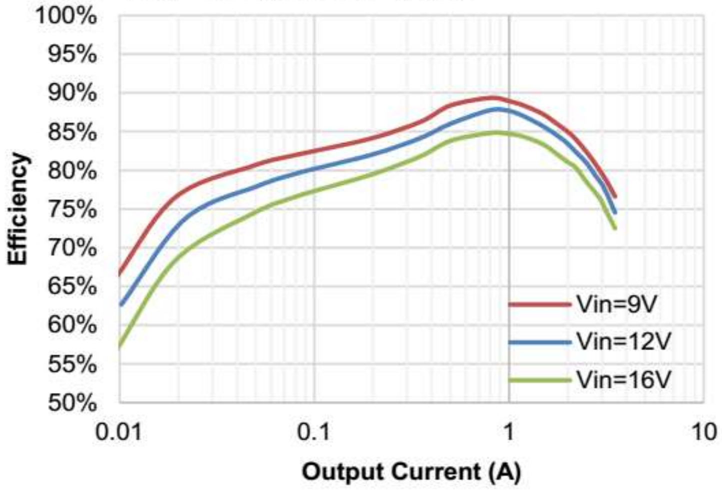
Efficiency

V_{OUT} =5V, L=4.7μH, DCR=30mΩ



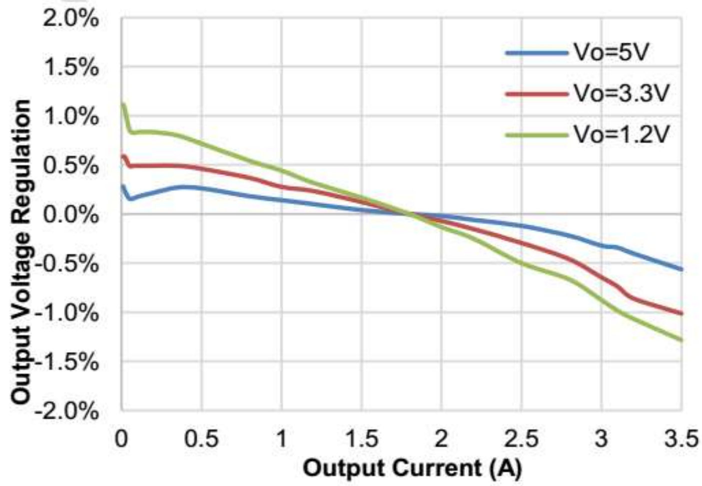
Efficiency

V_{OUT}=1.2V, L=2.2μH, DCR=20mΩ



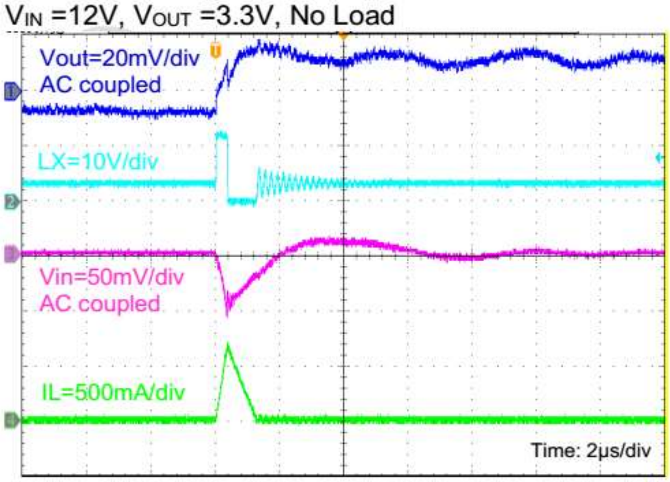
Load Regulation

V_{IN}=12V, T_A=25°C



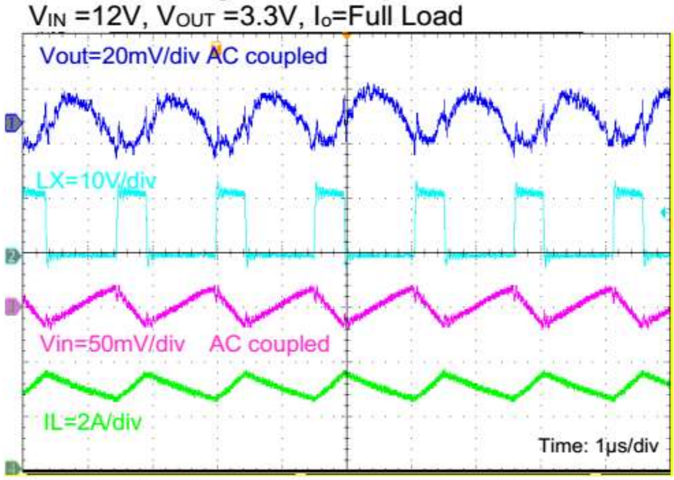
Steady State Operation

V_{IN} =12V, V_{OUT} =3.3V, No Load



Steady State Operation

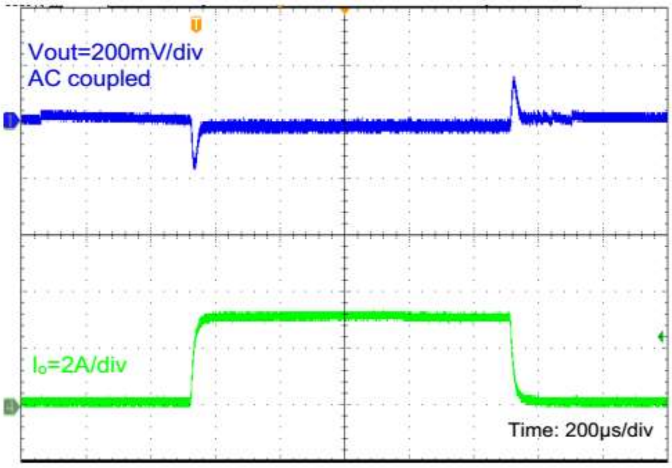
V_{IN} =12V, V_{OUT} =3.3V, I_o=Full Load



Typical Performance Characteristics(Con.)

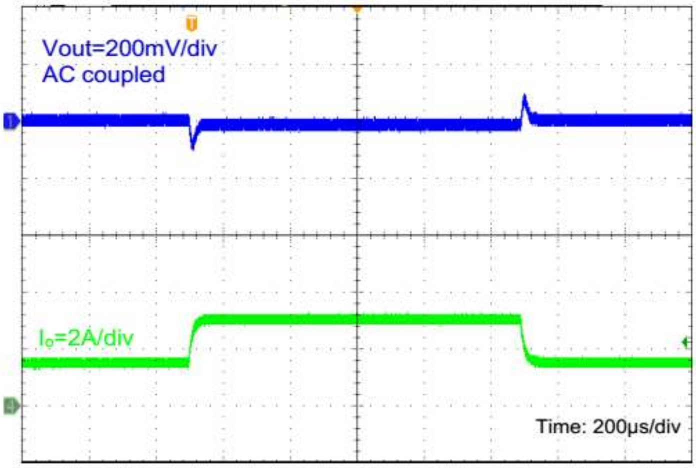
Load Transient

V_{IN} =12V, V_{OUT} =3.3V, I_o =0A to 3A



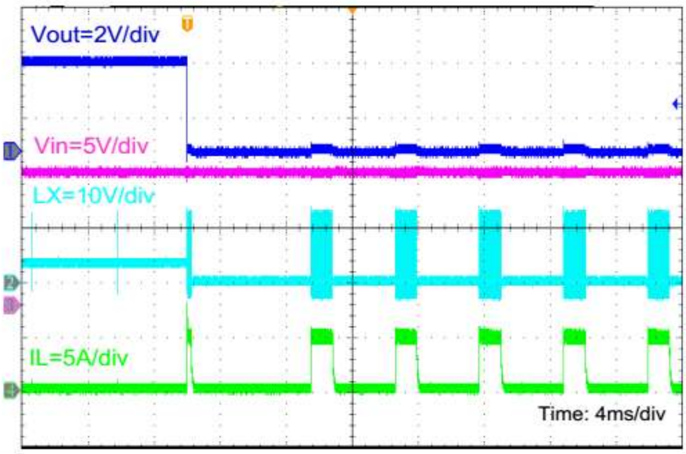
Load Transient

V_{IN} =12V, V_{OUT} =3.3V, I_o =1.5A to 3A



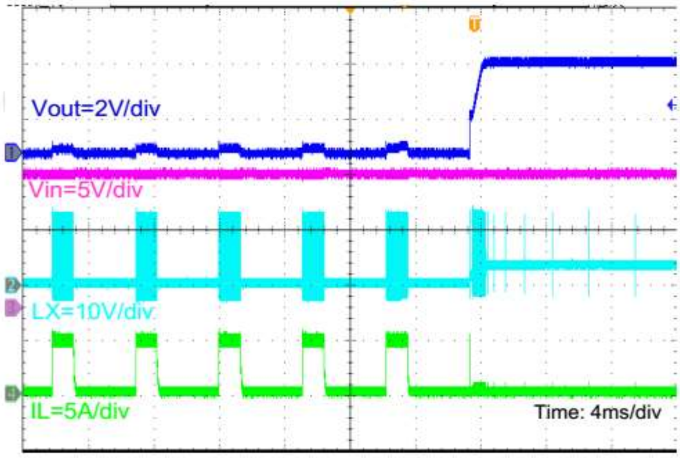
Output Short Entry

V_{IN} =12V, V_{OUT} =3.3V, No Load



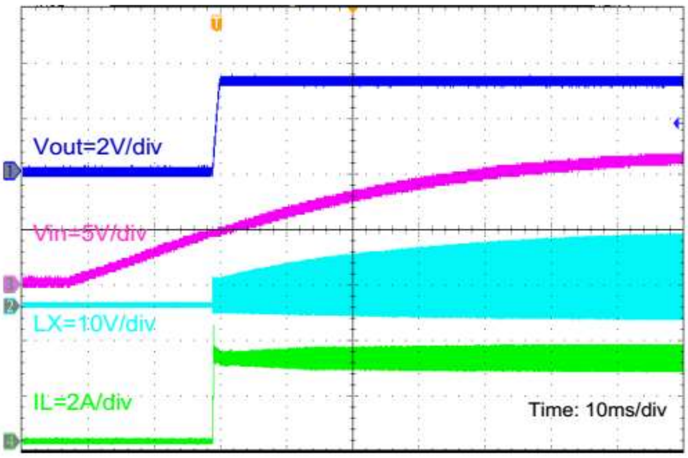
Output Short Recovery

V_{IN}=12V, V_{OUT} =3.3V, No Load



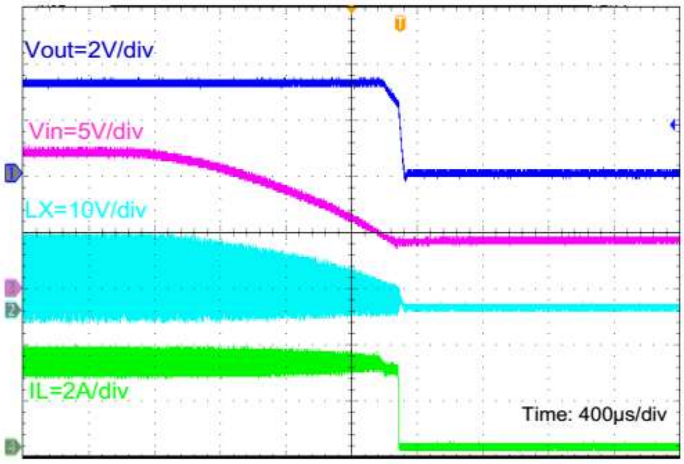
Input Power On

V_{IN} =12V, V_{OUT} =3.3V, I_o =Full Load



Input Power Down

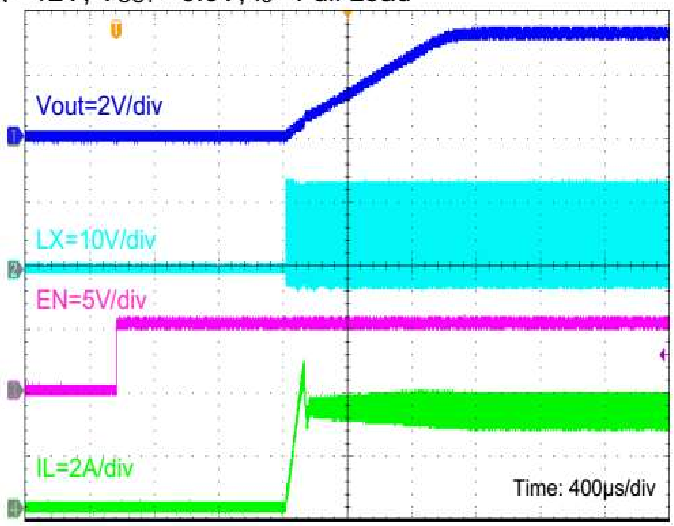
V_{IN} =12V, V_{OUT} =3.3V, I_o =Full Load



Typical Performance Characteristics(Con.)

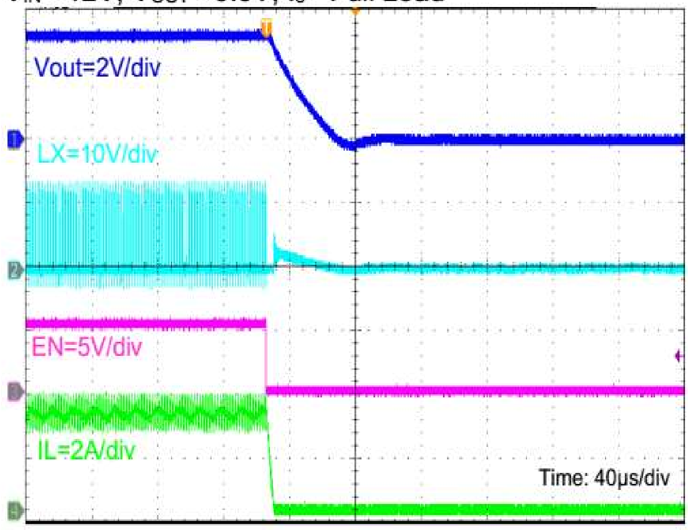
EN Enable

V_{IN} =12V, V_{OUT} =3.3V, I_o =Full Load



EN Disable

V_{IN} =12V, V_{OUT} =3.3V, I_o =Full Load



Functional Block Diagram

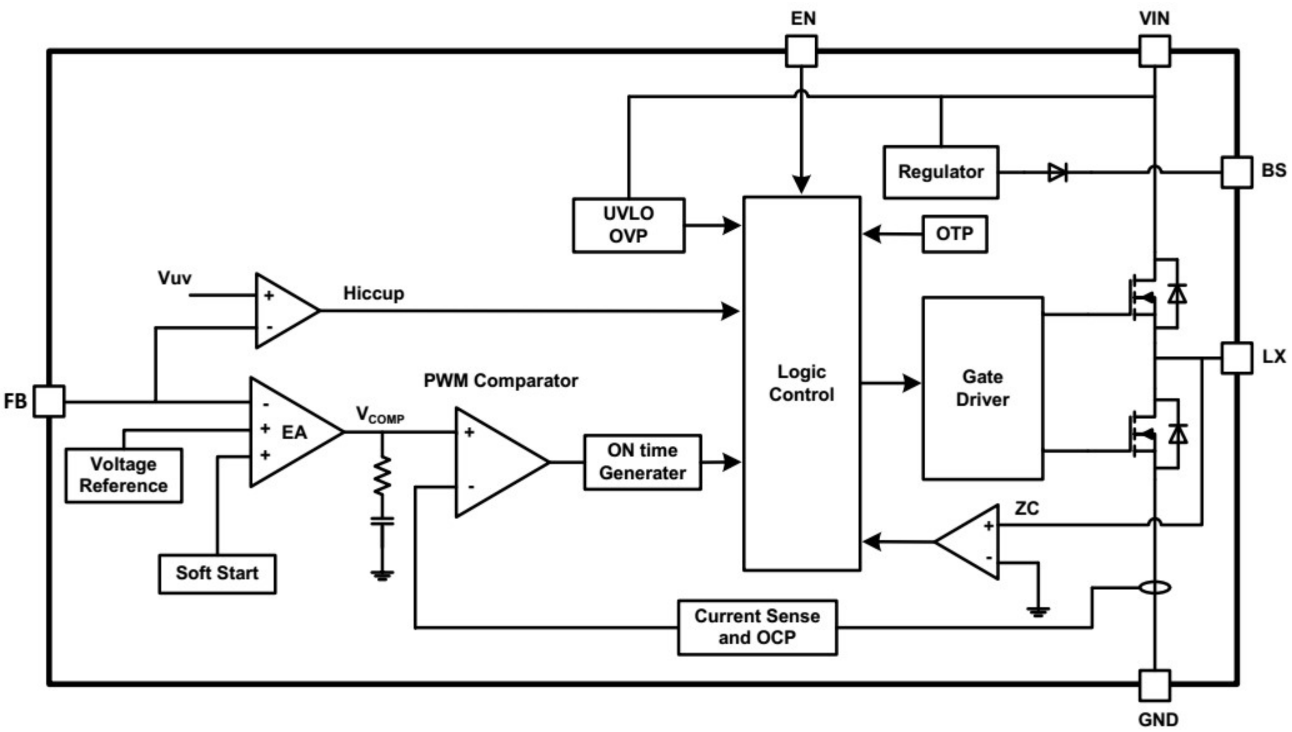


Figure 3. Functional Block Diagram of HCR3153M/S/T

Operation Description

Internal Regulator

The HCR3153M/S/T is a constant on-time(COT) step down DC/DC converter that provides excellent transient response with no extra external compensation components.This device contains low resistance, high voltage high side and low side power MOSFETs and operates at 600KHz operating frequency to ensure a compact, high efficiency design with excellent AC and DC performance.

Error Amplifier

The HCR3153M/S/T adopts operational transcondu--ctance amplifier(OTA) as error amplifier. The error amplifier compares the FB pin voltage with the internal FB reference (V_{REF}) and outputs a current proportional to the difference between the two. This output current is then used to charge or discharge the internal compensation network to form the V_{COMP} voltage, which is used to compare with the low side power MOSFET current sensing signal and trigger on time pulse. The optimized internal compensation network minimizes the external component counts and simplifies the control loop design.

Internal Soft-Start

The soft-start is implemented to prevent the converter output voltage from overshooting during startup.When the chip starts, the internal circuitry generates a soft-start voltage(SS) ramping up from 0V to VREF. When it is lower than the internal FB refernce(VREF),SS over rides REF so the error amplifier uses SS as the reference.When SS is higher than VREF, VREF regains control.The SS time is internally fixed to 1ms typically.

OCP and Short Circuit Protection

The HCR3153M/S/T has cycle-by-cycle valley current limit function. when the inductor current valley value is larger than the valley current limit during low side MOSFET on state, the device enters into valley over current protection mode and low side MOSFET keeps equal or lower than the valley current limit, and then on time pulse could be generated and high side MOSFET could turn on again. If the output is short to GND and the output voltage drop until feedback voltage VFB is below the output under-voltage VUV threshold which is typically 55% of V_{REF}, The HCR3153M/S/T enters into hiccup mode to periodically disable and restart switching operation. The hiccup mode helps to reduce power dissipation and thermal rise during ouput short condition. The period of HCR3153M/S/T hiccup mode is typically 4.8ms.

Start up and Shutdown

If both V_{IN} and EN are higher than their appropriate thresholds, the chip starts switching operation. the reference block starts first,generating stable reference voltage and currents, and then the internal regulator is enabled. The regulator provides stable supply for the remaining circuits. Three events can shutdown the chip:EN low. VIN low and thermal shutdown. In the shutdown procedure, the signaling path is first blocked to avoid any fault triggering. The V_{COMP} voltage and the internal supply rail are then pulled down. The floating driver is not subject to this shutdown command.

Application Information

Setting the Output Voltage

The external resistor divider is used to set the output voltage(see Figure 4).The feedback resistor R1 also sets the feedback loop bandwidth with the internal compensation capacitor. Choose R1 to be around 39KΩ for optimal transient response. R2 is then given by:

$$R_2 = \frac{R_1}{V_{out}/V_{FB} - 1}$$

Use a T-type network for when VOUT is low.

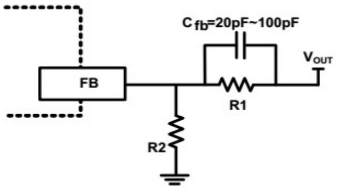


Table 1:

Selection for common output voltage(VFB=0.8V)

VOUT(V)	R1(KΩ)	R2(KΩ)	CFB(pF)	L(uH)
5.0	39	7.43	33	4.7
3.3	39	12.5	33	4.7
2.5	39	18.3	33	3.3
1.8	39	31.2	33	2.2
1.5	39	44.6	33	2.2
1.2	39	78	33	1.5
1.0	18	72	33	1.0

Inductor Selection

A DC current rating of at least 25% percent higher than the maximum load current is recommended for most applications. Inductance value is related to inductor ripple current value, input voltage, output voltage setting and switching frequency. The inductor value can be derived from the following equation:

$$L = \frac{V_{OUT} \times (V_{IN} - V_{OUT})}{V_{IN} \times \Delta I_L \times f_{OSC}}$$

Where ΔIL is inductor ripple current. Large value inductors result in lower ripple current & small value inductors result in high ripple current, So inductor value has effect on output voltage ripple value. DC resistance of inductor which has impact on efficiency of DC/DC converter should be taken into account when selecting the inductor.

The maximum inductor peak current is:

$$I_{L(MAX)} = I_{LOAD} + \frac{\Delta I_L}{2}$$

Under light load conditions below 100mA, larger inductance is recommended for improved efficiency.

Output Capacitor Selection

The output capacitor (Co1 and Co2) is required to maintain the DC output voltage. Ceramic tantalum, or low ESR electrolytic capacitors are recommended. Low ESR capacitors are preferred to keep the output voltage ripple low. The output voltage ripple can be estimated by:

$$\Delta V_{OUT} = \frac{V_{OUT}}{f_S \times L} \times \left[1 - \frac{V_{OUT}}{V_{IN}}\right] \times \left[R_{ESR} + \frac{1}{8 \times f_S \times C_2}\right]$$

where L is the inductor value and RESR is the equivalent series resistance(ESR) value of the output capacitor. In the case of ceramic capacitors, the impedance at the switching frequency is dominated by the capacitance.

the output voltage ripple is mainly caused by the capacitance. For simplification, the output voltage ripple can be estimated by:

$$\Delta V_{OUT} = \frac{V_{OUT}}{8 \times f_S^2 \times L \times C_2} \times \left[1 - \frac{V_{OUT}}{V_{IN}}\right]$$

In the case of tantalum or electrolytic capacitors, the ESR dominates the impedance at the switching frequency. For simplification, the output ripple can be approximated to:

$$\Delta V_{OUT} = \frac{V_{OUT}}{f_S \times L} \times \left[1 - \frac{V_{OUT}}{V_{IN}}\right] \times R_{ESR}$$

The characteristics of the output capacitor also affect the stability of the regulation system. the HCR3153M/S/T can be optimized for a wide range of capacitance and ESR values.

Layout Consideration

when laying out the printed circuit board, the following checking should be used to ensure proper operation of the HCR3153M/S/T. Check the following in your layout:

1.1) Keep the path of switching current short and minimize the loop area formed by input capacitor, IN pin and GND.

1.2) Bypass ceramic capacitors are suggested to be put close to the IN Pin.

1.3) Ensure all feedback connections are short and direct. Place the feedback resistors as close to the chip as possible.

1.4)VOUT, LX away from sensitive analog areas as FB.

1.5)Connect IN, LX, and especially GND respectively to a large copper area to cool the chip to improve thermal performance and long-term reliability.

Typical Application Circuit-1

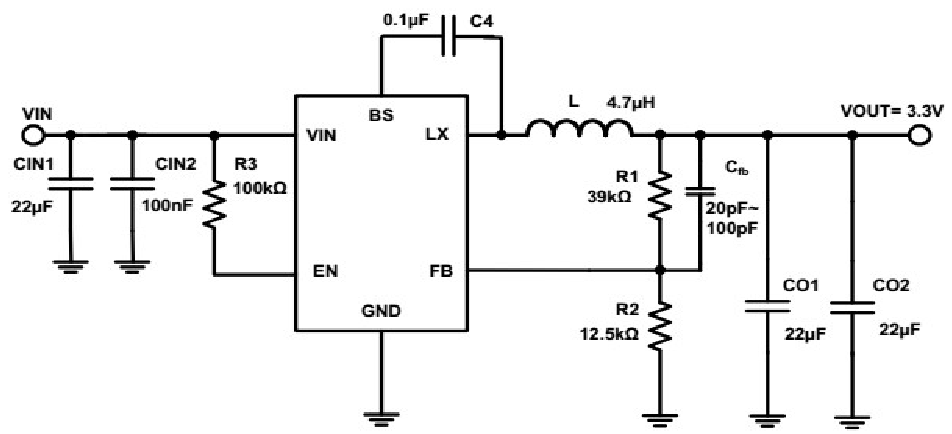


Figure 4. Typical Application Circuit of HCR3153M/S/T

Typical Application Circuit-2

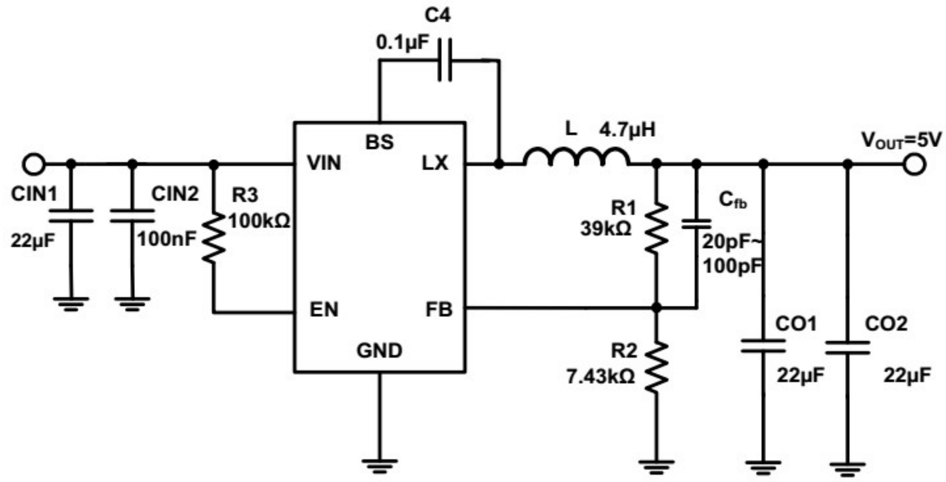


Figure 5. 12VIN, 5V Output (VFB=0.8V) Circuit

Typical Application Circuit-3

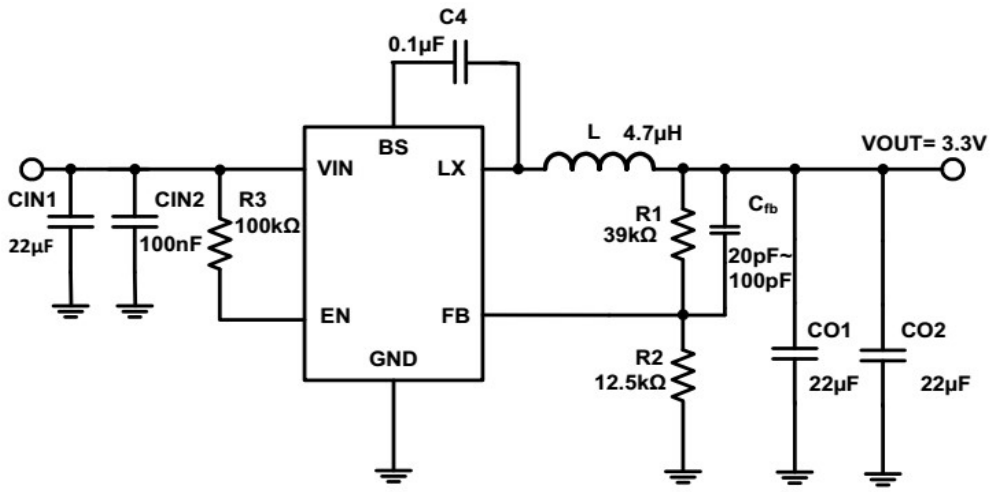


Figure 6. 12VIN, 3.3V Output (VFB=0.8V) Circuit

Typical Application Circuit-4

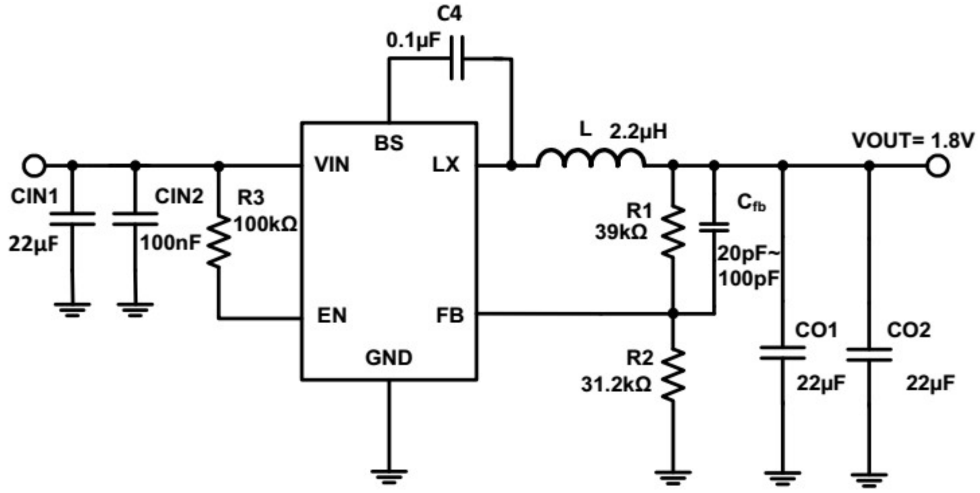


Figure 7. 12VIN, 1.8V Output (VFB=0.8V) Circuit

Typical Application Circuit-5

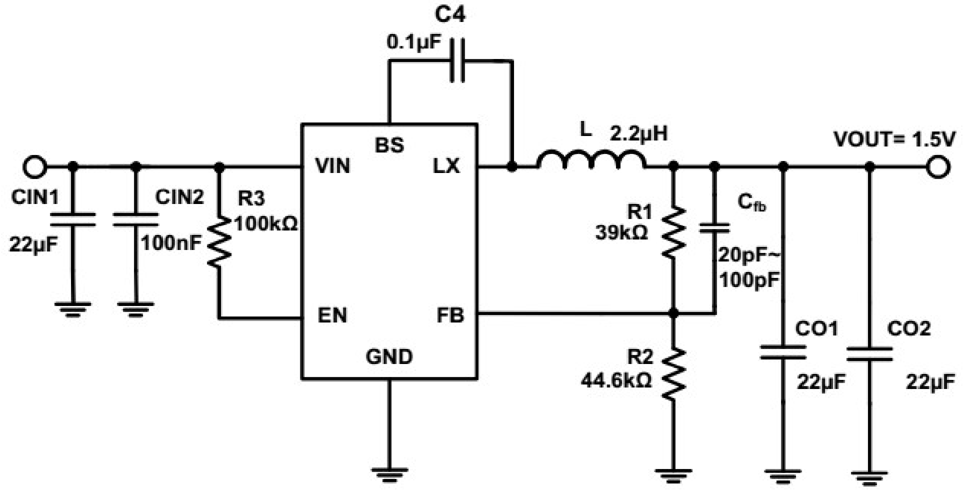


Figure 8. 12VIN, 1.5V Output (VFB=0.8V) Circuit

Typical Application Circuit-6

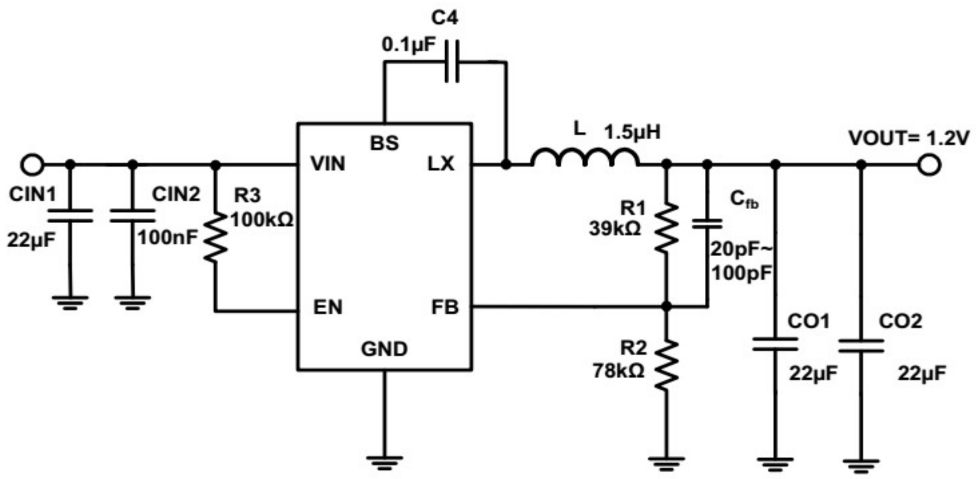
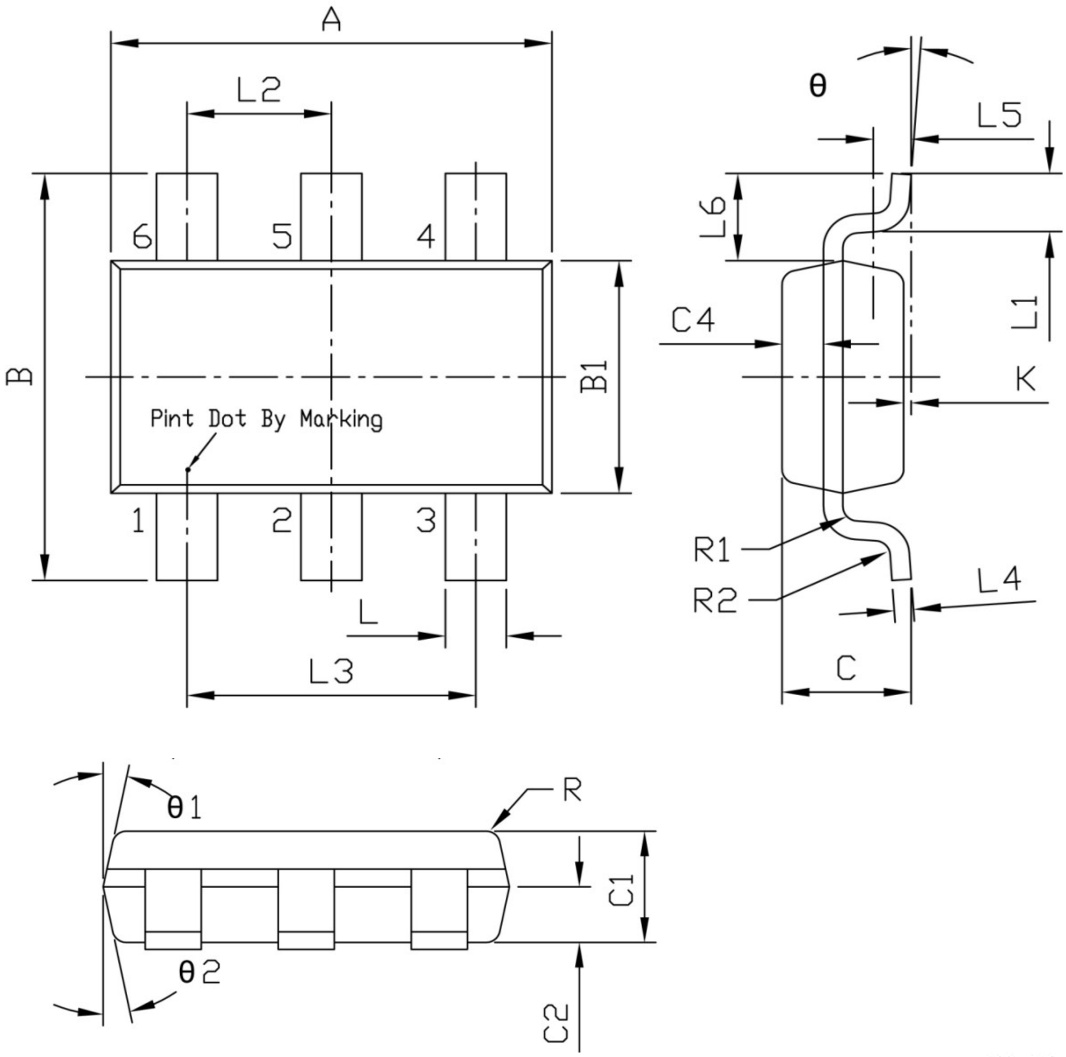


Figure 9. 12VIN, 1.2V Output (VFB=0.8V) Circuit

Mechanical Dimensions

M6L PKG: TSOP-6 (SOT23-6L)

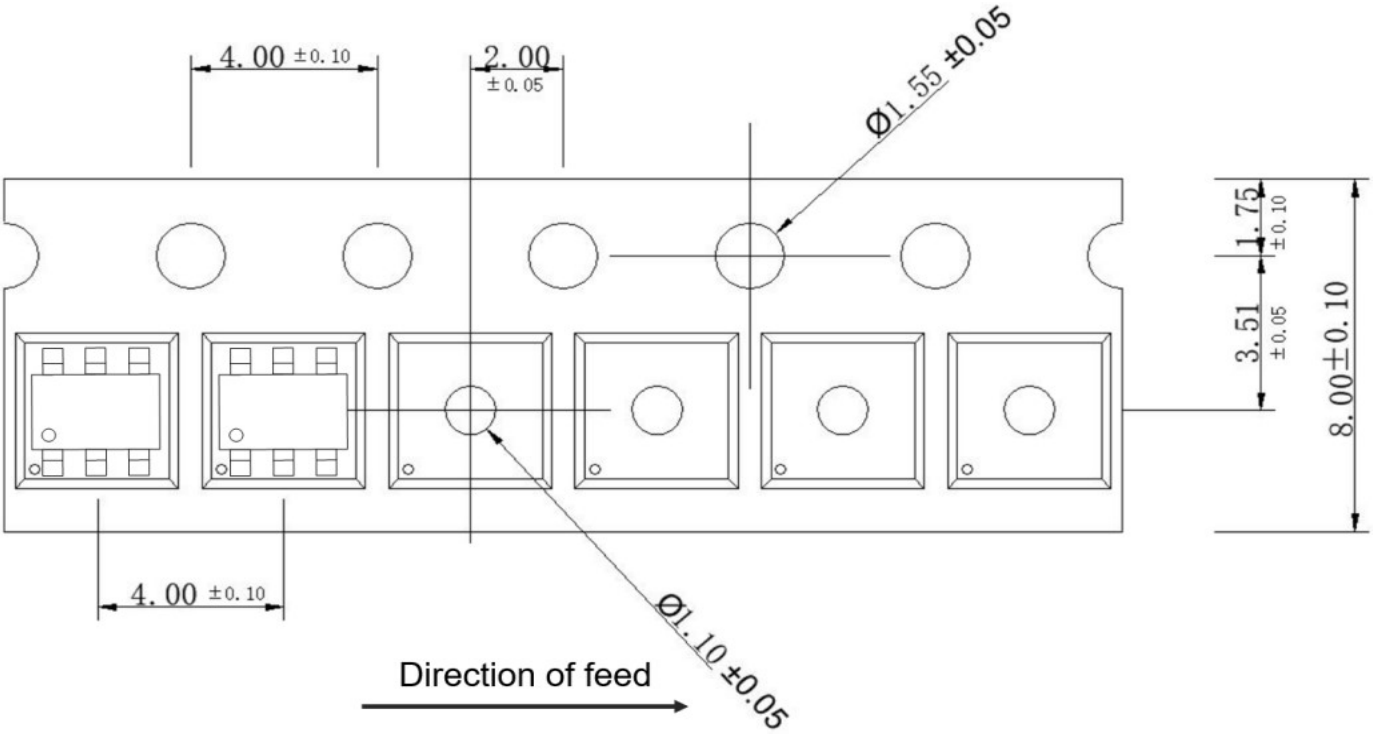


Unit: mm

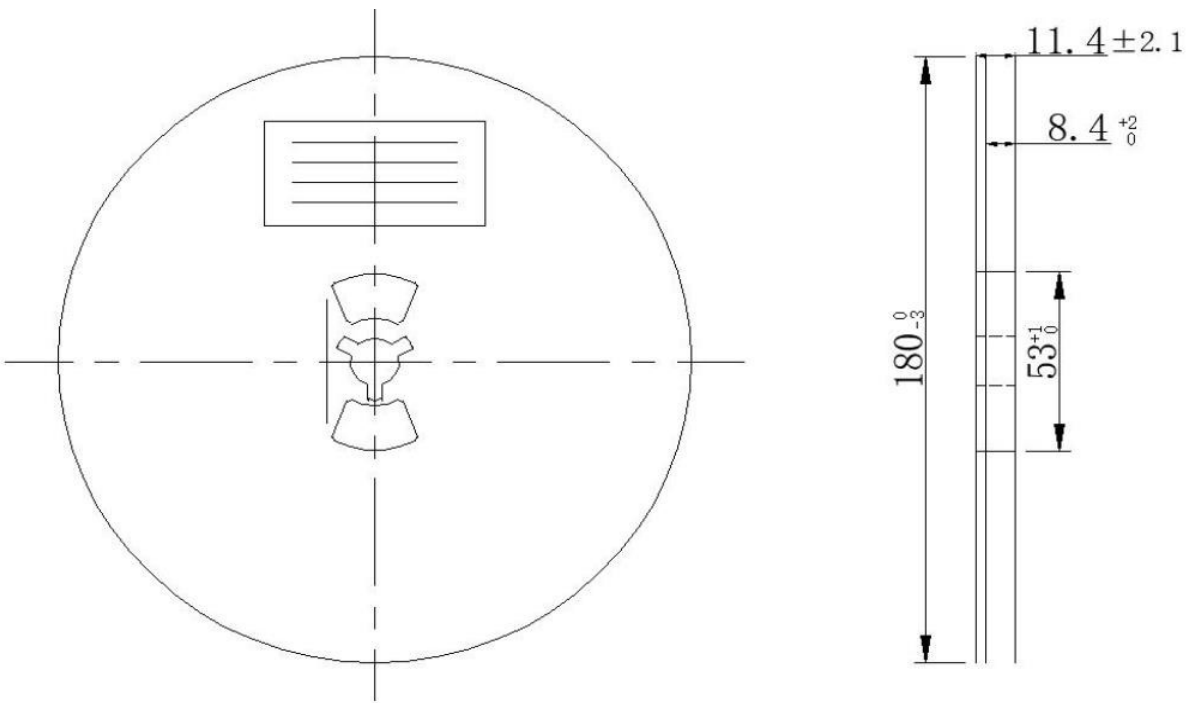
Symbol	Dimensions In Millimeters			Symbol	Dimensions In Millimeters		
	Min	Typ	Max		Min	Typ	Max
A	2.80	2.90	3.00	L3	1.800	1.900	2.000
B	2.60	2.80	3.00	L4	0.077	0.127	0.177
B1	1.50	1.60	1.70	L5	-	0.250	-
C	-	-	1.05	L6	-	0.600	-
C1	0.60	0.80	1.00	θ	0°		0°
C2	0.35	0.40	0.45	Θ1	10°	12°	14°
C4	0.223	0.273	0.323	Θ2	10°	12°	14°
K	0.000	0.075	0.150	R	-	0.100	-
L	0.325	0.400	0.475	R1	-	0.100	-
L1	0.325	0.450	0.550	R2	-	0.100	-
L2	0.850	0.950	1.050				

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.