AM3603

3A, 36V, 250kHz
Synchronous Step down Converter

DESCRIPTION

The AM3603 is a high frequency synchronous rectified step-down switch mode converter with built in internal power MOSFETs. It offers a very compact solution to achieve 3A continuous output current over a wide input supply range with excellent load and line regulation. Current mode operation provides fast transient response and eases loop stabilization. Full protection features include OCP and thermal shut down. The AM3603 requires a minimum number of readily available standard external components and is available in a space saving 8-pin SOIC package with an exposed pad.

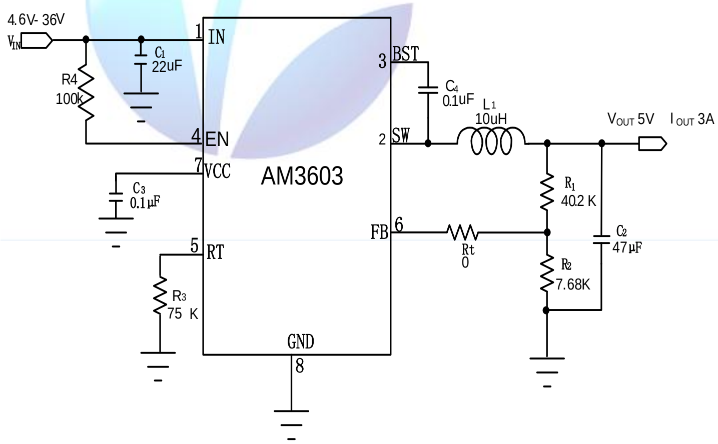
FEATURES

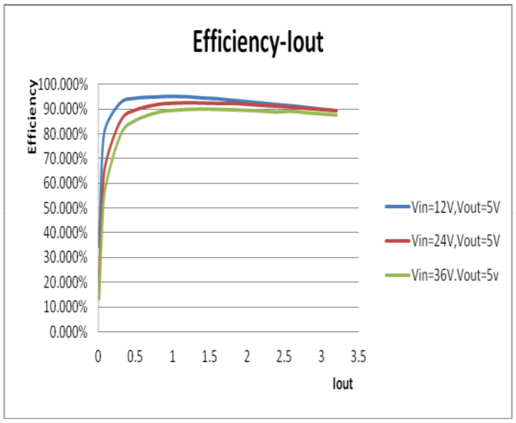
- Wide 4.5V to 36V Operating Input Range
- High Efficiency Synchronous Mode Operation
- Over-Current-Protection and Thermal Shutdown
- Short Circuit Protection (Hiccup)
- Programmable Output Current Threshold
- Programmable Cable Compensation
- 3A Output Current
- Low R_{ds}(on) Internal Power MOSFETs
- Proprietary Switching Loss Reduction Technique
- Available in a Thermally Enhanced 8-pin SOIC Package

APPLICATIONS

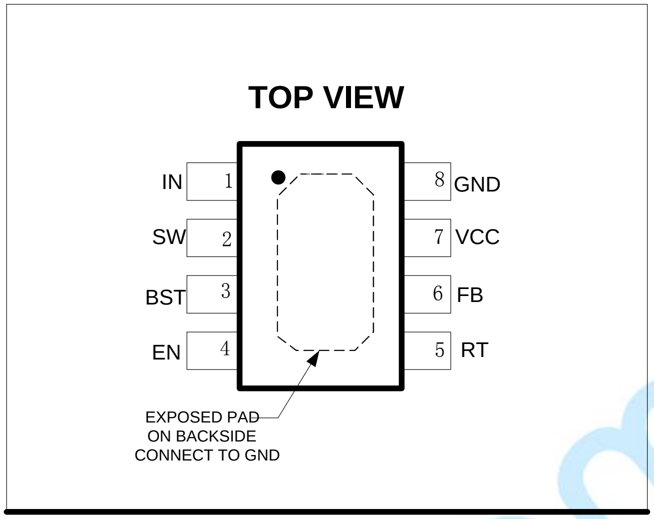
- Car USB charger
- Networking Systems
- Digital Set Top Boxes
- Personal Video Recorders
- Flat Panel Television and Monitors
- Distributed Power Systems

TYPICAL APPLICATION





PACKAGE REFERENCE



ABSOLUTE MAXIMUM RATINGS [1]

Supply Voltage V_{IN}…………………………..40V

V_{SW}………….........-0.3V (-5V for <10ns) to 40V

All Other Pins……………………....-0.3V to +6V

Continuous Power Dissipation (T_A = +25℃)[2]

……………………………..……………2.5W

Junction Temperature ………………..........150℃

Lead Temperature………………………..260℃

Storage Temperature……..……...-65℃ to +150℃

Recommended Operating Conditions [3]

Supply Voltage V_{IN}…………………...4.5V to 36V

Operating Temperature…………..-20℃ to +85℃

Thermal Resistance [4]...θ_{JA} ...θ_{Jc}

SOIC8E (Exposed Pad)........ ....50...... 10...℃/W

Notes:

1. Exceeding these ratings may damage the device.
2. The maximum allowable power dissipation is a function of the maximum junction temperature T_J (MAX), the junction-to-ambient thermal resistance θ_{JA}, and the ambient temperature T_A. The maximum allowable continuous power dissipation at any ambient temperature is calculated by PD (MAX) = (T_J(MAX)-T_A)/ θ_{JA}. Exceeding the maximum allowable power dissipation will cause excessive die temperature, and the regulator will go into thermal shutdown. Internal thermal shutdown circuitry protects the device from permanent damage.
3. The device is not guaranteed to function outside of its operating conditions.
4. Measured on AM3603, 2-layer PCB board

ELECTRICAL CHARACTERISTICS

V_{IN} = 12V, T_A = +25℃, unless otherwise noted.

Parameters	Symbol	Condition	Min	Typ	Max	Units
Supply Current (Shutdown)	I_{IN}	V_{EN} = 0V			10	µA
Supply Current (Quiescent)	I_{IN}	V_{EN} = 2V, V_{FB} = 1V		0.7		mA
HS Switch On Resistance(5)	HS_{RDS-ON}			120		mΩ
LS Switch On Resistance(5)	LS_{RDS-ON}			100		mΩ
Switch Leakage	SW_{LKG}	V_{EN} = 0V, V_{SW} = 0V or 12V		0	10	µA
Current Limit(5)	I_{LIMIT}	Duty = 40%, RT=100K		4		A
Oscillator Frequency	F_{SW}	V_{FB} = 0.75V	200	250	300	kHZ
Fold-back Frequency	F_{FB}	V_{FB} = 300mV		0.25		f_{SW}
Maximum Duty Cycle	D_{MAX}	V_{FB} = 700mV	85	90		%
Feedback Voltage	V_{FB}			800		mV
Feedback Current	I_{FB}	V_{FB} = 800mV		10	50	nA
EN Input Low Voltage	VIL_{EN}				0.4	V
EN Input High Voltage	VIH_{EN}		2			V
EN Input Current	I_{EN}	V_{EN} = 2V		2		µA
		V_{EN} = 0V		0		
EN Turn Off Delay	EN_{Td-Off}			5		µs
V_{IN} Under Voltage Lockout Threshold Rising	$INUV_{Vth}$		3.8	4.0	4.2	V
V_{IN} Under Voltage Lockout Threshold Hysteresis	$INUV_{HYS}$			880		mV
V_{CC} Regulator	V_{CC}			5		V
V_{CC} Load Regulation		I_{CC} = 2mA		5		%
Soft-Start Period				2		ms
Thermal Shutdown	T_{SD}			150		℃

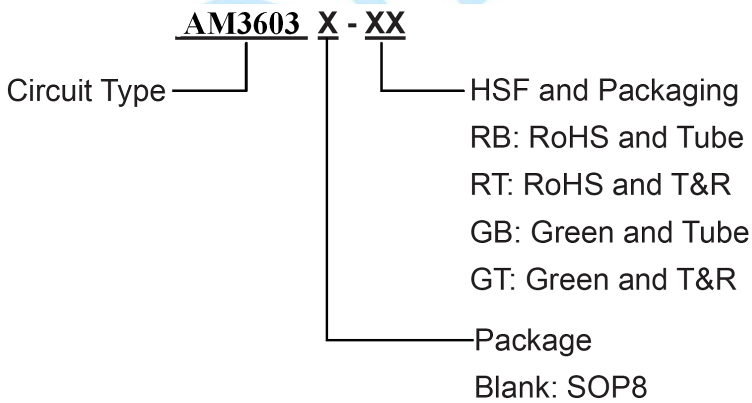
Note:

(5) Guaranteed by design.

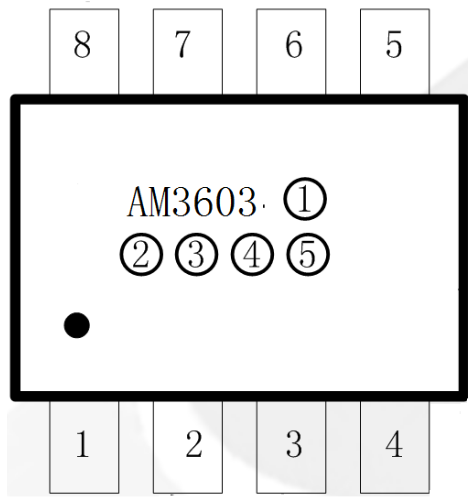
PIN FUNCTIONS

Pin	Name	Description
1	IN	Supply Voltage. The AM3603 operates from a +4.6V to +36V input rail. C_1 is needed to decouple the input rail. Use wide PCB trace to make the connection.
2	SW	Switch Output. Use wide PCB trace to make the connection.
3	BST	Bootstrap. A capacitor connected between SW and BS pins is required to form a floating supply across the high-side switch driver.
4	EN	EN=1 to enable the AM3603. For automatic start-up, connect EN pin to V_{IN} with 100KΩ resistor.
5	RT	Programs the current limit for the device. If connect to VCC, the current limit will default to 3.5A.
6	FB	Feedback. An external resistor divider from the output to GND, tapped to the FB pin, sets the output voltage. To prevent current limit run away during a short circuit fault condition the frequency fold-back comparator lowers the oscillator frequency when the FB voltage is below 500mV.
7	VCC	Bias Supply. Decouple with 0.1uF~0.22uF cap. And the capacitance should be no more than 0.22uF.
8	GND	System Ground. This pin is the reference ground of the regulated output voltage. For this reason care must be taken care in PCB layout. Suggested to be connected to GND with copper and via.

ORDERING INFORMATION



MARKING RULE



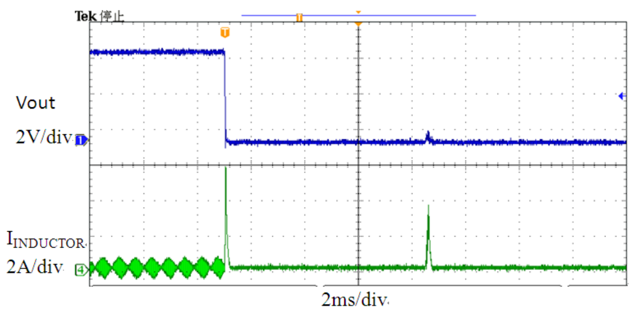
①: Represents Version (0,1,2 or 3)

②③④⑤: for internal reference

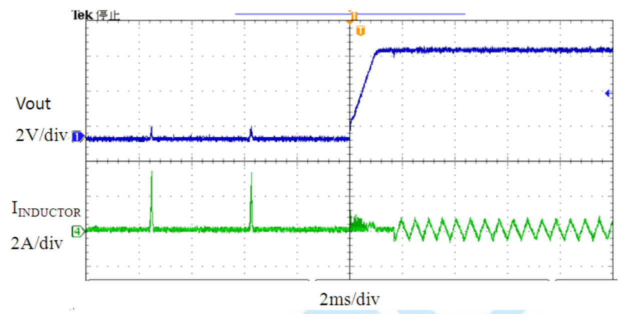
TYPICAL PERFORMANCE CHARACTERISTICS

V_{IN} = 12V, V_{OUT} = 5V, L= 10μH, T_A = +25℃, unless otherwise noted.

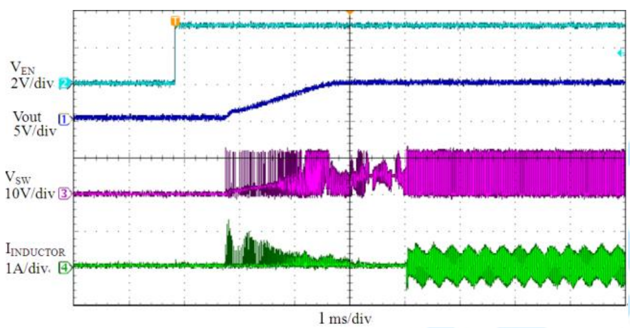
Short Entry



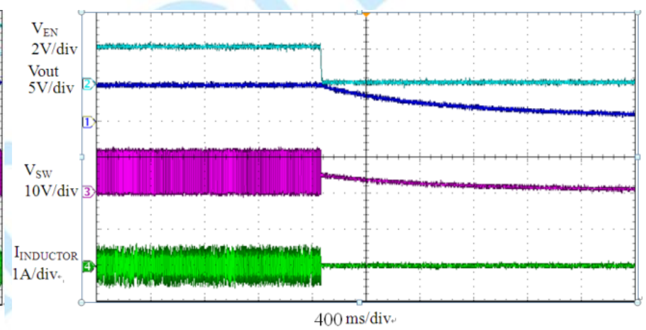
Short Recovery



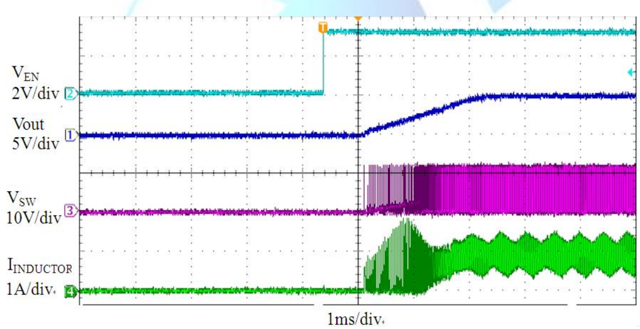
Enable startup without load



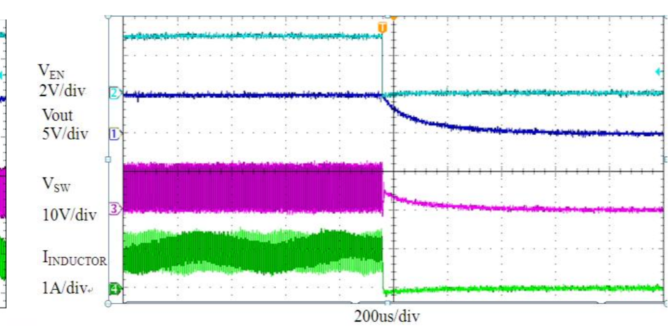
Disable startup without load



Enable startup with 5ohm load

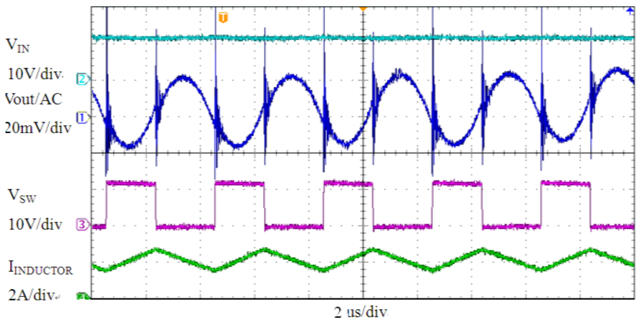


Disable startup with 5ohm load



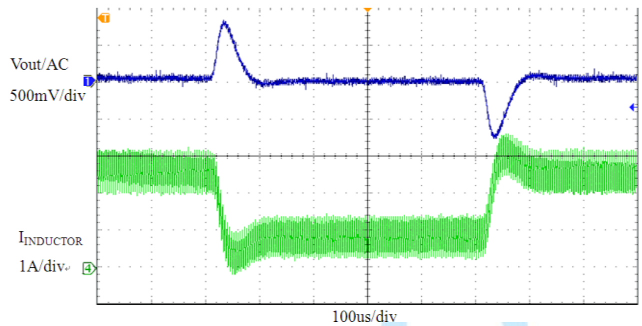
Output Ripple Voltage

Iout=2A



Load Transient Response

Iout=0.8A to 2.5A



BLOCK DIAGRAM

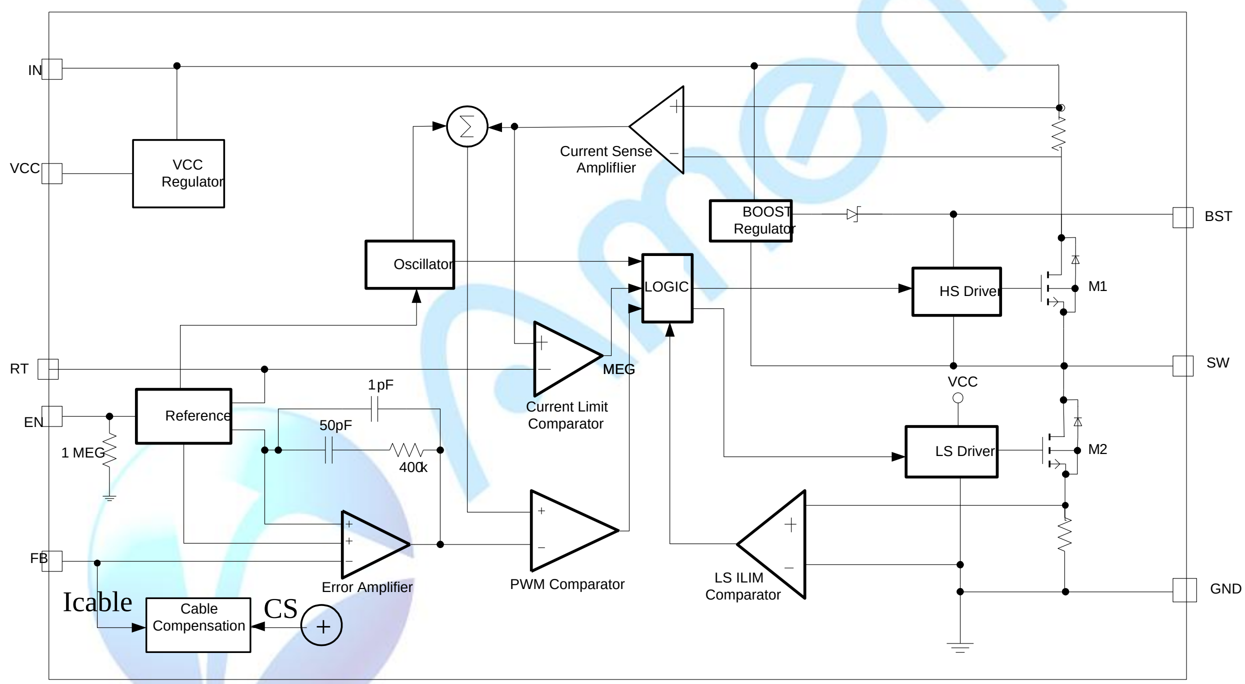


Figure1- Functional Block Diagram

OPERATION

The AM3603 is a high frequency synchronous rectified step-down switch mode converter with built in internal power MOSFETs. It offers a very compact solution to achieve 3A continuous output current over a wide input supply range with excellent load and line regulation.

The AM3603 operates in a fixed frequency, peak current control mode to regulate the output voltage. A PWM cycle is initiated by the internal clock. The integrated high-side power MOSFET is turned on and remains on until its current reaches the value set by the COMP voltage. When the power switch is off, it remains off until the next clock cycle starts. If, in 90% of one PWM period, the current in the power MOSFET does not reach the COMP set current value, the power MOSFET will be forced to turn off.

Internal Regulator

Most of the internal circuitries are powered from the 5V internal regulator. This regulator takes the V_{IN} input and operates in the full V_{IN} range. When V_{IN} is greater than 5.0V, the output of the regulator is full regulation. When V_{IN} is lower than 5.0V, the output decreases, a 0.1µF ceramic capacitor for decoupling purpose is required.

Error Amplifier

The error amplifier compares the FB pin voltage with the internal 0.8V reference (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 COMP voltage, which is used to control the power MOSFET current. The optimized internal compensation network minimizes the external component counts and simplifies the control loop design.

Enable Control

The AM3603 has a dedicated Enable control pin (EN). By pulling it high or low, the IC can be enabled and disabled by EN. Tie EN to V_{IN} for automatic start up. To disable the part, EN must be pulled low for at least 5 µs.

Under-Voltage Lockout (UVLO)

Under-voltage lockout (UVLO) is implemented to protect the chip from operating at insufficient supply voltage. The AM3603 UVLO comparator monitors the output voltage of the internal regulator, VCC. The UVLO rising threshold is about 4.0V while its falling threshold is a consistent 3.2V.

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 1.2V. When it is lower than the internal reference (REF), SS overrides REF so the error amplifier uses SS as the reference. When SS is higher than REF, REF regains control. The SS time is internally fixed to 2ms.

Over-Current-Protection

The AM3603 has cycle-by-cycle over current limit when the inductor current peak value exceeds the set current limit threshold. Meanwhile, output voltage starts to drop until FB is below the Under-Voltage (UV) threshold, typically 30% below the reference. If connect RT to VCC, the current limit is decided by internal 60k Resistance.

Normal current limit is decided by the following equation.

$$I_{OCP} = \frac{240 \times 10^3}{R_T}$$

Short Circuit Protection (Hiccup)

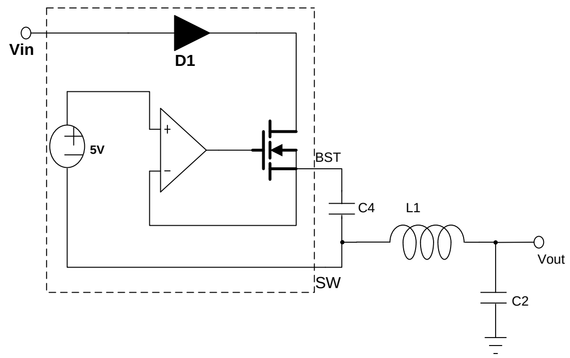
When the inductor current peak value exceeds the set current limit threshold, the output voltage starts to drop, and the frequency fold-back comparator lowers the oscillator frequency when the FB voltage is below 500mV, the AM3603 enters hiccup mode to periodically restart the part(Typical restart time is nearly 8ms). This protection mode is especially useful when the output is dead-short to ground. The average short circuit is greatly reduced to alleviate the thermal issue and to protect the regulator. The AM3603 exits the hiccup mode once the over current condition is removed.

Thermal Shutdown

Thermal shutdown is implemented to prevent the chip from operating at exceedingly high temperatures. When the silicon die temperature is higher than 150℃, it shuts down the whole chip. When the temperature is lower than its lower threshold, typically 140℃, the chip is enabled again.

Floating Driver and Bootstrap Charging

The floating power MOSFET driver is powered by an external bootstrap capacitor. This floating driver has its own UVLO protection. This UVLO's rising threshold is 2.2V with a hysteresis of 150mV. The bootstrap capacitor voltage is regulated internally by V_{IN} through D_1, M_3, C_4, L_1 and C_2 (Figure 2). If (V_{IN}-V_{SW}) is more than 5V, U_2 will regulate M_3 to maintain a 5V BST voltage across C_4.



Startup and Shutdown

If both V_{IN} and EN are higher than their appropriate thresholds, the chip starts. 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 circuitries. Three events can shut down the chip: EN low, V_{IN} Low and thermal shutdown. In the shutdown procedure, the signaling path is first blocked to avoid any fault triggering. The COMP voltage and the internal supply rail are then pulled down. The floating driver is not subject to this shutdown command.

Output Cable Resistance Compensation

To compensate for resistive voltage drop across the charger's output cable, the WS5601B integrates a simple, user-programmable cable voltage drop compensation using the impedance at the FB pin.

As the converter load increases from no-load to the full current load, the cable sink current at the FB pin increases in line . The cable compensation voltage can set with Rt、R1、R2(Figure3).

$$I_{Cable} = (I_{LOAD} + \frac{1}{2}\Delta I_L - 0.5) * 10e-6$$

APPLICATION INFORMATION

Setting the Output Voltage

The external resistor divider is used to set the output voltage (see Typical Application on page 1). The feedback resistor R_1 also sets the feedback loop bandwidth with the internal compensation capacitor (see Typical Application on page 1). Choose R_1 to be around 40.2kΩ for optimal transient response. R_2 is then given by:

$$R2 = \frac{R1}{\frac{V_{OUT}}{0.8} - 1}$$

The T-type network is highly recommended when V_O is low, as Figure 3 shows.

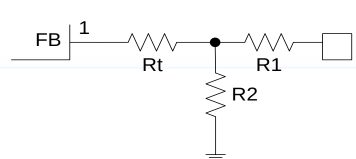


Figure 3- T-type Network

Consider the cable compensation, the Volatage of Vout is

$$V_{OUT} = V_{REF}\frac{R_1+R_2}{R_2} + I_C(\frac{R_1+R_2}{R_2}R_t + R_1)$$

Ic is the cable current at FB pin. The amount of compensation can be programmed by R1、R2、Rt.

Selecting the Inductor

A 1µH to 10µH inductor with a DC current rating of at least 25% percent higher than the maximum load current is recommended for most applications. For highest efficiency, the inductor DC resistance should be less than 15mΩ. For most designs, the inductance 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 ΔI_L is the inductor ripple current.

Choose inductor ripple current to be approximately 30% if the maximum load current 3A. 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.

Selecting the Input Capacitor

The input current to the step-down converter is discontinuous, therefore a capacitor is required to supply the AC current to the step-down converter while maintaining the DC input voltage. Use low ESR capacitors for the best performance. Ceramic capacitors with X5R or X7R dielectrics are highly recommended because of their low ESR and small temperature coefficients. For most applications, a 22µF capacitor is sufficient.

Since the input capacitor (C_1) absorbs the input switching current it requires an adequate ripple current rating. The RMS current in the input capacitor can be estimated by:

$$I_{C1} = I_{LOAD}\times\sqrt{\frac{V_{OUT}}{V_{IN}}\times\left(1-\frac{V_{OUT}}{V_{IN}}\right)}$$

The worse case condition occurs at :

$V_{IN} = 2V_{OUT}$, where $I_{C1} = \frac{I_{LOAD}}{2}$

For simplification, choose the input capacitor whose RMS current rating greater than half of the maximum load current. The input capacitor can be electrolytic, tantalum or ceramic. When using electrolytic or tantalum capacitors, a high quality ceramic capacitor should be placed as close to the IC as possible. When using ceramic capacitors, make sure that they have enough capacitance to provide sufficient charge to prevent excessive voltage ripple at input. The input voltage ripple caused by capacitance can be estimated by:

$$\Delta V_{IN} = \frac{I_{LOAD}}{f_S \times C1} \times \frac{V_{OUT}}{V_{IN}} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right)$$

Selecting the Output Capacitor

The output capacitor (C_2) 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:

$$\Delta V_{OUT} = \frac{I_{LOAD}}{f_S \times L} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right) \times \left(R_{ESR} + \frac{1}{8 \times f_S \times C2}\right)$$

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:

$$\Delta V_{OUT} = \frac{V_{OUT}}{8 \times f_S^2 \times L \times C2} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right)$$

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 AM3603 can be optimized for a wide range of capacitance and ESR values.

External Bootstrap Diode

An external bootstrap diode may enhance the efficiency of the regulator, the applicable conditions of external BST diode is:

Duty cycle is high: $D = \frac{V_{OUT}}{V_{IN}} > 65\%$

In this case, an external BST diode is recommended from the VCC pin to BST pin, as shown in Figure 5

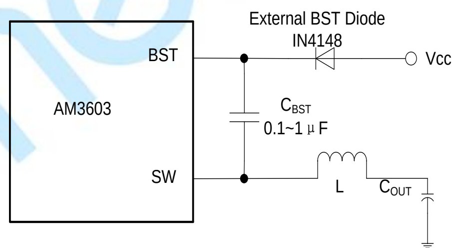


Figure 5-Add Optional External Bootstrap Diode to Enhance Efficiency

The recommended external BST diode is IN4148, and the BST cap is 0.1~1μF.

PCB Layout

PCB layout is very important to achieve stable operation. Please follow these guidelines and take Figure 4 for references.

1) Keep the connection of input ground and GND pin as short and wide as possible.

2) Keep the connection of input capacitor and IN pin as short and wide as possible.

3) Ensure all feedback connections are short

and direct. Place the feedback resistors and compensation components as close to the chip as possible.

4) Route SW away from sensitive analog areas such as FB.

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

6) Adding RC snubber circuit from IN pin to SW pin can reduce SW spikes.

TOP LAYER **BOTTOM LAYER**

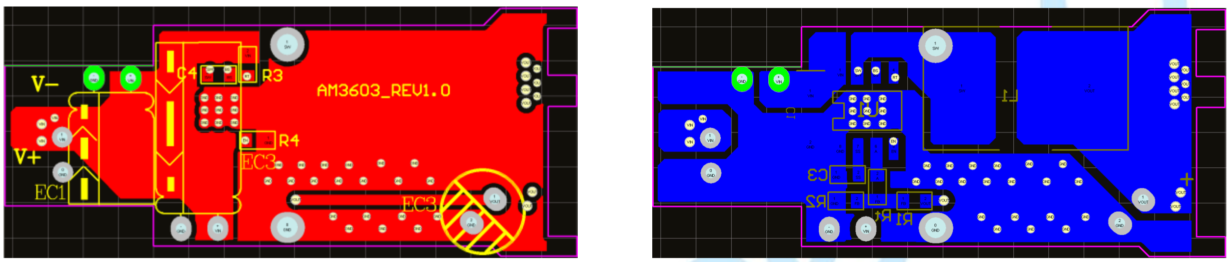
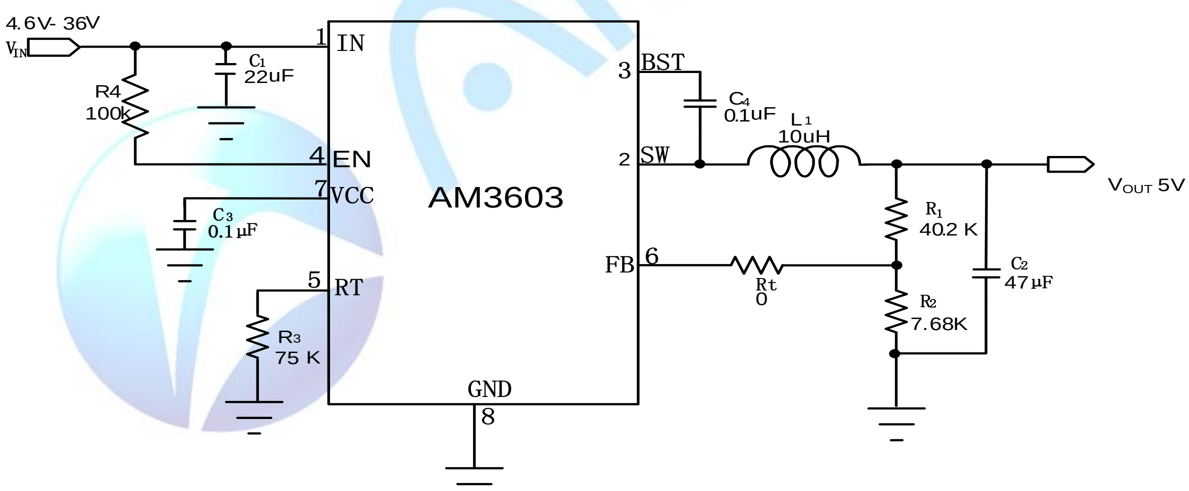


Figure 4

Typical Application Circuit for 5V/3A Car Charger



BOM List for 5V/3A Car Charger

ITEM	REFERENCE	DESCRIPTION	QTY
1	U1	IC, AM3603,DC-DC Converter	1
2	C1	Capacitor, 22µF/50V,1206, SMD	1
3	C2	Capacitor,47µF/50V,1206, SMD	1
4	C3	Capacitor,0.1µF/6.3V,0603, SMD	1
5	C4	Capacitor,0.1µF/6.3V,0603, SMD	1
6	R1	Resistor, 40.2kΩ, 0603, 1%	1
7	R2	Resistor, 7.68kΩ, 0603, 1%	1
8	R3	Resistor, 75kΩ, 0603, 5%	1
9	R4	Resistor, 100kΩ, 0603, 1%	1
10	Rt	Resistor, 0Ω, 0603, 1%	1
11	L1	Inductor,10µH, 5A, SMD	1

PACKAGE INFORMATION

SOIC8E (EXPOSED PAD