PFM/PWM Step-Down DC/DC Controller

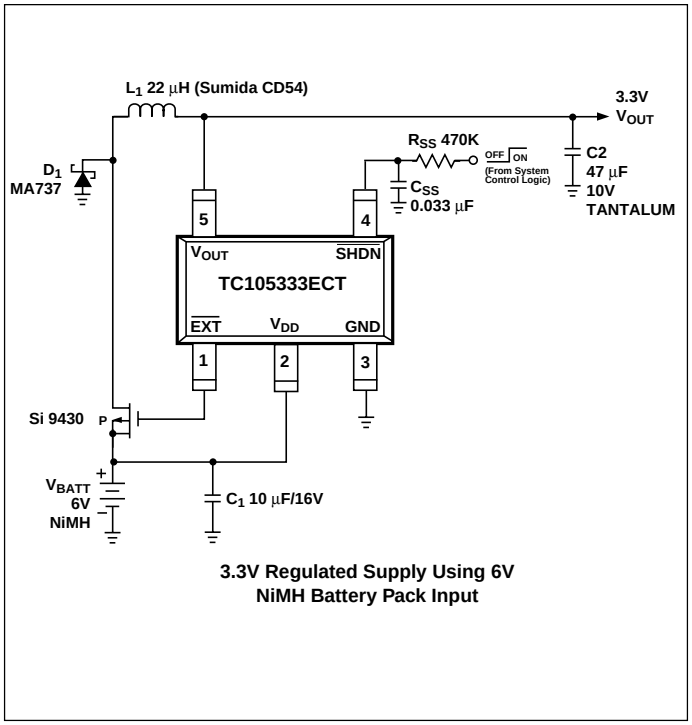
FEATURES

- **Space-Saving 5-Pin SOT-23A Package**
- **57 μA (Typ) Supply Current**
- **1A Output Current**
- **0.5 μA Shutdown Mode**
- **300 KHz Switching Frequency for Small Inductor Size**
- **Programmable Soft-Start**
- **92% Typical Efficiency**

TYPICAL APPLICATIONS

- **Palmtops**
- **Battery Powered Systems**
- **Positive LCD Bias Generators**
- **Portable Communicators**
- **Hand-Held Scanners**
- **5V to 3V Down Converters**

TYPICAL APPLICATION



3.3V Regulated Supply Using 6V NiMH Battery Pack Input

GENERAL DESCRIPTION

The TC105 is a step-down (Buck) switching controller that furnishes output currents of up to 1A (max) while delivering a typical efficiency of 92%. The TC105 normally operates in pulse width modulation mode (PWM), but automatically switches to pulse frequency modulation (PFM) at low output loads for greater efficiency. Oscillator frequency is 300 KHz, allowing use of small (22 μH) inductors. Supply current draw is only 102 μA (max), and is reduced to less than 0.5 μA when the $\overline{SHDN}$ input is brought low. Regulator operation is suspended during shutdown. The TC105 accepts a maximum input voltage of 10V.

The TC105 is housed in a tiny 5-pin SOT-23A package, occupies minimum board space, and is ideal for a wide range of applications.

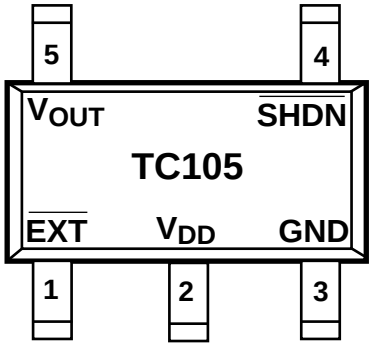
ORDERING INFORMATION

Part Number	Output Voltage* (V)	Package	Osc. Freq. (KHz)	Operating Temp. Range
TC105503ECT	5.0	5-Pin SOT-23A	300	–40 to +85°C
TC105333ECT	3.3	5-Pin SOT-23A	300	–40 to +85°C
TC105303ECT	3.0	5-Pin SOT-23A	300	–40 to +85°C

NOTE: *Other output voltages available. Please contact Microchip Technology for details.

PIN CONFIGURATION

5-Pin SOT-23A



TC105

ABSOLUTE MAXIMUM RATINGS*

Voltage on V_{DD} ..... –0.3V to +12V
EXT Output Current ..... ±100 mA
Voltage on V_{OUT}, EXT, $\overline{SHDN}$ Pins .... –0.3V to V_{DD} +0.3V
Power Dissipation ..... 150 mW
Operating Temperature ..... –40°C to +85°C
Storage Temperature ..... –40°C to +125°C

*Static-sensitive device. Unused devices must be stored in conductive material. Protect devices from static discharge and static fields. Stresses above those listed under Absolute Maximum Ratings may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these or any other conditions above those indicated in the operational sections of the specifications is not implied. Exposure to Absolute Maximum Rating Conditions for extended periods may affect device reliability.

ELECTRICAL CHARACTERISTICS: Note 1, f_{OSC} = 300 KHz; T_A = 25°C, unless otherwise noted.

Symbol	Parameter	Test Conditions	Min	Typ	Max	Unit	
V_{DD}	Operating Supply Voltage			2.2	—	10.0	V
V_{DDMIN}	Minimum Input Voltage	$\overline{EXT}$ = High; No External Components; V_{OUT} = 0V; $\overline{SHDN}$ = V_{IN}		0.9	—	2.2	V
I_{DD}	Operating Supply Current	No External Components; V_{OUT} = 0V; $\overline{SHDN}$ = V_{IN},	V_R = 3.0V, 3.3V V_R = 5.0V	— —	57 67	102 122	µA µA
I_{STBY}	Standby Supply Current	No External Components; V_{OUT} = $\overline{SHDN}$ =	V_R = 3.0V, 3.3V V_{IN}, V_R = 5.0V	— —	15 16	27 29	µA µA
I_{SHDN}	Shutdown Supply Current	$\overline{SHDN}$ = GND		—	—	0.5	µA
f_{OSC}	Oscillator Frequency	V_{IN} = V_{OUT} + 0.3V		255	300	345	KHz
V_{OUT}	Output Voltage	Note 2		V_R x 0.975	V_R	V_R x 1.025	
DTYMAX	Maximum Duty Cycle (PWM Mode)			100	—	—	%
DTYPFM	Duty Cycle (PFM Mode)	I_{OUT} = 0 mA		15	25	35	%
V_{IH}	$\overline{SHDN}$ Input Logic High	V_{OUT} = 0V; No External Components		0.65	—	—	
V_{IL}	$\overline{SHDN}$ Input Logic Low	V_{OUT} = 0V; No External Components		—	—	0.20	V
REXTH	EXT ON Resistance to V_{DD}	No External Components; V_{OUT} = $\overline{SHDN}$ = V_{IN}; $V_{\overline{EXT}}$ = (V_{IN} – 0.4V)	V_R = 3.0 V_R = 3.3 V_R = 5.0	— — —	17 16 12	24 22 17	Ω Ω Ω
REXTL	EXT ON Resistance to GND	No External Components; V_{OUT} = 0V; $\overline{SHDN}$ = V_{IN}; $V_{\overline{EXT}}$ = 0.4V	V_R = 3.0 V_R = 3.3 V_R = 5.0	— — —	15 14 10	20 19 14	Ω Ω Ω
η	Efficiency			—	92	—	%

Note: 1. V_R = 3.0V V_{IN} = 4.5V, I_{OUT} = 200mA
V_R = 3.3V V_{IN} = 5.0V, I_{OUT} = 220mA
V_R = 5.0V V_{IN} = 7.5V, I_{OUT} = 320mA

2. V_R is the factory output voltage setting.

PIN DESCRIPTION

Pin Number	Name	Description
1	$\overline{EXT}$	Switch Transistor Control Output. This terminal connects to the gate of an external P-channel MOSFET (or to the base of an external PNP transistor through a current limiting resistor).
2	V_{DD}	Power Supply Voltage Input.
3	GND	Ground Terminal.
4	$\overline{SHDN}$	Shutdown Input (Active Low). The TC105 enters a low-power shutdown state when this input is brought low. During shutdown, regulator action is suspended, and supply current is reduced to less than 0.5 µA. The TC105 resumes normal operation when $\overline{SHDN}$ is again brought high.
5	V_{OUT}	Voltage Sense Input. This input senses output voltage for regulation and must be connected to the output voltage node as shown in the application schematics in this data sheet.

DETAILED DESCRIPTION

TC105 is a PFM/PWM step-down DC/DC controller for use in systems operating from two or more cells, or in line-powered applications. It uses PWM as the primary modulation scheme, but automatically converts to PFM at output duty cycles less than approximately 10%. The conversion to PFM provides reduced supply current, and therefore higher operating efficiency at low loads. The TC105 uses an external switching transistor, allowing construction of switching regulators with output currents of up to 1A. The TC105 consumes only 102 µA, max, of supply current when V_{IN} = 5V and V_{OUT} = 3.3V, and can be placed in a 0.5 µA shutdown mode by bringing the shutdown input ($\overline{SHDN}$) low. The regulator remains disabled while in shutdown mode, and output voltage discharges to zero through the load. Normal operation resumes when $\overline{SHDN}$ is brought high. Other features include a built-in undervoltage lockout (UVLO) and externally programmable soft start time. The TC105 is housed in a tiny 5-pin SOT-23A package.

Low Power Shutdown Mode

The TC105 enters a low power shutdown mode when $\overline{SHDN}$ is brought low. While in shutdown, the oscillator is disabled and the output switch is shut off. Normal regulator operation resumes when $\overline{SHDN}$ is again brought high. $\overline{SHDN}$ may be tied to the input supply if not used.

Soft Start

Soft start allows the output voltage to gradually ramp from 0 to rated output value during start-up. This action minimizes (or eliminates) overshoot, and in general, reduces stress on circuit components. Figure 1 shows the circuit required to implement soft start (values of 470K and 0.033 µF for R_{SS} and C_{SS}, respectively, are adequate for most applications).

Undervoltage Lockout (UVLO)

The TC105 is disabled when V_{IN} is below the undervoltage lockout threshold. This threshold is equal to the guaranteed minimum operating voltage for the TC105 (i.e. 2.2V). When UVLO is active, the TC105 is completely disabled.

Input Bypass Capacitors

Using an input bypass capacitor reduces peak current transients drawn from the input supply and reduces the switching noise generated by the regulator. The source impedance of the input supply determines the size of the capacitor that should be used.

Output Capacitor

The effective series resistance of the output capacitor directly affects the amplitude of the output voltage ripple. (The product of the peak inductor current and the ESR determines output ripple amplitude.) Therefore, a capacitor with the lowest possible ESR should be selected. Smaller capacitors are acceptable for light loads or in applications where ripple is not a concern. The Sprague 595D series of tantalum capacitors are among the smallest of all low ESR surface mount capacitors available. Table 1 lists suggested component numbers and manufacturers.

Inductor Selection

Selecting the proper inductor value is a trade-off between physical size and power conversion requirements. Lower value inductors cost less, but result in higher ripple current and core losses. They are also more prone to saturate since the coil current ramps faster and could overshoot the desired peak value. This not only reduces

efficiency, but could also cause the current rating of the external components to be exceeded. Larger inductor values reduce both ripple current and core losses, but are larger in physical size and tend to increase the start-up time slightly. A 22 µH inductor is recommended as the best overall compromise. For highest efficiency, use inductors with a low DC resistance (less than 20 mΩ). To minimize radiated noise, consider using a toroid, pot core, or shielded-bobbin inductor.

Output Diode

The high operating frequency of the TC105 requires a high-speed diode. Schottky diodes such as the MA737 or 1N5817 through 1N5823 (and the equivalent surface mount versions) are recommended. Select a diode whose average current rating is greater than the peak inductor current and whose voltage rating is higher than $V_{DD(max)}$.

External Switching Transistor Selection

$\overline{EXT}$ is a complementary output with a maximum ON resistance of 22Ω to V_{DD} when high and 19Ω to ground when low. It is designed to directly drive a P-channel MOSFET or a PNP bipolar transistor through a base current limiting resistor (Figure 2). A PNP transistor is recommended in applications where V_{IN} is less than 2.5V. Otherwise, a P-Channel MOSFET is preferred as it affords the highest efficiency because it does not draw any gate drive current. However, P-Channel MOSFETs are typically more expensive than bipolar transistors.

P-Channel MOSFET selection is determined mainly by the on-resistance, gate-source threshold, and gate charge requirements. Also, the drain-to-source and gate-to-source breakdown voltage ratings must be greater than $V_{DD(max)}$. The total gate charge specification should be less than 100 nC for best efficiency. The MOSFET must be capable of handling the required peak inductor current, and should have a very low on-resistance at that current. For example, an Si9430 MOSFET has a drain-to-source rating of –20V, and a typical on-resistance $r_{DS(ON)}$ of 0.07Ω at 2A, with V_{GS} = –4.5V. Table 1 lists suppliers of external components recommended for use with the TC105.

Board Layout Guidelines

As with all inductive switching regulators, the TC105 generates fast switching waveforms, which radiate noise. Interconnecting lead lengths should be minimized to keep stray capacitance, trace resistance, and radiated noise as low as possible. In addition, the GND pin, input bypass capacitor, and output filter capacitor ground leads should be connected to a single point. The input capacitor should be placed as close to power and ground pins of the TC105 as possible. The length of the $\overline{EXT}$ trace must also be kept as short as possible.

APPLICATIONS

Circuit Examples

Figure 3 shows a TC105 using a PNP switching transistor (Zetex FZT749) that has an h_{FE} of 180 and V_{CESAT} of 100 mV at I_C = 1A. Other high beta transistors can be used, but the values of R_B and C_B may need adjustment if h_{FE} is significantly different from that of the FZT749.

The circuit of Figure 4 utilizes a P-Channel MOSFET switching transistor (Silconix Si9430). This transistor is a member of the Littlefoot ™ family of small outline MOSFETs.

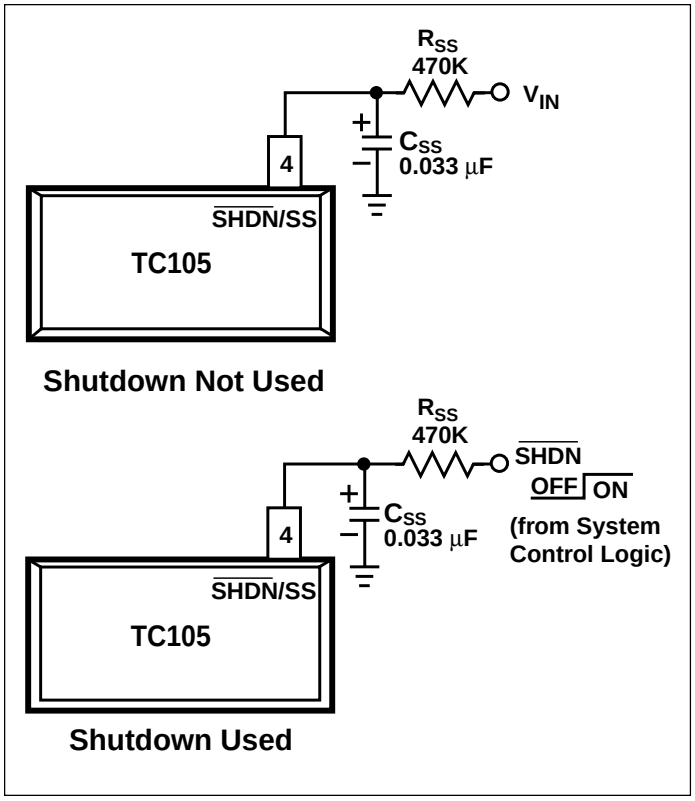


Figure 1. Soft Start Circuit

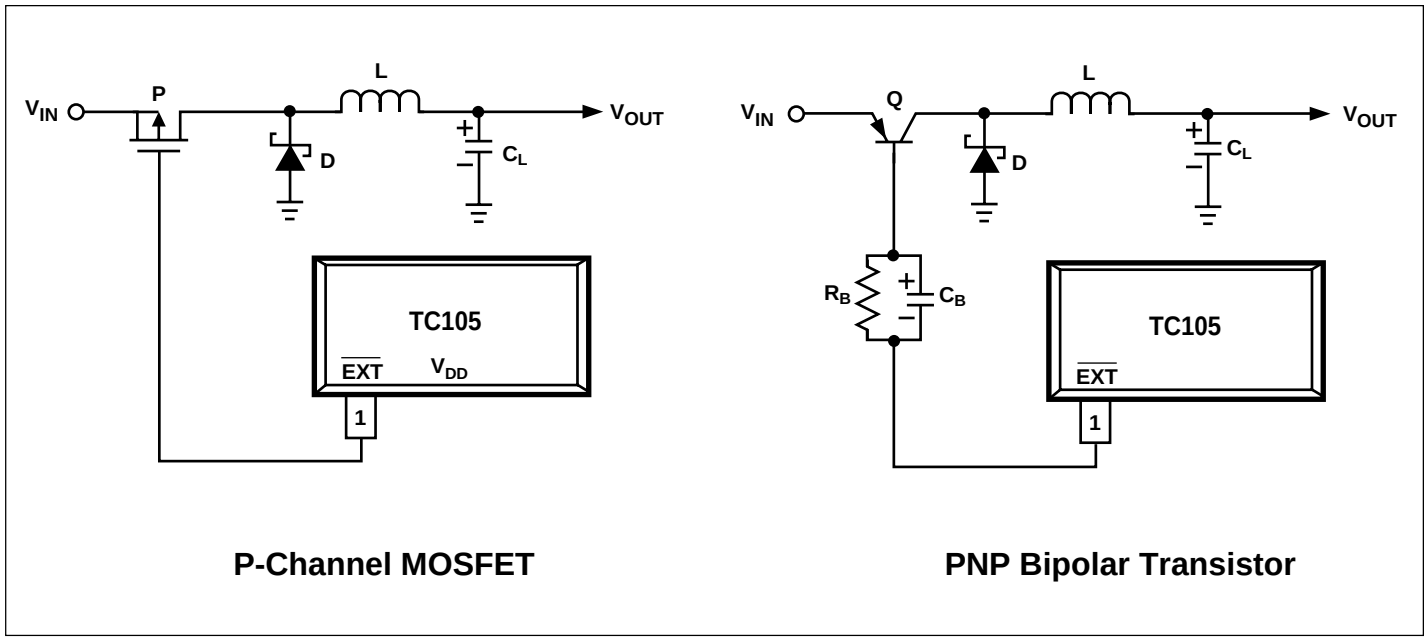


Figure 2. External Transistor Connection

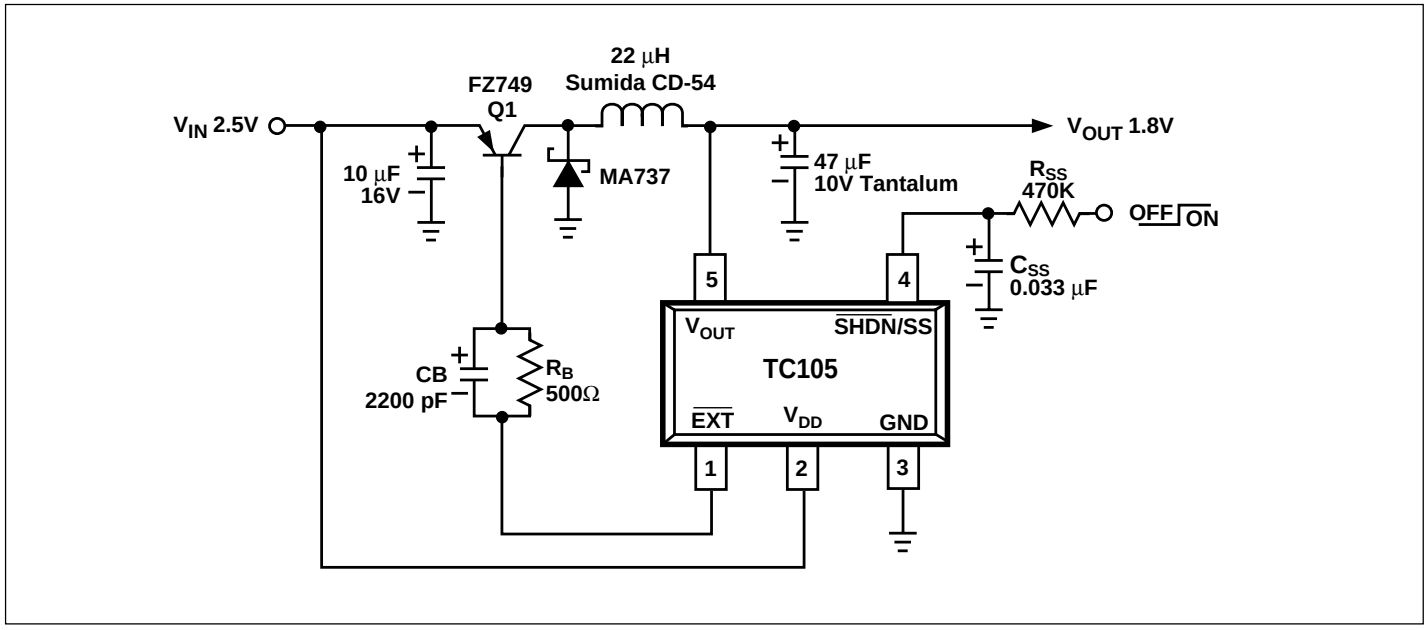


Figure 3. Regulator Using PNP Transistor

TC105

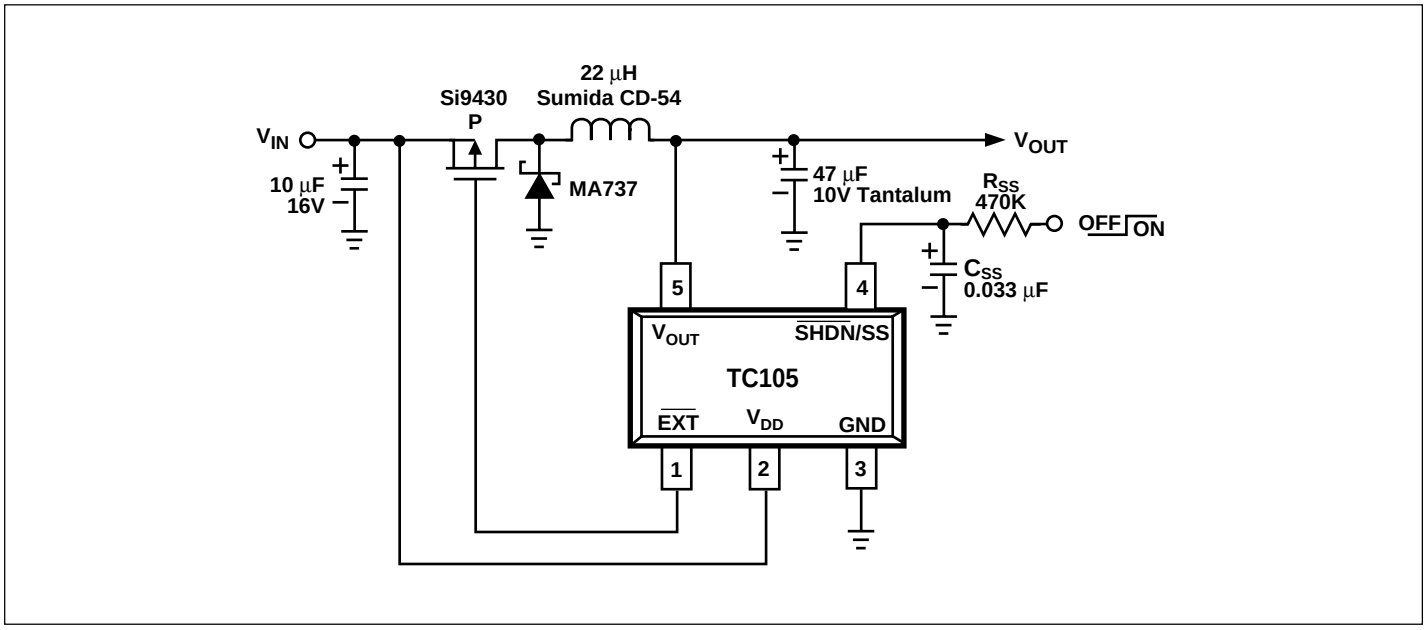


Figure 4. Regulator Using P-Channel MOSFET

Table 1. Suggested Components and Manufacturers

Type	Inductors	Capacitors	Diodes	Transistors
Surface Mount	Sumida CD54 Series CDRH Series Coilcraft DO Series	AVX TPS Series Sprague 595D Series	Motorola MBRS340T3 NiHon NSQ Series Matsushita MA737	Silconix Little Foot MOSFET Zetex FZT749 PNP Bipolar Transistor Toshiba 2SA1213 PNP Transistor
Series				
Miniature Through Hole	Sumida RCH Series	Sanyo OS-CON Series	IRC OAR Series	
Standard Through-Hole	Coilcraft PCH Series Coiltronics CTX Series	Nichicon PL Series United Chemi-Con LXF Series		Motorola TMOS Power MOSFETs (Example: MTP30P06V)

TC105DEMO

The TC105DEMO allows the user to quickly prototype TC105-based circuits. The TC105DEMO consists of a printed circuit board and the TC105. Supporting components (Schottky diode, input capacitor, output capacitor, external P-channel FET switch, soft-start resistor (R_{SS}), soft-start capacitor (C_{SS}), and 22 µH inductor) may be selected by the design engineer, (reference Table 1). The circuit schematic appears in Figure 5.

The board is designed to accept either a 47 µH or 22 µH power inductor. The remaining components install in accordance with the component side layout diagram of Figure 6. Jumper blocks J1 and J2 control shutdown and an optional device current measurement mode respectively. Shorting J1, terminal X to OFF places the TC105 in shutdown; normal operation is enabled when J1 terminal X is shorted to ON (the TC105's soft-start feature is disabled in this mode). A logic control signal can be connected to terminal X on J1 to provide true soft-start operation using the R_{SS} and C_{SS} components. Shorting J2, terminal CM+ to CM– selects the typical operating mode; if J2 terminal CM+ to CM– is unconnected, a current meter can be placed across these terminals to measure the total device current (including current drawn from the $\overline{SHDN}$ input in the normal mode of operation).

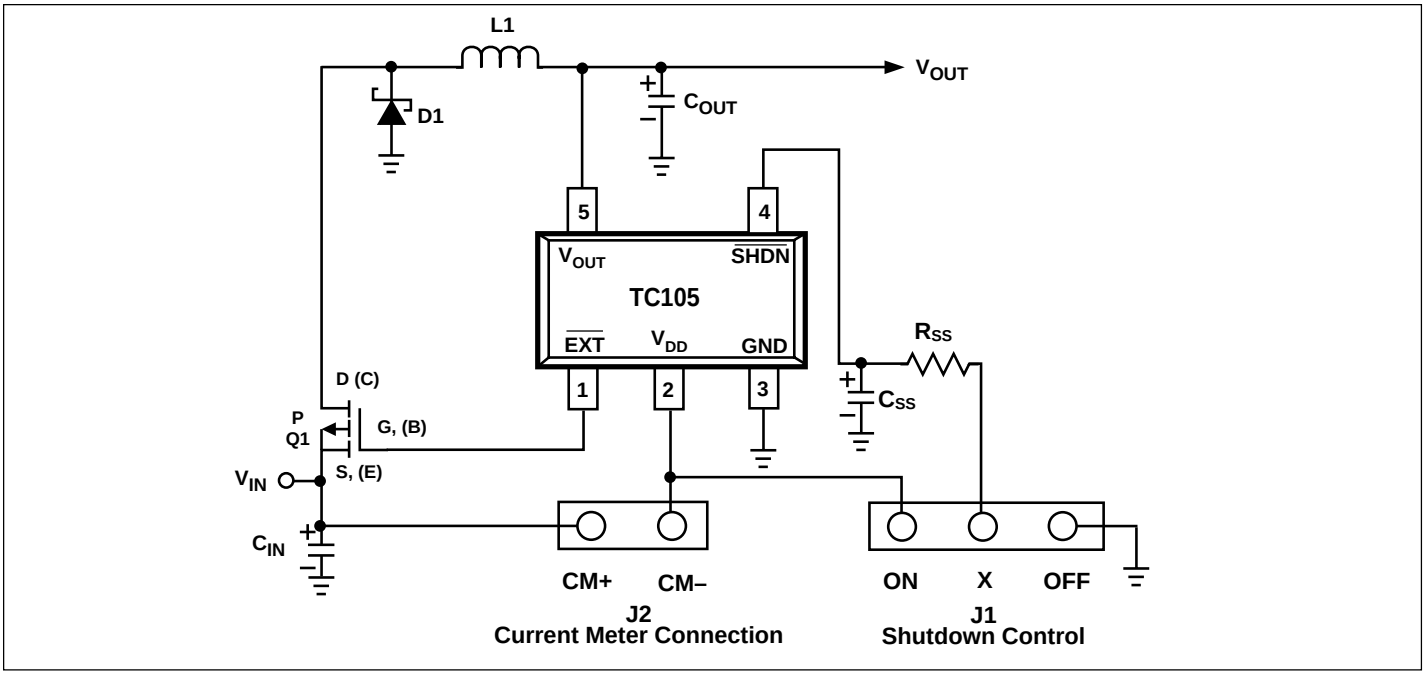
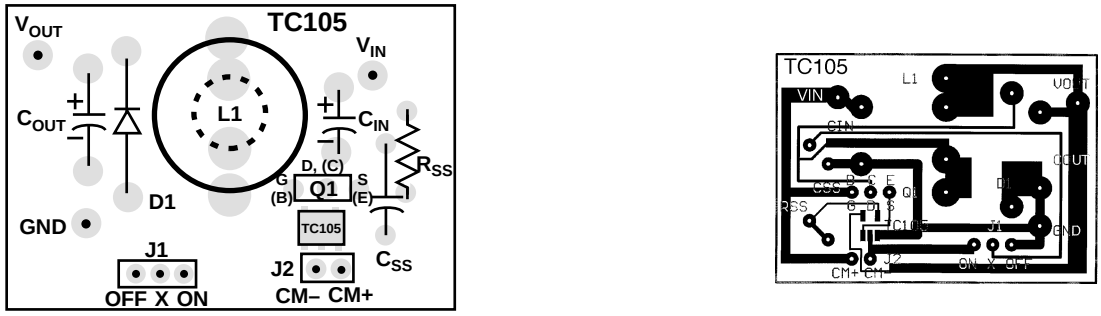


Figure 5. TC105 DEMO Card Schematic



Component Placement (Blank Side of Board)

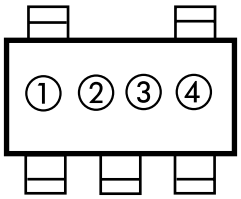
Circuit Side of Board (Actual Size)

Figure 6. Component Placement

TC105

MARKINGS

5-Pin SOT-23A



① represents product classification; TC105 = M

② represents 1st integer of voltage and frequency

Symbol	
300KHz	**Output Voltage**
1	1.
2	2.
3	3.
4	4.
5	5.
6	6.

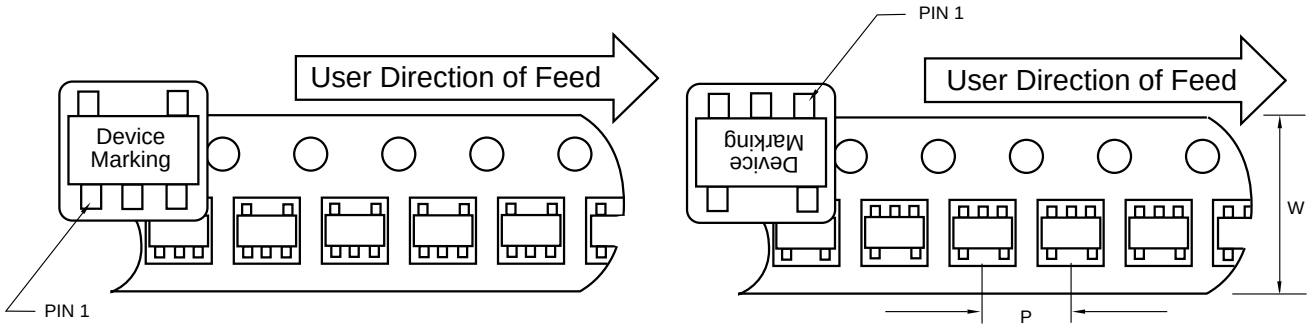
③ represents 1st decimal of voltage and frequency

Symbol	
300KHz	**Output Voltage**
A	.0
B	.1
C	.2
D	.3
E	.4
F	.5
H	.6
K	.7
L	.8
M	.9

④ represents production lot ID number

TAPING FORMS

Component Taping Orientation for 5-Pin SOT-23A (EIAJ SC-74A) Devices



Standard Reel Component Orientation
TR Suffix Device
(Mark Right Side Up)

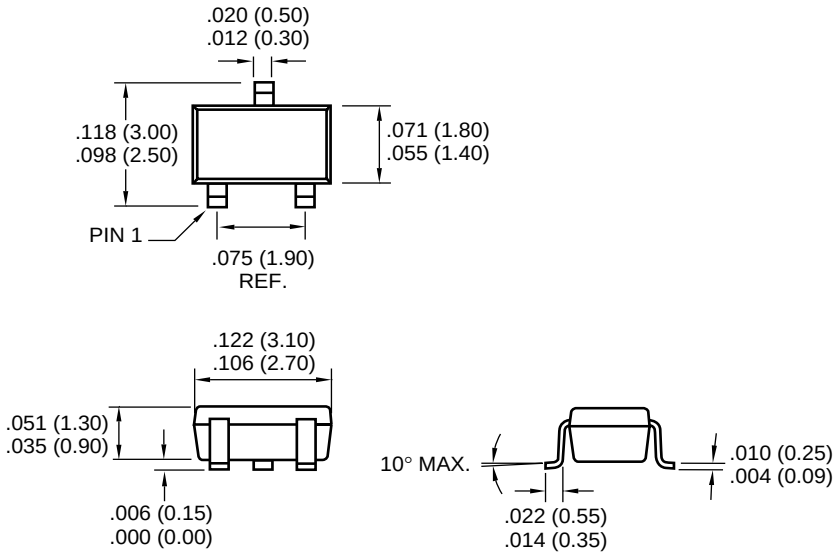
Reverse Reel Component Orientation
RT Suffix Device
(Mark Upside Down)

Carrier Tape, Number of Components Per Reel and Reel Size

Package	Carrier Width (W)	Pitch (P)	Part Per Full Reel	Reel Size
5-Pin SOT-23A	8 mm	4 mm	3000	7 in

PACKAGE DIMENSIONS

3-Pin SOT-23A (EIAJ SC-59)



Dimensions: inches (mm)

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