FAIRCHILD

A Schlumberger Company

SH1605
5 A Efficient
Switching Regulator

Hybrid Products

Description

The SH1605 is a hybrid switching regulator with high output current capabilities. It incorporates a temperature-compensated voltage reference, a duty-cycle controllable oscillator, error amplifier, high current-high voltage output switch, and a power diode. The SH1605 can supply 5 A of regulated output current over a wide range of output voltage.

- **STEP DOWN SWITCHING REGULATOR**
- **OUTPUT ADJUSTABLE FROM 3.0 TO 30 V**
- **5 A OUTPUT CURRENT**
- **HIGH EFFICIENCY**
- **UP TO 150 W OUTPUT POWER**

Absolute Maximum Ratings $T_A = 25°C$ unless otherwise specified

$V_{IN} - V_{OUT(min)}$	5 V
Input Voltage	35 V Max
Output Current	6 A
Operating Temperature T_J	150°C
Internal Power Dissipation	20 W
Storage Temperature Range	−65°C to +150°C
Duty Cycle	$20 \leq D \leq 80\%$
V_{7-8}	60 V
I_{7-8}	6 A

Connection Diagram
8-Pin TO-3 Type
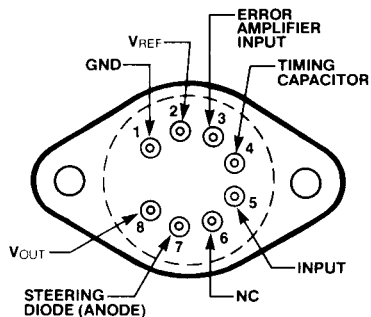
Case = Ground

Order Information

Type	Package	Code	Part No.
SH1605	Metal	8G	SH1605S

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Block Diagram
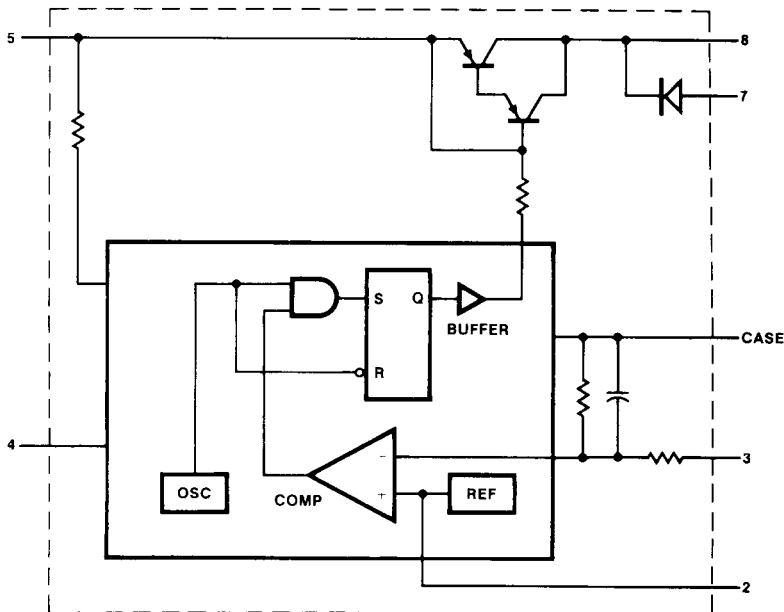
Electrical Characteristics $T_C = 25°C$, $V_{IN} = 15$ V unless otherwise specified.

Symbol	Characteristics	Conditions	SH1605			Units
			Min	Typ	Max	
V_{OUT}	Output Voltage	$V_{IN} \geq V_O + 5$ V, $I_O = 2$ A	3.0		30.0	V
V_S	Switch Saturation	$I_{OUT} = 5.0$ A,		1.5	2.0	V
		$I_{OUT} = 2.0$ A		1.0	1.2	V
V_F	Diode On Voltage	$I_{OUT} = 5.0$ A,		2.2	2.8	V
		$I_{OUT} = 2.0$ A		1.6	2.0	V
V_{CC}	Supply Voltage		10		35	V
I_{RD}	Diode Reverse Current	$V_{RD} = 25$ V		2.0		μA
I_Q	Quiescent Current	$I_{OUT} = 0.2$ A		30		mA

Reference and Oscillator Section

V_3	Voltage on Pin 3			2.5		V
$\Delta V_3 / T$	V_3 Temperature Coefficient			150		ppm / °C
I_4	Charging Current—Pin 4			25		μA
V_4	Voltage Swing—Pin 4			0.5		V
I_14	Discharging Current—Pin 4			225		μA

Switching Characteristics

Symbol	Characteristics	Conditions	Min	Typ	Max	Units
t_r	Voltage Rise Time	$I_{OUT} = 2.0$ A		700		ns
		$I_{OUT} = 5.0$ A		1.8		μs
t_f	Voltage Fall Time	$I_{OUT} = 2.0$ A		700		ns
		$I_{OUT} = 5.0$ A		900		ns
t_s	Storage Time	$I_{OUT} = 5.0$ A		2.6		μs
t_d	Delay Time	$I_{OUT} = 5.0$ A		2.5		μs

Thermal Characteristics

P_D	Power Dissipation	$I_{OUT} = 5.0$ A $V_{OUT} = 10$ V		16		W
η	Efficiency	$V_{OUT} = 10$V, $I_{OUT} = 5$ A		75		%
θ_{J-C}	Thermal Resistance			4.5		°C / W

Notes
1. θ_{C-A}. Typical is 30°C/W for natural convection cooling.
2. For heatsinking requirements see power derating curve.

Power Derating Curve
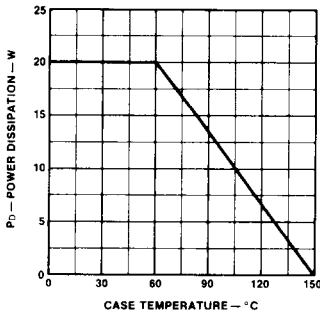
Design Equations

$$\text{Efficiency } (\eta) = \frac{P_{OUT} \times 100}{P_{IN}}$$

$$\text{Transistor DC Losses } (P_T) = I_{OUT} \times V_S \frac{t_{ON}}{t_{ON} + t_{OFF}}$$

$$\text{Diode DC Losses } (P_D) = I_{OUT} \times V_F \frac{t_{OFF}}{t_{ON} + t_{OFF}}$$

$$\text{Drive Circuit Losses } (D_L) = \frac{V_{IN}2}{300} \times \frac{t_{ON}}{t_{ON} + t_{OFF}}$$

Switching Losses Transistor:

$$(P_S) = V_{IN} \times I_{OUT} \frac{t_r + t_f}{2(t_{ON} + t_{OFF})}$$

$$\text{Transistor Duty Cycle} = \frac{t_{ON}}{t_{ON} + t_{OFF}} = \frac{V_{OUT}}{V_{IN}}$$

$$\text{Diode Duty Cycle} = \frac{t_{OFF}}{t_{ON} + t_{OFF}} = 1 - \frac{V_{OUT}}{V_{IN}}$$

$$\text{Power Inductor } (P_L) = I_{OUT}^2 \times R_L \text{ (Winding Resistance)}$$

Efficiency:

$$(\eta) = \frac{V_{OUT}\, I_{OUT}}{V_{OUT}\, I_{OUT} + P_T + P_D + D_L + P_S + P_L} \times 100$$

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Design Considerations

Figure 1 is a typical design of a step-down switching regulator using the SH1605.

Nominal Design Objectives

V_{OUT} = +5 V	Line Regulation = 2%
$I_{OUT(max)}$ = 5.0 A	Load Regulation = 2%
$I_{OUT(min)}$ = 1.0 A	Ripple (max) = 0.1 $V_{pk\text{-}pk}$
V_{IN} = 12 to 18 V	Efficiency = 70%

First, R3 is calculated from *Equation 5*:

$$R3 = \frac{(2 \times 10^3)(V_{OUT} - 2.5)}{2.5} = 2\ k\Omega$$

Since the required $I_{OUT(min)}$ is 1 A to maintain continouous operation, the peak-to-peak current excursion must be equal to 2 A or less, i.e.,

$$\Delta I_1 = 2\ I_{OUT(min)}$$

To calculate the value of the inductor, assume the nominal on time of the system as 60 μs. This value is chosen keeping the efficiency/component-size trade-off in mind. From *Equation 1*.

$$L1 = \left(\frac{V_{IN} - V_{OUT}}{\Delta I_1}\right) t_{on} = \frac{10}{2}(6 \times 10^{-5}) = 300\ \mu H$$

where $V_{IN(nom)}$ = 15 V, t_{on} = 60 μs

$$\Delta I_1 = 2\ A$$

One very important element in achieving the optimum performance in a switching regulator is to insure the inductor is kept below the specified saturation limits.

Since the timing capacitor controls the 60 μs on time, C_T can be determined using *Equation 7*:

$$C_T = \frac{(t_{on})(I_C)}{\Delta V} = \frac{(6 \times 10^{-5})(2.5 \times 10^{-5})}{5 \times 10^{-1}} = 3000\ pF$$

where I_C = 25 μA nominal per data sheet.

The final step is to determine the requirements for the output capacitor C_O to obtain the desired value of ripple voltage. Consideration must be given to the absolute value of C_O as well as the internal effective series resistance (ESR). Since the capacitor size is inversely proportional to the operating frequency, the lowest frequency of operation must be calculated. Minimum operating frequency can be determined by using $\Delta I_{1(max)}$ vs $\Delta I_{1(nom)}$ in *Equation 9*.

$$\text{Minimum Frequency} = \frac{1}{1.3 \times 10^{-4}} = 7.7\ kHz$$

The output capacitor can now be determined as follows:

$$C_{O(min)} = \frac{\Delta I_1}{(8\ f_{(min)}\ V_{ripple(max)})}$$

$$= \frac{2}{(8 \times 7.7 \times 10^3) \times (1 \times 10^{-1})}$$

$$= 325\ \mu F$$

The maximum acceptable ESR is therefore

$$ESR(max) = \frac{V_{ripple(max)}}{\Delta I_{1(max)}} = 0.025\Omega$$

Normally, the minimum capacitance value should be increased considerably if a low ESR capacitor is not used.

As a final step for minimizing switching transients at the device input, a low ESR capacitor must be used for decoupling purposes between the input terminal and ground.

The SH1605 is a highly versatile building block for high current, step-down switching regulator systems. However, to attain optimum performance and reliability the following guidelines should be followed:
- Keep operating period long, relative to the device switching times, for optimum efficiency.
- Insure that the inductor stays out of saturation and minimize the series resistance.
- Use high quality capacitors for input and output to minimize ripple and noise.

Fig. 1 Design Example
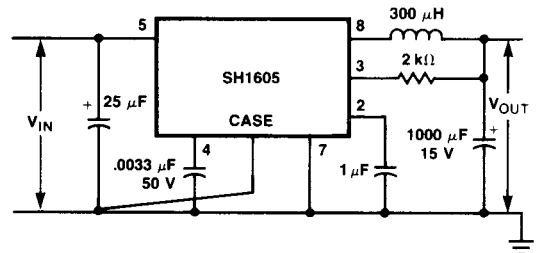
Note

Circuit Performance

V_{IN} = 12-18 V

V_{OUT} = 5.06 V

Load Reg. = 50 mV (1 A ≤ I_{OUT} ≤ 5 A)

Line Reg. = 50 mV (12 V ≤ V_{IN} 18 V)

SH1605 must be mounted on a heat sink with a maximum thermal resistance of ϕ_{CA} ≤ 4° C/W.