High-Efficiency, Step-Down DC/DC Controller

FEATURES

- 4V to 18V Input Voltage Operation.
- High Efficiency (up to 95%).
- Low Quiescent Current at 90μA.
- Pulse-Skipping and Pulse-Frequency Modulation.
- Inputs-Uncommitted Current Sense Comparator.
- Duty Cycle Adjustable.
- 90KHz to 280KHz Oscillator Frequency.
- Power-Saving Shutdown Mode (8μA Typical).
- Push-Pull Driver Output.

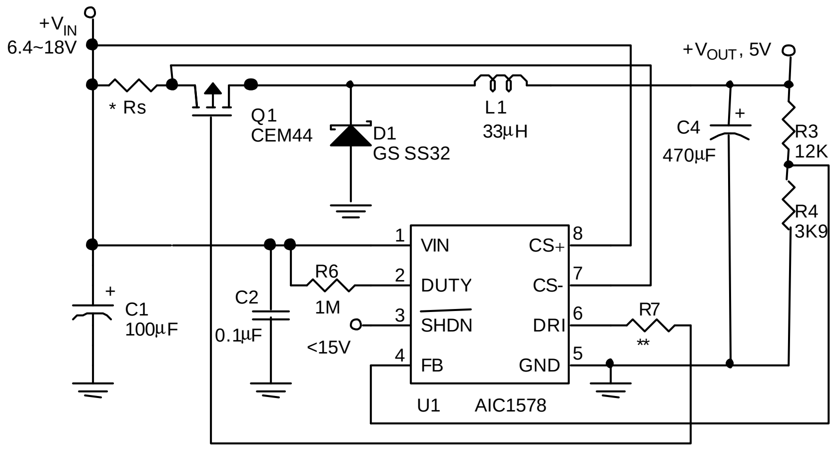
APPLICATIONS

- Notebook 5V/3.3V Main Power
- Step-Down DC/DC Controller Module.
- Constant Current Source for Battery Chargers.

DESCRIPTION

The AIC1578 is a high performance step-down DC/DC controller, designed to drive an external P-channel MOSFET to generate programmable output voltages. Two main schemes of Pulse-Skipping and Pulse-Frequency Modulation are employed to maintain low quiescent current and high conversion efficiency under wide ranges of input voltage and loading condition. The AIC1578 delivers 10mA to 2A of output current with 87%~93% efficiency at V_{IN}=9V, V_{OUT}=5V condition. A current sense comparator with both inverting and non-inverting input uncommitted is included to provide the crucial function of either current limit protection or constant output current control. When the AIC1578 is used in a high-side current sensing step-down constant current source, the efficiency is typically greater than 90%. Duty cycle can be adjusted to greater than 90% by connecting a resistor from DUTY pin to V_{IN}. Quiescent current is about 90μA and can be reduced to 8μA in shutdown mode. Switching frequency being in around 90KHz to 280KHz range, small size switching components are ideal for battery powered portable equipment.

TYPICAL APPLICATION CIRCUIT



$$I_P = I_{O,MAX} + \frac{V_O(V_{IN} - V_O)}{2V_{IN} \times f_S \times L}$$

$$R_S = \frac{V_{TH}}{I_P} = \frac{50mV}{I_P} = \frac{0.1V_{IN} f_S L}{2V_{IN} f_S L I_{O,MAX} + V_{IN} V_O - V_O^2}$$

V_{IN}: Input voltage
V_{OUT}: Output voltage
f_S: Working frequency
L= Inductor value
$I_{O,MAX}$: Maximum Output current
V_{TH}: Current Limit Sense Threshold
**V_{IN}>15V, R7=15Ω
$V_{IN} \leq 15V$, R7=0Ω

DC/DC Buck Converter

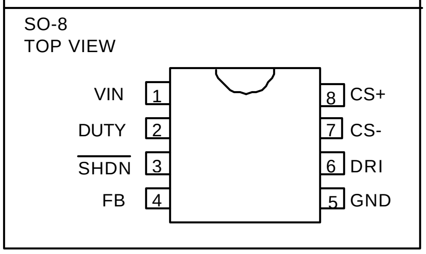
ORDERING INFORMATION

AIC1578CXXX

- PACKING TYPE
  TR: TAPE & REEL
  TB: TUBE
- PACKAGING TYPE
  S: SMALL OUTLINE
  N: PLASTIC DIP

Example: AIC1578CSTR
→ in SO-8 Package & Taping & Reel Packing Type
(CN is not available in TR packing)

PIN CONFIGURATION



ABSOLUTE MAXIMUM RATINGS

VIN Supply Voltage... 20V

DUTY Voltage... 20V

$\overline{SHDN}$ Voltage.. 15V

Operating Temperature Range.. 0°C~70°C

Storage Temperature Range.. -65°C~ 150°C

TEST CIRCUIT

Refer to TYPICAL APPLICATION CIRCUIT.

ELECTRICAL CHARACTERISTICS (V_{IN}= 13V, T_A=25°C, unless otherwise specified.)

PARAMETERS	CONDITIONS	MIN.	TYP.	MAX.	UNIT
Operation Voltage		4		20	V
Quiescent Current	V_{FB} = 1.5V		90	160	µA
Shutdown Mode Current	$V_{\overline{SHDN}}$ = 0V		8	20	µA
Internal Reference Voltage		1.16	1.22	1.28	V
Driver Sinking "ON Resistance"			16		Ω
Driver Sourcing "ON Resistance"			11		Ω
Current Limit Sense Threshold	V_{CS+} = 13V	50	70	90	mV
Shutdown Threshold		0.8	1.5	2.4	V
$\overline{SHDN}$ Pin Leakage Current	$V_{\overline{SHDN}}$ < 15V			1	µA
Duty Cycle	V_{DUTY} = V_{IN}		71		%
Oscillator Frequency	V_{DUTY} = V_{IN}		225		KHz

■ TYPICAL PERFORMANCE CHARACTERISTICS

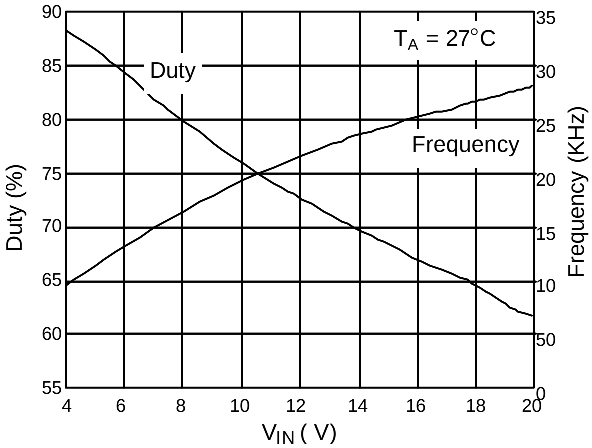


Fig. 1 Frequency & Duty Cycle vs. V_{IN}

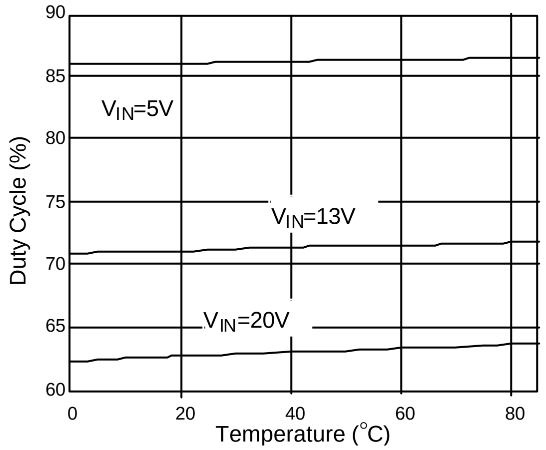


Fig. 2 Duty Cycle vs.Temperature

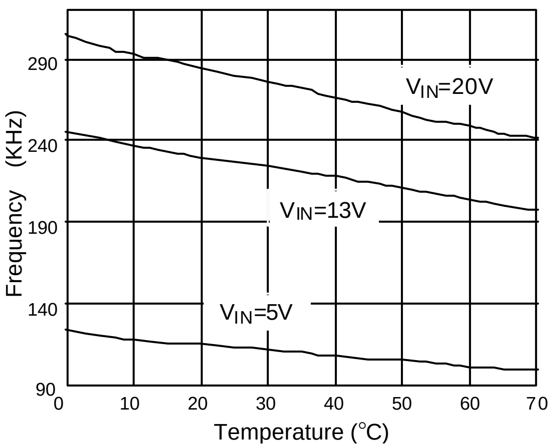


Fig. 3 Frequency vs. Temperature

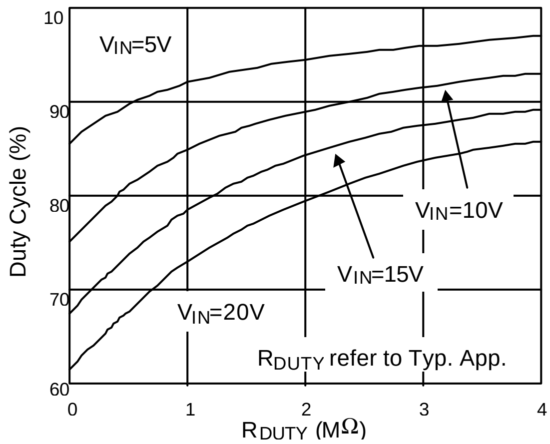


Fig. 4 Duty Cycle vs. R_{DUTY}

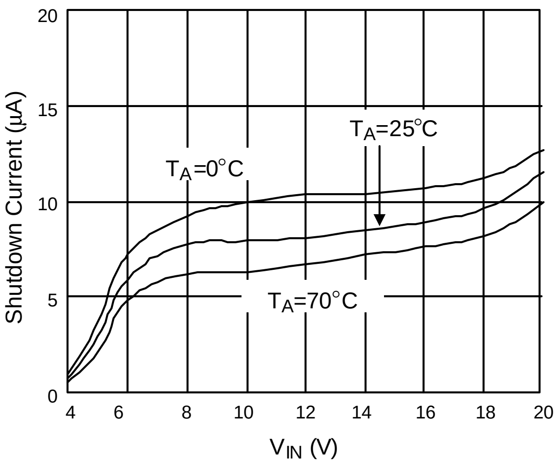


Fig. 5 Shutdown Current vs. V_{IN}

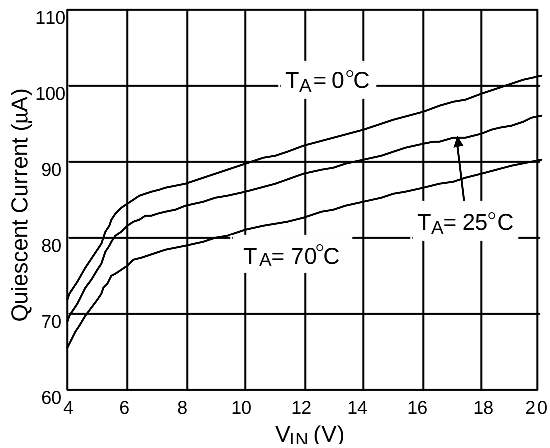
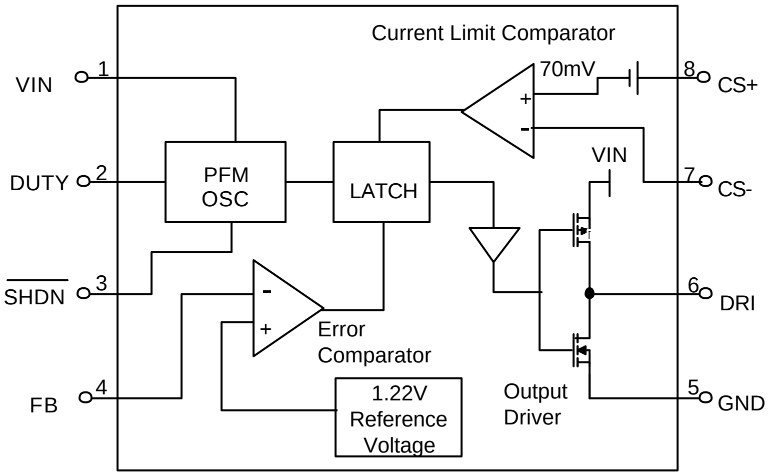


Fig. 6 Quiescent Current vs. V_{IN}

■ BLOCK DIAGRAM



■ PIN DESCRIPTIONS

PIN 1: VIN - Input supply voltage, ranged from 4V to 18V is recommended.

PIN 2: DUTY - Duty cycle adjustment pin. To be tied to the VIN pin directly or through a resistor R_{DUTY} to adjust oscillator duty cycle. R_{DUTY} must be over 1MΩ if V_{IN}=20V.
See TYPICAL PERFORMANCE CHARACTERISTICS.

PIN 3: $\overline{SHDN}$ - Logical input to shutdown the chip:
$V_{\overline{SHDN}}$ = High for normal operation.
$V_{\overline{SHDN}}$ = Low for shutdown.
This pin should not be floating or be forced to over 15V. In shutdown mode DRI pins is at high level.

PIN 4: FB - Feedback comparator input, to compare the feedback voltage with the internal reference voltage. Connecting a resistor R1 to converter output node and a resistor R2 to ground yields the output voltage:

V_{OUT}=1.22 x (R1+R2)/ R2

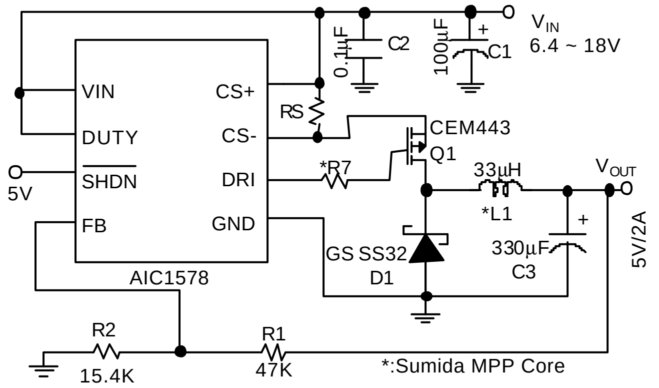
PIN 5: GND - Power ground.

PIN 6: DRI - Push-pull driver output to drive an external P-channel MOSFET or PNP transistor. When driving a PNP bipolar transistor, a base resistor and a capacitor to the base of PNP are recommended.

PIN 7: CS- - Current sense comparator inverting input. This pin voltage should go over 2V but not to exceed VIN voltage.

PIN 8: CS+ - Current sense comparator non-inverting input. This pin voltage should go over 2V but not to exceed V_{IN} voltage.

■ APPLICATION EXAMPLES



V_{IN}>15V, R7=15Ω
V_{IN}≤15V, R7=0Ω

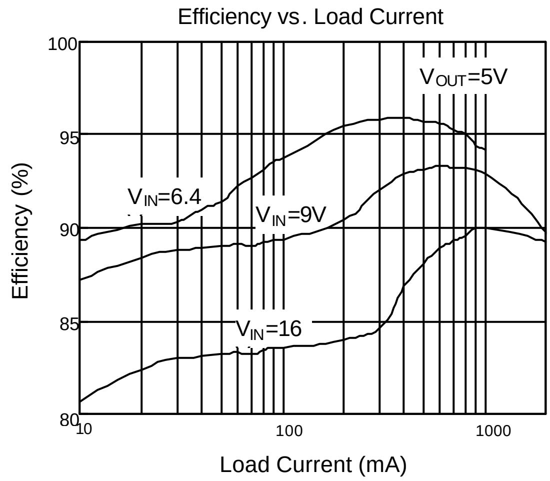
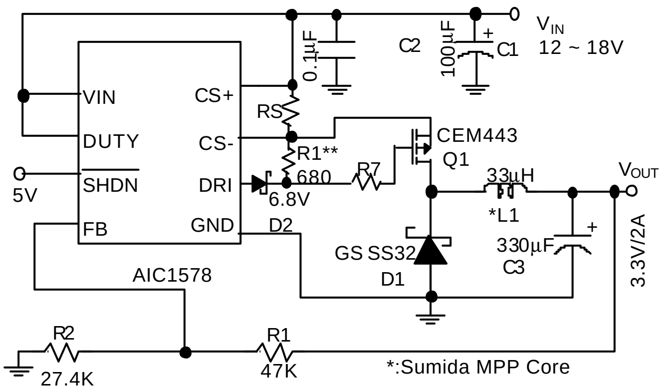


Fig. 7 5V Step-Down Converter



V_{IN}>15V, R7=15Ω
V_{IN}≤15V, R7=0Ω
**R1 value is based on the current rating of D2

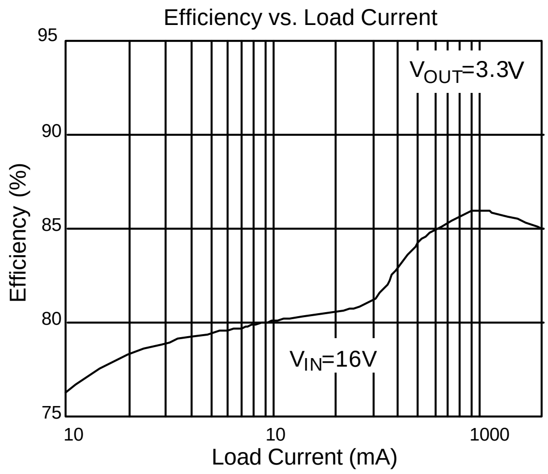
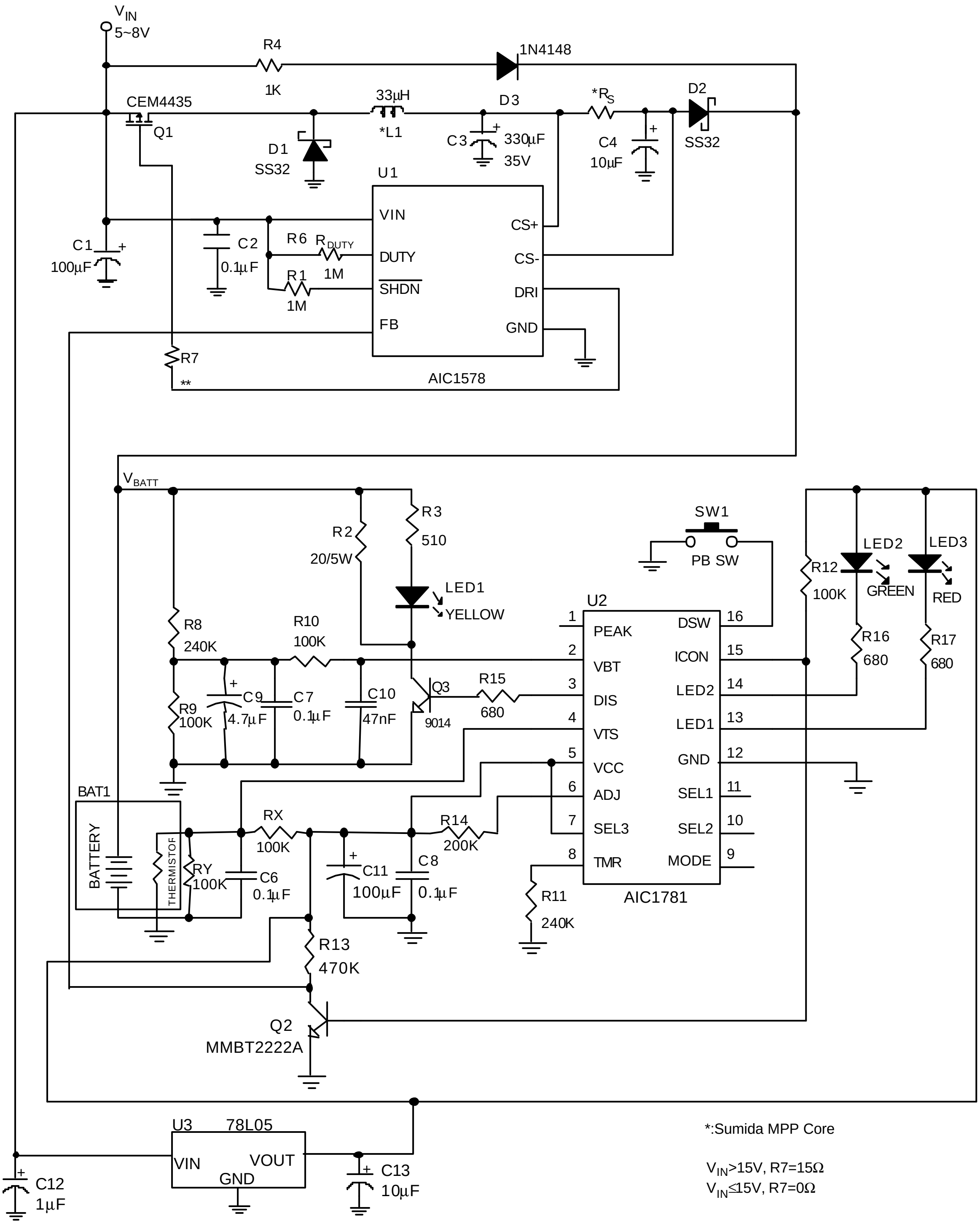


Fig. 8 3.3V Step-Down Converter

APPLICATION EXAMPLES (Continued)



NOTE: R_S =0.1Ω, charge current =0.5A ±10%, V_{IN}>V_{BATT} +3.5V
R_S =0.05Ω, charge current =1A±10%, V_{IN}>V_{BATT} +4V
R_S =0.033Ω, charge current =1.5A ±10%, V_{IN}>V_{BATT} +4.5V
Efficiency>90%, measured at CS- node
3~5 NiMH/NiCd Cells

Fig. 9 Battery Charge Circuit with High-Side Current Sensing Constant Current Source

APPLICATION INFORMATION

A. Start Up Design

In order to eliminate the over shoot issue which happens when Vout is under 5V, we are offering two solutions for AIC1578 Buck Controller.

1. Buck Converter with 12V<Vin<18V

While AIC1578 is used at Buck Circuit with V_{OUT}<5V, add a resistor R1 at 680 ohm and Zener diode D2 at 6.8V.

This solution will promote the temperature of MOSFET Q1. The smaller the resistor value is, the lower temperature rises. The resistor value is depended on the reverse current rating of the Zener diode. Refer to its databook for the reverse current rating. Note that the current is strictly limited by the spec.

A temperature rise of 1°C for Q1 results from the addition of R1=680ohm, D2=6.8V to the original condition (Vin=12V, Vout=3.3V and I_{OUT}=1.5A). Yet, the efficiency of the system remains nearly the same.

Note: The input voltage rating in this circuit is 12V rather than 4V. And the rating can be various depending on the value of Zener diode D2. Please refer to Fig3.

The current sense resistor Rs is used for over current protection. Due to the concerns about the power loss, cost, and size, many users do not choose Rs in their Buck converter application. Damage caused by unexpected current (over rating current) could be done to Q1, U1 and the circuits attached to V_{OUT} when Rs is not used.

For the calculation of Rs, please refer to the formula of Rs in "Typical Application" above.

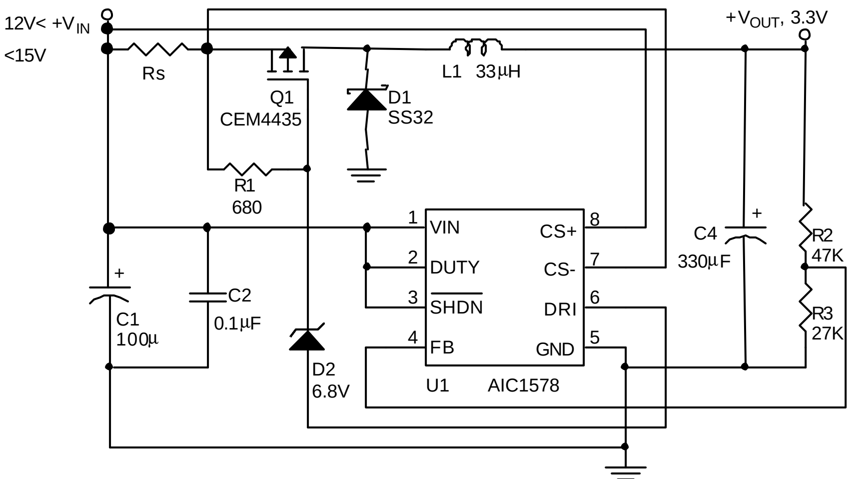
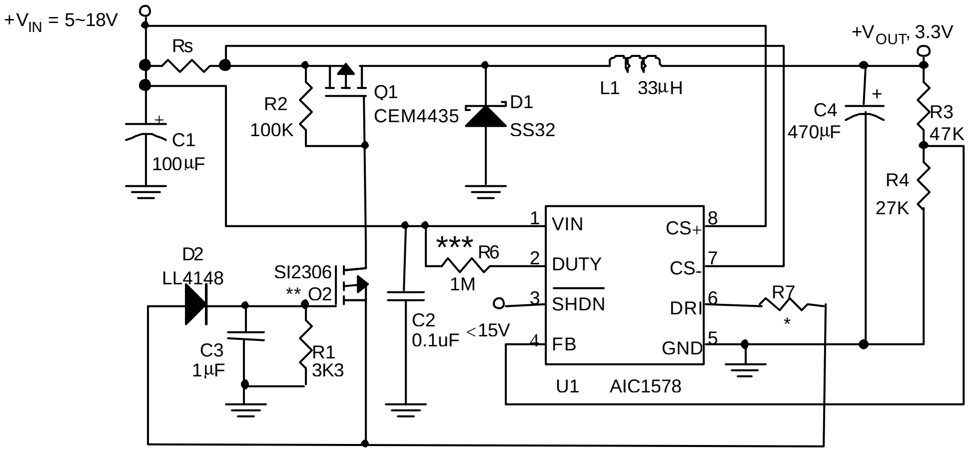


Fig. 10 DC/DC Buck Converter V_{OUT}=3.3V



* V_{IN}>15V, R7=15Ω

V_{IN}≤15V, R7=0Ω*

** Q2 = CES7002 when V_{IN}=5V

*** R6 can adjust the duty cycle Max. It can be 0Ω

Fig 11. DC/DC Buck Converter V_{OUT}=3.3V

B. Short Circuit Protection Design

1. As we know, Short Circuit Protection (abbreviated as SCP) does not always exist in the DC-DC converter circuit. The fact is usually the DC-DC converter provides the circuits attached to VOUT with low power or low voltage. Sometimes it has less concern about safety. And its probability of short-circuit is quite low. That gives users reasons to ignore the use of SCP circuit. However, we would still like to point out the importance of the protection. With SCP, the system will be well protected in any situation. Two SCP circuits are introduced as follows for your reference.

2. Design1: shown as Fig. 12.

   Method: Add a fast fuse to V_{OUT}.

   Fuse select guide: Fuses, which can take the start up current, and break down fast on unexpected current.

   Note: Replacement of fuse is needed after short circuit.

3. Design 2: shown as Fig. 13.

   Method: Add a SCP circuit

   Note: 1. The time constant, which is directly related to R1 and C1, has a serious effect on the circuit.

   2. Circuit can be recovered by removing the short circuit event from the system.

   3. The condition for applying this design is V_{OUT} ≥3V.

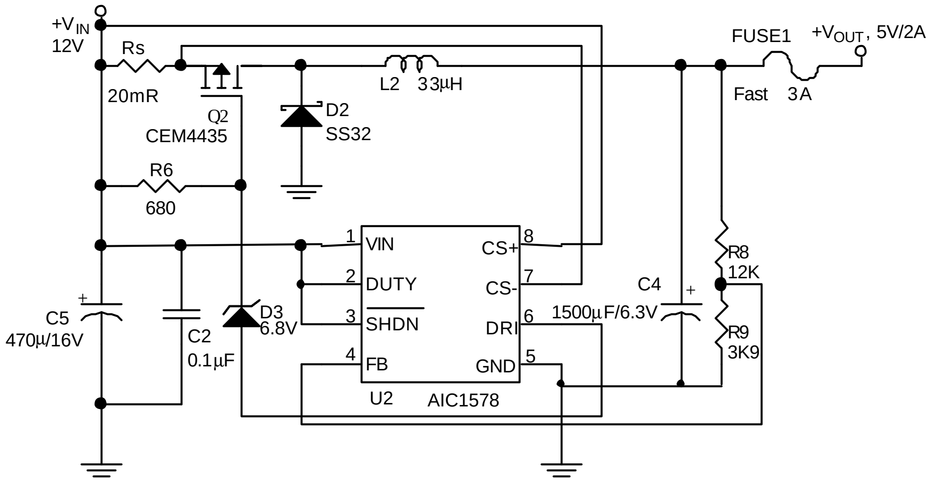


Fig 12. Add a Fast Fuse Solution

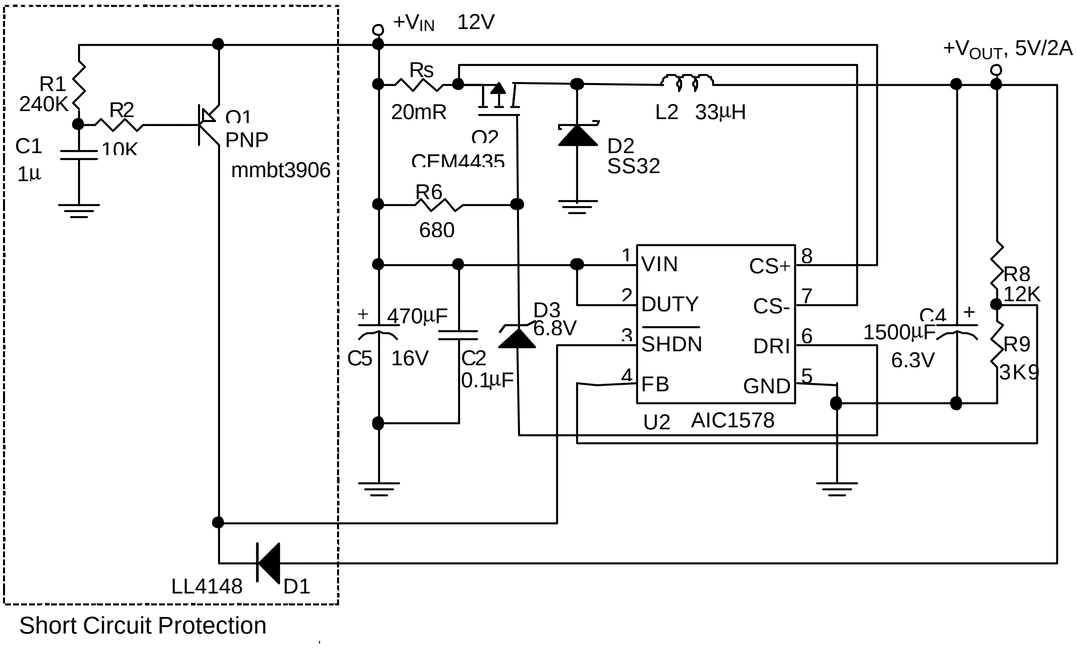
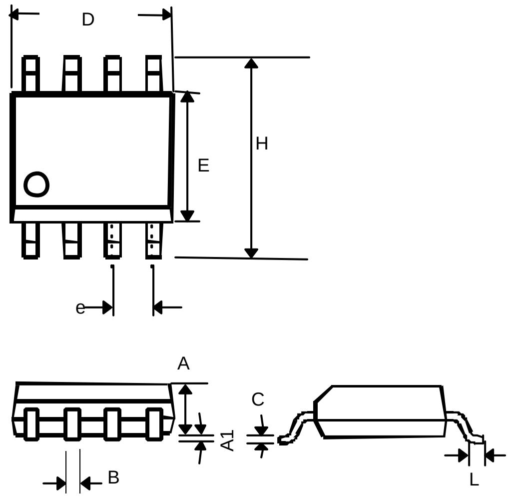


Fig 13. Add A Short Circuit Protection Circuit Solution

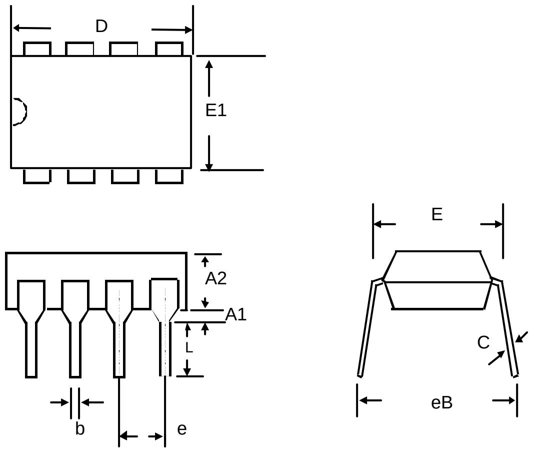
■ PHYSICAL DIMENSIONS

- **8 LEAD PLASTIC SO (unit: mm)**



SYMBOL	MIN	MAX
A	1.35	1.75
A1	0.10	0.25
B	0.33	0.51
C	0.19	0.25
D	4.80	5.00
E	3.80	4.00
e	1.27(TYP)	
H	5.80	6.20
L	0.40	1.27

- **8 LEAD PLASTIC DIP (unit: mm)**



SYMBOL	MIN	MAX
A1	0.381	—
A2	2.92	4.96
b	0.35	0.56
C	0.20	0.36
D	9.01	10.16
E	7.62	8.26
E1	6.09	7.12
e	2.54 (TYP)	
eB	—	10.92
L	2.92	3.81