TSM108

VOLTAGE AND CURRENT STEPDOWN PWM CONTROLLER

- OUTPUT HIGH SIDE CURRENT SENSING
- PRECISE CC/CV REGULATION
- ADJUSTABLE SWITCHING FREQUENCY
- ADJUSTABLE OVP/UVP UVLO THRESHOLDS
- STANDBY MODE FEATURE
- SUSTAINS 60V
- MINIMAL EXTERNAL COMPONENTS COUNT
- DRIVES EXTERNAL P-CHANNEL MOSFET OR PNP BIPOLAR TRANSISTORS

DESCRIPTION

TSM108 is a step-down PWM controller designed to drive an external P-channel MOSFET, providing constant voltage and constant current regulations in battery charger applications.

TSM108 can easily be configured for very wide voltage and current needs.

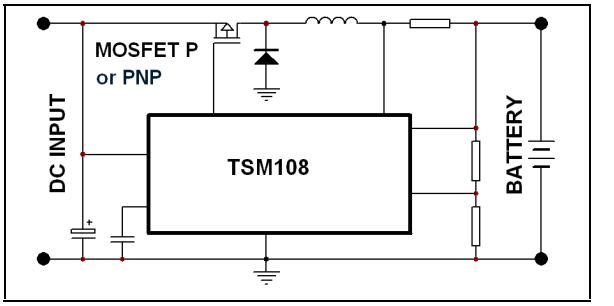
It has been realized in rugged BCD technology and includes a PWM generator, Voltage and Current control loops, a precise Voltage Reference, and a Gate Driver. The device can sustain 60V on Vcc, and therefore meet the standard Load Dump requirements of the 12V cars battery.

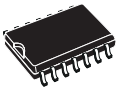
On boards there are other security functions which lock the external power in OFF state: OVLO (Over Voltage Lockout) and UVLO (Under Voltage Lockout). The mosfet gate is also protected from over voltage drive thanks to a 12V clamping protection circuit.

Moreover, a standby feature allows very low quiescent current when activated, but keeping safe the external power element when Off.

The IC is suitable for 12V car accessories, as well as other DC/DC step down converters.

APPLICATION DIAGRAM





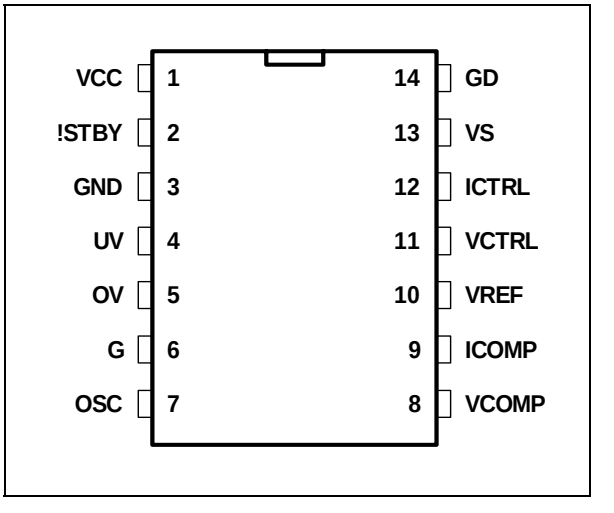
D
SO14
(Plastic Micropackage)

ORDER CODE

Part Number	Temperature Range	Package
		D
TSM108I	-40°, +125°C	•

D = Small Outline Package (SO) - also available in Tape & Reel (DT)

PIN CONNECTIONS (top view)



PIN DESCRIPTION

Name	Pin	Description
VCC	1	Supply voltage of both the signal part and the gate drive
!STBY	2	Standby Command; when Low, the device goes in standby
GND	3	Ground. Current return for both the gate drive and quiescent currents
UV	4	Programmable Under Voltage Lockout. Preset value is 8V min
OV	5	Programmable Over Voltage Lockout. Preset value is 33V max
G	6	Internally Connected to Ground
OSC	7	Oscillator pin to set operating frequency via external capacitor
VCOMP	8	Error amplifier output of voltage loop
ICOMP	9	Error amplifier output of current loop
VREF	10	2,52V Voltage Reference
VCTRL	11	Error amplifier of voltage loop, non inverting
ICTRL	12	Error amplifier of current loop inverting input
VS	13	Current sense Input
GD	14	Totem pole gate driver for external P-channel MOSFET

ABSOLUTE MAXIMUM RATINGS

Symbol	Parameter	Value	Unit
V_{CC}	Supply Voltage - Transient conditions (400ms max.)	60	V
T_j	Maximum Junction Temperature	150	°C
R_{thja}	Thermal Resistance Junction to Ambient (SO package)	130	°C/W
T_{stg}	Storage Temperature	-55 to +125	°C
V_{max}	Out Terminal Voltage (ICTRL, VS)	10	V

OPERATING CONDITIONS

Symbol	Parameter	Value	Unit
V_{CC}	Supply Voltage	UVLO to OVLO	V
V_{ter1}	Out Terminal Voltage (ICTRL, VS)	0 to 9	V
V_{ter2}	Out Terminal Voltage (UV, OV, OSC)	0 to 6	V

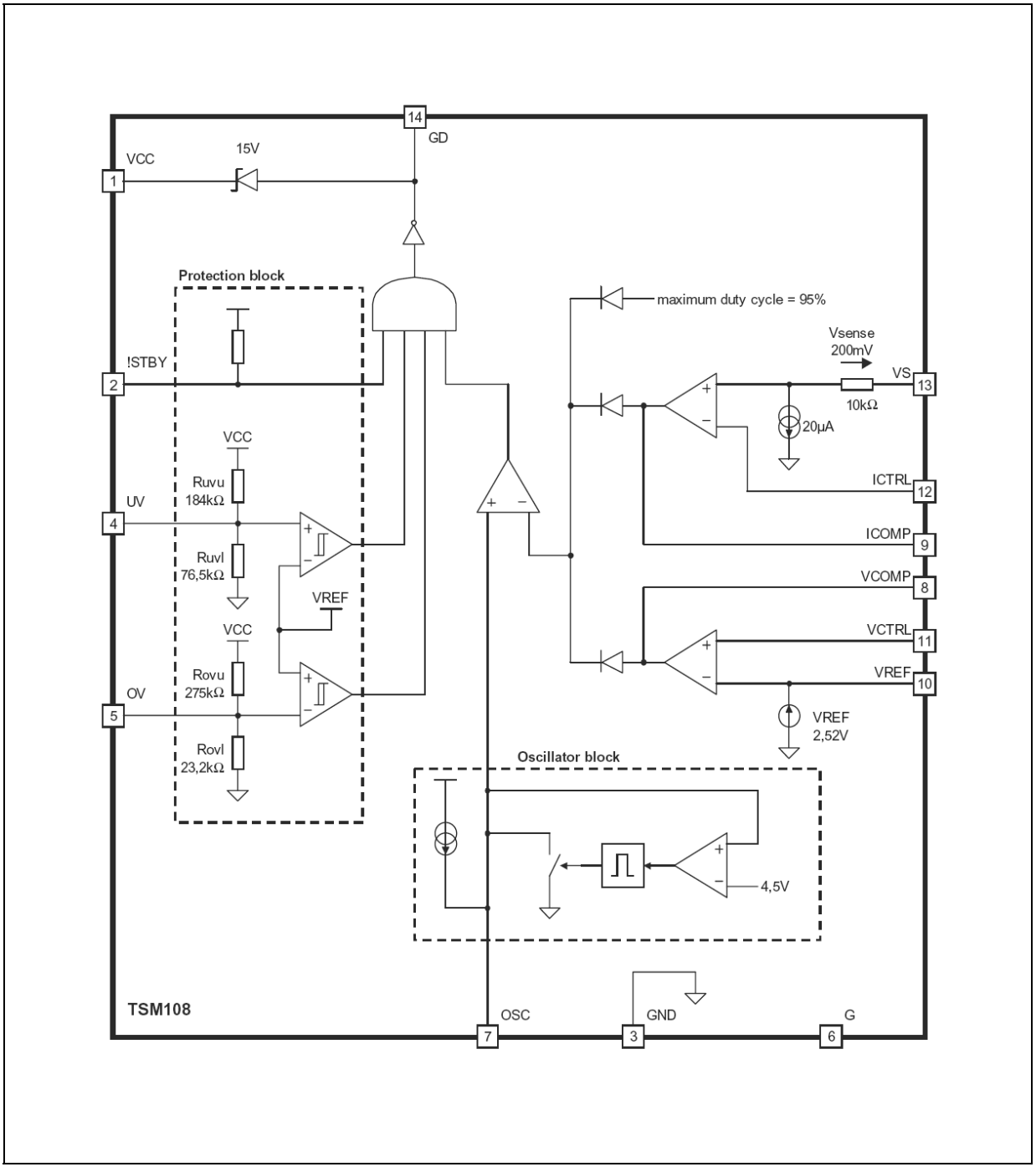
ELECTRICAL CHARACTERISTICS

T_{amb} = 25°C, V_{CC} + 12V (unless otherwise specified)

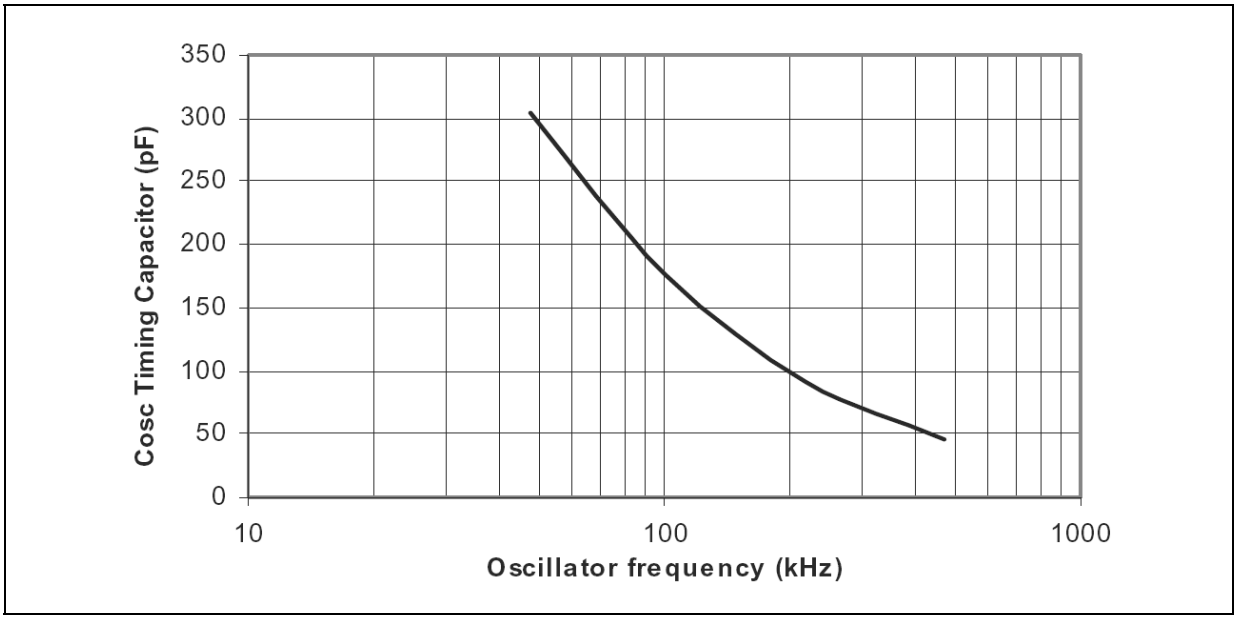
Symbol	Parameter	Test Condition	Min.	Typ.	Max.	Unit
CURRENT CONSUMPTION						
I_{CC}	Current Consumption			4	7	mA
STANDBY						
I_{stby}	Current Consumption in Standby Mode			150		µA
V_{sh}	Input Standby Voltage High Impedance	Internal Pull up resistor. Stby pin should be left open	2			V
V_{sl}	Input Standby Voltage Low				0.8	V
OSCILLATOR						
F_{OSC}	Frequency of the Oscilator	C_{OSC} = 220pF	70	100	130	kHz
VOLTAGE CONTROL [1) 2)]						
V_{ref}	Voltage Control Reference	T_{amb} = 25°C -25°C < T_{amb} < 85°C	2.450	2.520	2.590	V
CURRENT CONTROL [3) 4) 5)]						
V_{sense}	Current Control Reference Voltage	T_{amb} = 25°C -25°C < T_{amb} < 85°C	196 191	206	216 221	mV
GATE DRIVE - P CHANNEL MOSFET DRIVE						
I_{sink}	Sink Current - Switch ON	T_{amb} = 25°C -25°C < T_{amb} < 85°C	15	40		mA
I_{source}	Source Current - Swith OFF	T_{amb} = 25°C -25°C < T_{amb} < 85°C	30	80		mA
C_{load}	Input Capacitance of the PMOSFET [6)]			1	1.5	nF
PWM						
$\Delta_{max.}$	Maximum Duty Cycle of the PWM function			95	100	%
UVLO						
UV	Under Voltage Lock Out [7)]	-25°C < T_{amb} < 85°C	8		9	V
UV_{hyst}	UVLO Voltage Hysteresis - low to high			200		mV
R_{uvl}	Upper Resistor of UVLO bridge [8)]	T_{amb} = 25°C		184		kΩ
R_{uvl}	Lower Resistor of UVLO bridge (see note 8)	T_{amb} = 25°C		76.5		kΩ
OVLO						
OV	Over Voltage Lock Out (see note 7)	-25°C < T_{amb} < 85°C	32		35	V
OV_{hyst}	OVLO Voltage Hysteresis - low to high			400		mV
R_{ovl}	Upper Resistor of OVLO bridge (see note 8)	T_{amb} = 25°C		275		kΩ
R_{ovl}	Lower Resistor of OVLO bridge (see note 8)	T_{amb} = 25°C		23.2		kΩ

1. V_{ref} parameter indicates global precision of the voltage control loop.
2. Control Gain : A_v = 95dB ; Input Resistance : R_{in} = infinite ; Output Resistance : R_{out} = 700MΩ ; Output Source/Sink Current : I_{so}, I_{si} = 150µA ; Recommended values for the compensation network are : 22nF & 22kΩ in series between output and ground.
3. V_{sense} parameter indicated global precision of the current control loop.
4. Control Gain : A_v = 105dB ; Input Resistance : R_{in} =380kΩ ; Output Resistance : R_{out} = 105MΩ ; Output Source/Sink Current : I_{so}, I_{si} = 150µA ; Recommended values for the compensation network are : 22nF & 22kΩ in series between output and ground.
5. A current foldback function is implemented thanks to a systematic -6mV negative offset on the current amplifier inputs which protects the battery from over charging current under low battery voltage conditiions, or output short circuit conditions.
6. The Gate Drive output stage has been optimized for PMosfets with input capacitance equal to Cload. A bigger Mosfet (with input capacitance higher than Cload) can be used with TSM108, but the gate drive performances will be reduced (in particular when reaching the Dmax. PWM mode).
7. The given limits comprise the hysteresis (UV_{hyst}).
8. It is possible to modify the UVLO and OVLO limits by adding a resistor (to ground or to V_{CC}) on the pins UV and OV. The internal values of the resistor should be taken into account.

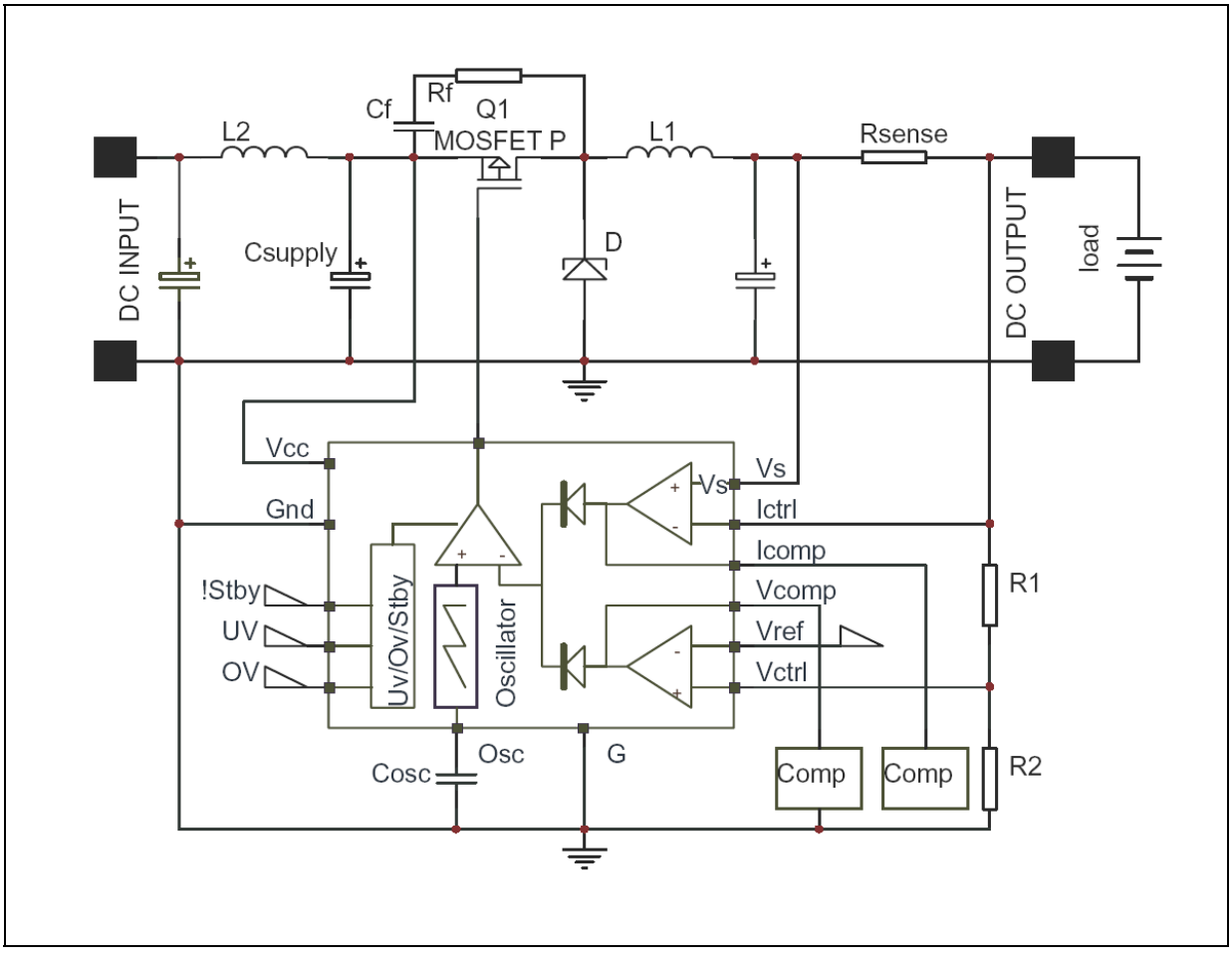
DETAILED INTERNAL SCHEMATIC



OSCILLATOR FREQUENCY VERSUS TIMING CAPACITOR



TSM108 AS A STAND ALONE DC/DC CONVERTER FOR CIGARETTE LIGHTER ACCESSORIES



PRINCIPLE OF OPERATION AND APPLICATION HINTS

Description of a DC/DC step down battery charger

1. Voltage and Current Controller

The device has been designed to drive an external P-Channel MOSFET in PWM mode and in Step Down topology. Its two integrated operational amplifiers ensure accurate Voltage and Current Regulation loops.

The Voltage Control dedicated operational amplifier acts as an error amplifier and compares a part of the output voltage (external voltage divider) to an integrated highly precise voltage reference (V_{ref}).

The Current Control dedicated operational amplifier acts as an error amplifier and compares the drop voltage through the sense resistor to an integrated low value voltage reference (V_s).

These two amplified errors are ORed through diodes, and the resulting signal ("max of") is a reference for the PWM generator to set the switching duty cycle of the P-Channel MOSFET transistor.

The PWM generator comprises an oscillator (saw tooth) and a comparator which gives a variable duty cycle from 0 to 95%. This PWM signal is the direct command of the output totem pole stage to drive the Gate of the P-Channel MOSFET.

Thanks to this architecture, the TSM108 is ideal to be used from a DC power supply to control the charging Voltage and Current of a battery in applications such as accessories for cellular phones chargers and post-regulation in power supplies.

2. Voltage Control

The Voltage Control loop can be set by an external voltage divider connected between the output positive line and the Ground reference. The middle point has to be connected to the V_{ctrl} pin of TSM108, and, if R1 is the upper resistor, and R2, the lower resistor of the voltage divider, the values of R1 and R2 are:

- eq1: Vref = Vout x R2 / (R1 + R2)

In Constant Voltage Control mode, the output voltage is fixed by to the R1/R2 resistor.

The total value of R1 + R2 voltage divider will determine the necessary bleeding current to keep the Voltage Control loop effective, even under "no load" conditions.

The current compensation loop is directly accessible from the pins Vcomp and Vref The compensation network is highly dependant of the operating conditions (switching frequency, external components R, L, C, MOSFET, output capacitor, etc...).

3. Current Control

The Current control loop can be set by the sense resistor that has to be placed in series on the output positive line. The output side of the Sense resistor has to be to Ictrl pin,and the common point between Rsense and the choke has to be connected to the Vs pin. If Ilim is the value of the charging current limit The value of Rsense should verify:

- eq2: $V_s = R_{sense} \times Il_{im}$

In Constant Current Control mode, the output current is fixed by to the Rsense resistor (under output short circuit conditions, please refer to this corresponding section).

The wattage calibration (W) of the sense resistor should be chosen according to:

- eq2a: $W > R_{sense} \times Il_{im}^2$

The current compensation loop is directly accessible from Icomp and Ictrl pin.

The compensation network is highly dependant on the operating conditions.

4. PWM frequency

The internal oscillator frequency is a saw tooth waveform that can be adjusted. In accessories like battery chargers, it is suggested to set the switching frequency at a typical 100kHz in order to obtain a good compromise between the ripple current and the choke size. An external capacitor connected between Osc pin and ground set the switching frequency

The maximum duty cycle of the PWM function is limited to 95% in order to ensure safe driving of the MOSFET.

5. Gate Drive

The Gate Drive stage is directly commanded from the PWM output signal. The Gate Drive stage is a totem pole Mosfet stage which bears different On resistances in order to ensure a slower turn ON than turn OFF of the P-Channel MOSFET. The values of the output Gate Drive currents are given by Isink (switch ON) and Isource (switch OFF).

The Gate Drive stage bears an integrated voltage clamp which will prevent the P-Channel MOSFET gate to be driven with voltages higher than 15V (acting like a zener diode between Vcc and GD (Gate Drive) pin.

6. Under Voltage Lock-Out, Over Voltage Lock-Out

The UVLO and OVLO security functions aim at the global application security.

When the Power supply decreases, there is the inherent risk to drive the P-Channel MOSFET with insufficient Gate voltage, and therefore to lead the MOSFET to linear operation, and to its destruction.

The UVLO is an input power supply voltage detection which imposes a complete switch OFF of the P-Channel MOSFET as soon as the Power Supply decreases below UV. To avoid unwanted oscillation of the MOSFET, a fixed hysteresis margin is integrated (UVhyst).

UVLO is internally programmed to ensure 8V min and 9V max, but thresholds can be adjusted by adding an external voltage divider to modify the value. The resistors typical values are given (Ruvh, Ruvl).

The OVLO is fixing the supply voltage at which the device (and the external power section) is switched OFF.

OVLO is internally programmed to ensure 32V min. and 33V max., but it can be adjusted with an external voltage divider.

Examples:

Let's suppose that the internally set value of the UVLO and / or OVLO level should be modified in a specific application, or under specific requirements.

6.1. UVLO decrease:

If the UVLO level needs to be lowered (UV1), an additional resistor (Ruvh1) must be connected between UV and Vcc following the equation:

- UV = Vref (Ruvh/Ruvl +1)
- UV1 = Vref ((Ruvh//Ruvh1)/Ruvl +1) (i)

where Ruvh//Ruvh1 means that Ruvh1 is in parallel to Ruvh

Solving i. we obtain:

- Ruvh1 = Ruvl x Ruvh (UV1 - Vref) / (Vref x Ruvh - Ruvl (UV1 - Vref))

As an example, if UV1 needs to be set to 6V, Ruvh1 = 256kΩ

6.2. UVLO increase:

If the UVLO level needs to be increased (UV2), an additional resistor (Ruvl2) must be connected between UV and Gnd following the equation.

- UV = Vref (Ruvh/Ruvl +1)
- UV1 = Vref (Ruvh/(Ruvl//Ruvl2) +1) (ii)

where Ruvl//Ruvl2 means that Ruvl2 is in parallel to Ruvl

Solving ii. we obtain:

- Ruvl2 = Vref x Ruvh Ruvl / (UV2 x Ruvl - Vref x (Ruvh + Ruvl))

As an example, if UV2 needs to be set to 12V, Ruvl2 = 132kΩ

6.3. OVLO decrease:

If the OVLO level needs to be lowered (OV1), an additional resistor (Rovh1) must be connected between OV and Vcc following the equation:

- OV = Vref (Rovh/Rovl +1)
- OV1 = Vref ((Rovh//Rovh1)/Rovl +1) (iii)

where Rovh//Rovh1 means that Rovh1 is in parallel to Rovh

Solving iii. we obtain:

- Rovh1 = Rovl x Rovh (OV1 - Vref) / (Vref x Rovh - Rovl (OV1 - Vref))

As an example, if OV1 needs to be set to 25V, Rovh1 = 867kΩ

6.4. OVLO increase:

If the OVLO level needs to be increased (OV2), an additional resistor (Rovl2) must be connected between OV and Gnd following the equation.

- OV = Vref (Rovh/Rovl +1)
- OV2 = Vref (Rovh/(Rovl//Rovl2) +1) (iv)

where Rovl//Rovl2 means that Rovl2 is in parallel to Rovl

Solving iv. we obtain:

- Rovl2 = Vref x Rovh Rovl / (OV2 x Rovl - Vref x (Rovh + Rovl))

As an example, if OV2 needs to be set to 40V, Rovl2 = 87kΩ

7. Standby Mode

In order to reduce to a minimum the current consumption of the TSM108 when in inactive phase, the Standby mode (!Stby pin of TSM108) imposes a complete OFF state of the P-Channel MOSFET, as well as a complete shut off of the main functions of the TSM108 (operational amplifier, PWM generator and oscillator, UVLO and OVLO) and therefore reduces the consuption of the device.

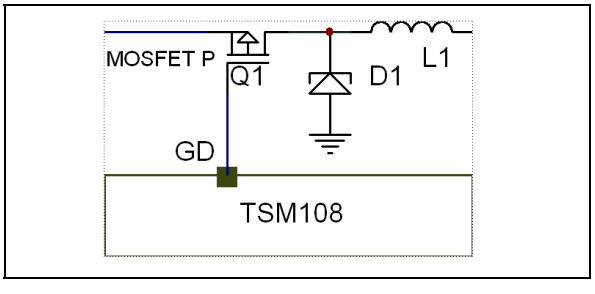
The !STBY command is TTL compatible.

8.Power Transistor: P-channel MOSFET or PNP Transistor?

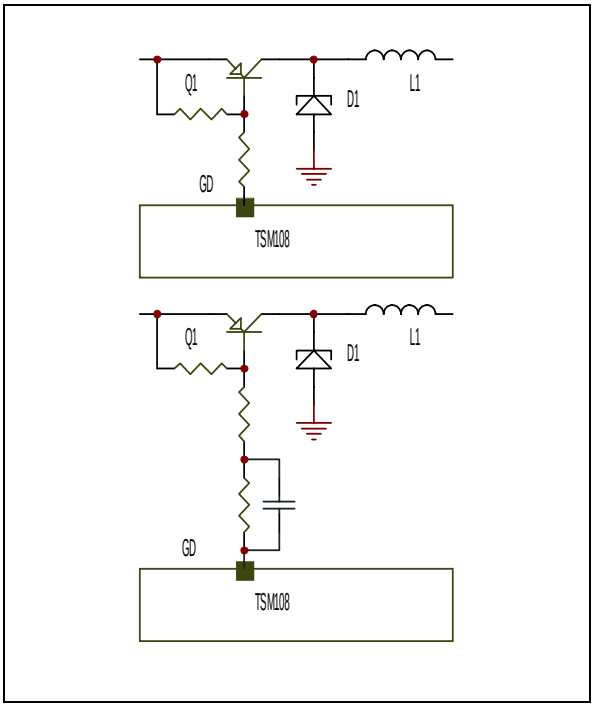
The TSM108 can drive, with minor external components change, either a P-channel MOSFET, or a PNP transistor. The user can choose the type of external power element, nevertheless, here follows a few considerations which will help to take this decision

The following figures shows two different schematics where both driving abilities of TSM108 are shown. The third schematic shows how to improve the switch off commutation when using a bipolar PNP transistor.

P-channel MOSFET



PNP transistor



The most immediate way to choose between a P-channel MOSFET or a PNP transistor is to consider the ratio between the output power of the application and the expected components price: the lower the power, the more suitable the PNP transistor is; the higher the power, the more suitable the P-channel MOSFET is. As an example, for a DC/DC adaptor built for 12V/6V, the recommended limit to choose between P-channel Mosfet and PNP transistor is around 200mA.

Below 200mA, the price/performance ratio of the PNP transistor is very attractive, whereas above 200mA, the P-channel Mosfet takes the advantage.

9. Calculation of the Passive Elements

Let's consider the following characteristics for a Cigarette Lighter Cellular Phone Battery Charger:

Vin = 12V - input voltage of the converter

Vout = 6V - output voltage of the converter

F = 100kHz - switching frequency of the converter adjustable with an external capacitor

Iout = 625mA - output current limitation

9.1. Inductor

The minimum inductor value to choose should apply to

Lmin = (1 - D) R / 2F

where R = Vout / Iout = 9.6W

and where D = Vout / Vin = 0.5

Therefore, Lmin = 24µH.

The frequency may vary depending on the temperature, due to the fact that the frequency is fixed by an external capacitor. Therefore, we must calculate the inductor value considering the worst case condition in order to avoid the saturation of the inductor, which is when the battery voltage is at it's highest, and the switching frequency at it's lowest. Thanks to the OVLO onboard function, the operation of the DC/DC converter will be stopped as soon as the voltage exceeds the OVLO level. Let's suppose the OVLO pin has been left open, therefore, the maximum input voltage of the DC/DC converter will be Vin max. = 32V. Frequency min stands in the range of 75kHz

In this case, D = 6 / 32 = 0.1875, therefore Lmin = 52µH.

If we allow a 25% security margin

Lmin = 68µH

9.2. Capacitor

The capacitor choice will depend mainly on the accepted voltage ripple on the output

Ripple = DVout / Vout = (1-D) / 8LCF²

Therefore, C = (1-D) / 8LRippleF². If C = 22µF, then Ripple = 0.4% which should be far acceptable.

Here again, the worst conditions for the ripple are set when the input voltage is at the highest (32V) and the frequency at it's lowest (75kHz).

with C = 22µF, Ripple = 1.2%

9.3. Ratings for the Inductor, Capacitor, Transistor and Diode

The inductor wire must be rated at the rms current, and the core should not saturate for peak inductor current. The capacitor must be selected to limit the output ripple to the design specifications, to withstand peak output voltage, and to carry the required rms current.

The transistor and the diode should be rated for the maximum input voltage (up to 60V). The recirculation diode has to be a Schottky type for efficiency maximization or ultrafast recovery.

A compromise between the switching and conduction losses of the external power element has to be found.

Losses in the switch are:

Pswitch = Prise + Pfall + Pon

where Prise + Pfall represent the switching losses and where Pon represents the conduction losses.

Prise + Pfall = Iout x Vin x (Trise + Tfall) x F / 2

Pon = Ron x Iout² x d

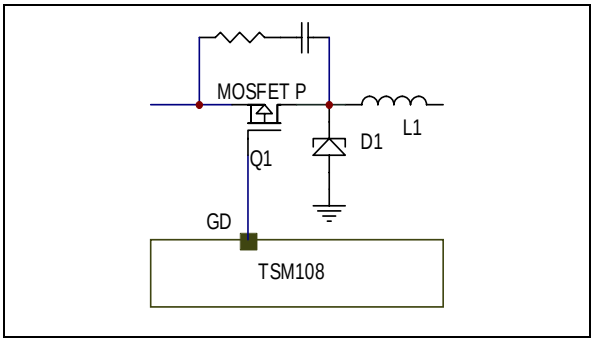
where Trise is the switching on time, and Tfall is the switching off time, and where d is the duty cycle of the switching profile, which can be approximated to 1 under full load conditions.

With the two last equations, we can see easily that what we may gain by choosing a performing low Rdson Pchannel MOSFET (for example) may be jeopardised by the long on and off switching times required when using a large input gate capacitance.

10. Electromagnetic Compatibility

The small schematic hereafter shows how to reduce the EMC noise when used in an EMC sensitive environment:

EMC Improvement



The RC components should realise a time constant corresponding to one tenth of the switching time constant of the TSM108 (i.e. in our example, the oscillator frequency is set to 10µs corresponding to 100kHz, therefore, the RC couple should realise a time constant close to 1µs).

Choosing the components must privilege a rather small resistivity (between 10 to 100W). A guess couple of values for RC in our example would be: R= 22W, C= 47nF

11. Efficiency Calculations (rough estimation)

The following gives a rough estimation of the efficiency of a car phone charger, knowing that the exact calculations depend on a lot of parameters, as well as on a wide choice of external components.

Let's consider the following characteristics of a classical car phone charger application:

- Vin = Vcc = 12V, Iout = 625mA, Vout = 6V

- ❑ Mosfet: Pchannel Mosfet: Rdson = 100mΩ, Ciss = 1nF.
- ❑ Driver: TSM108
- ❑ PWM frequency: 100kHz
- ❑ Free wheel diode: Vf = 0.7V
- ❑ Shunt: Rsense = 330mΩ

The efficiency (η) of a regulator is defined as the ratio of the charging power (Pout) to the total power from the supply (Pin).

- ❑ Eq3: η = Pout/Pin

The output power is:

Pout=Iout x Vout where Iout is the charging current (Vsense/Rsense = 625mA at full load) and Vout is the regulated voltage (Vref(1+R1/R2) = 6V).

Pout = 3.75W

The input power can be found by adding the output power (Pout) to the total power loss in the circuit (Plosses) i.e.

- ❑ Pin = Pout + Plosses

The power is lost partly on the chip and partly on the external components which are mainly the diode, the switch and the shunt. Plosses = Pchip + Pswitch + Pdiode + Pshunt.

In Plosses, we neglect the losses in the inductor (because the current through the inductor is smoothened making the serial resistor of the inductor very low), and the losses in the Gate (charge and discharge).

a. The power lost in the chip is Pchip = Vcc x Icc. (Vcc = 12V, Icc = 6mA) Pchip = 72mΩ

b. The power lost in the switch depends on the ON resistance of the switch and the current passing through it. Also there is power loss in the switch during switching time (commutation losses) and that depends on the switching frequency and the rise and fall time of the switching signal.

Rise time (Pchannel goes off) depends on the output source current of the TSM108 and the input gate capacitance of the Mosfet.

Trise = Ciss x Vgate / Isource

Fall time (Pchannel goes on) depends on the output sink current of the TSM108 and the input gate capacitance of the Mosfet .

Tfall = Ciss x Vgate / Isink

Trise = 150ns and Tfall = 300ns (Vgate is approx 12V).

- ❑ Pswitch = Prise + Pfall + Pon

where:

Prise = Iout x (Vcc+Vf) x Trise x PWMfreq / 2

Prise = 625mA x 12.7 x 150ns x 100kHz / 2.

Prise = 59.5mW

where:

Pfall = Iout x (Vcc+Vf) x Tfall x PWMfreq / 2

Pfall = 625mA x 12.7 x 300ns x 100kHz / 2.

Pfall = 119.1mW

where:

Pon = Rdson x $Iout^2$ x D (where D is the duty cycle - at full charge, D can be approximated to 1)

Pon = 100mΩ x $625mA^2$. Pon = 39.1mW

- ❑ Pswitch = 217.7mW

c. The power lost in the fly back diode is Pdiode = Vf x Iout(1-D) where D = Vout/Vcc = 6/12. D = 0.5

- ❑ Pdiode=219mW

d. the power lost in the sense resistor (shunt resistor) is Pshunt = Rsense x $Iout^2$

- ❑ Pshunt = 129mW

Therefore,

Plosses = Pchip+Pswitch+Pdiode+Pshunt

= 72mW + 217.7mW + 219mW + 129mW

- ❑ Plosses = 638mW

The yield (efficiency) is

- ❑ Pout / Pin = 3.75 / (3.75 + 0.638) = 85.5%

$\underline{\eta = 85.5\%}$

The following table gives a tentative yield improvement view following the choice of some external components. Be aware that some of the following choices have non negligeable cost effects on the total application.

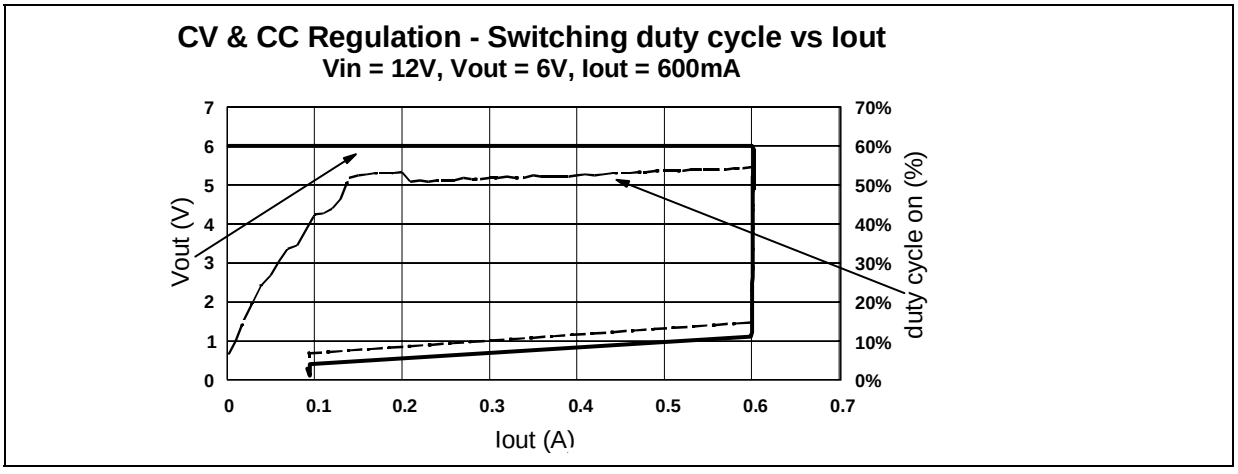
Improved yield - by changing the external components value one by one

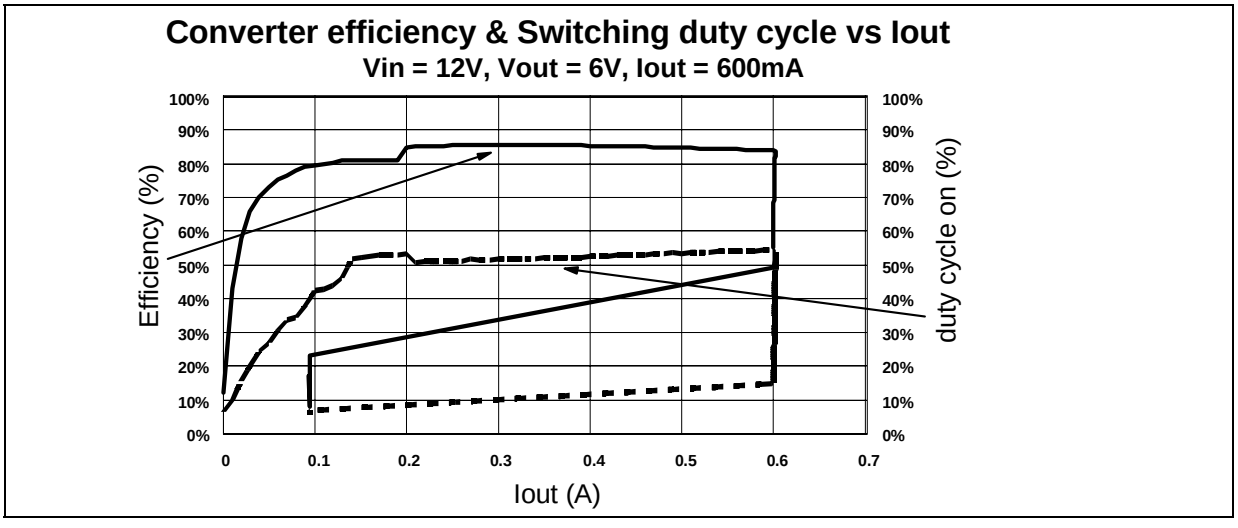
Rsense	330mΩ	220mΩ	-	-	-	-
Iout	625mA	936mA	-	-	-	-
Vout (R1/R2)	6V	-	7.5V	-	-	-
Rdson	100mΩ	-	-	140mΩ	-	-
Ciss	0nF	-	-	0.85nF	-	-
PWM Freq	100kHz	-	-	-	50kHz	-
Free Wheel	0.7V	-	-	-	-	0.3V
Yield	85.5%	85.6%	88.9%	85.7%	87.3%	88.1%
Cost influence	-	=	=	<	>	>>

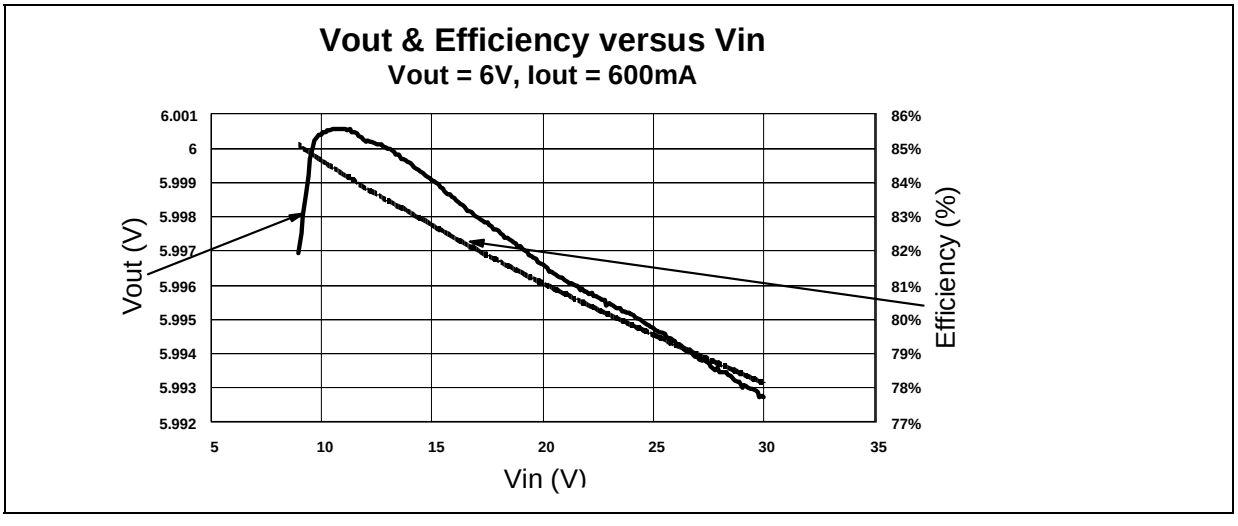
12. Measured Performances

The few following curves show the measured performances of TSM108 used in DC/DC step down converter, either with a Pchannel MOSFET or with a PNP bipolar transistor.

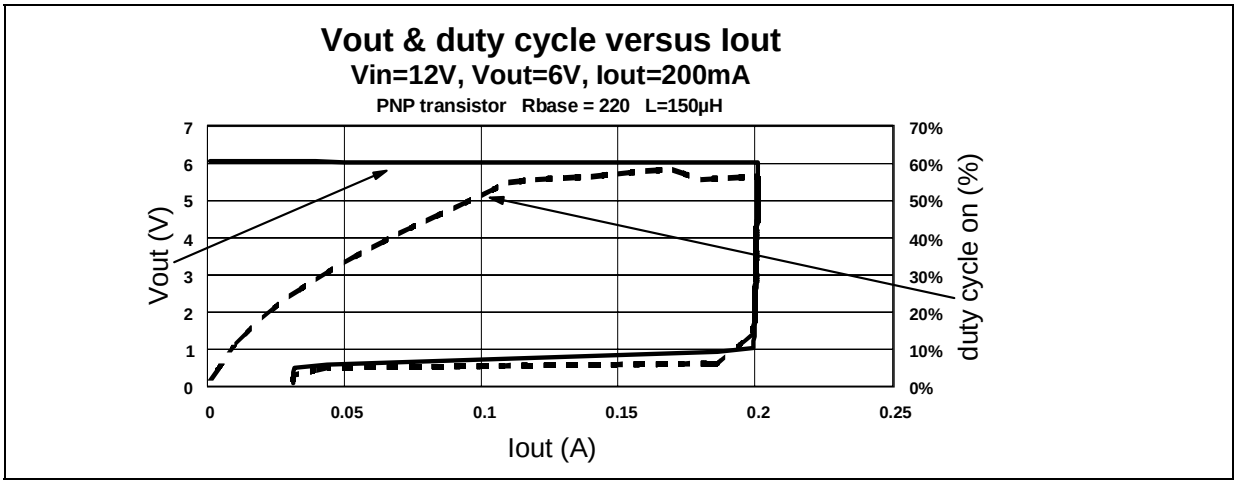
12.1. Voltage and Current Control, Efficiency Performances using a Pchannel MOSFET:

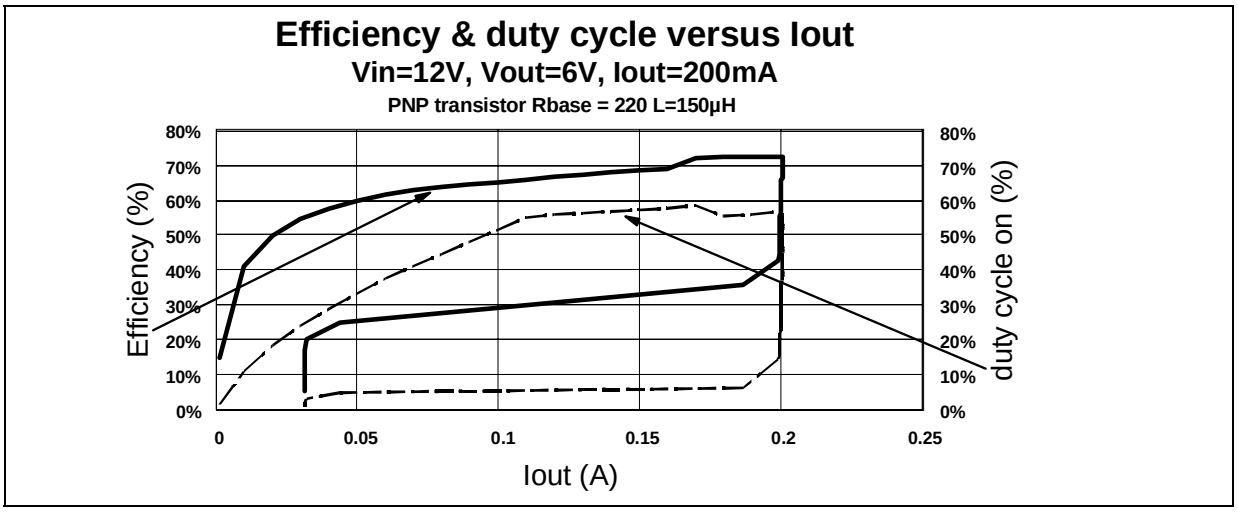


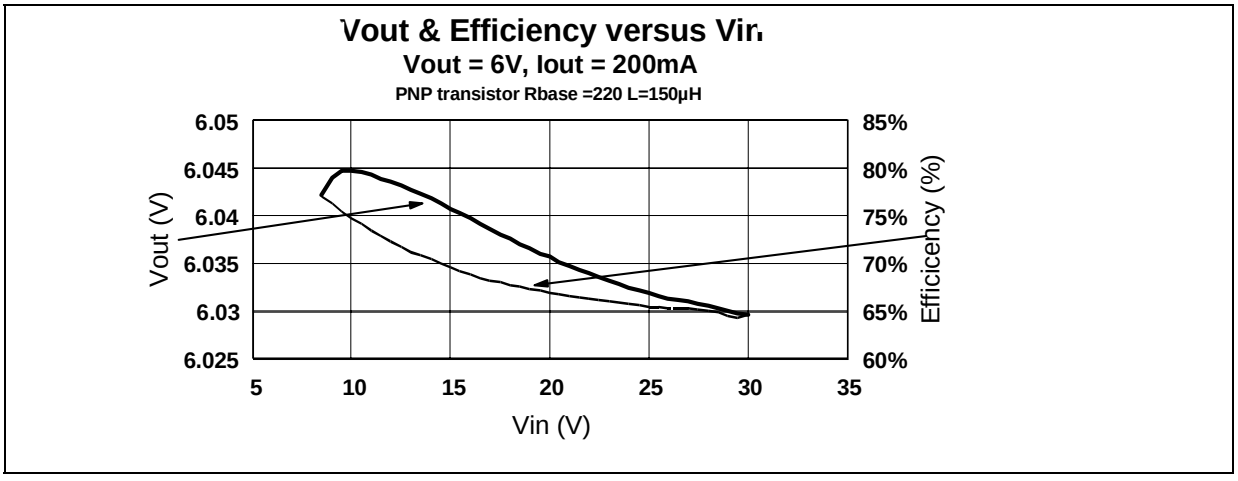




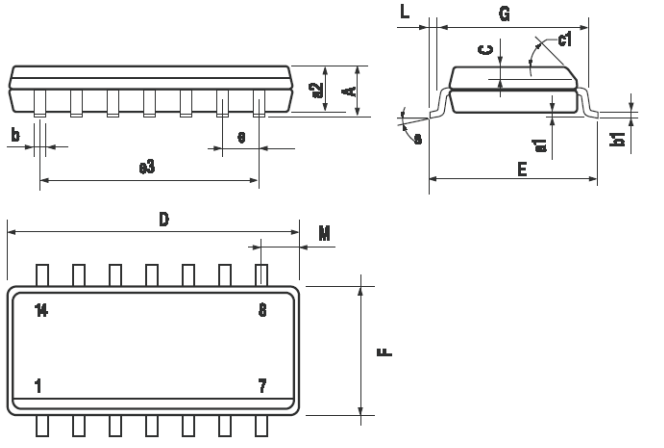
12.2. Voltage and Current Control, Efficiency Performances using a PNP bipolar transistor







PACKAGE MECHANICAL DATA
14 PINS - PLASTIC MICROPACKAGE (SO)



Dim.	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A			1.75			0.069
a1	0.1		0.2	0.004		0.008
a2			1.6			0.063
b	0.35		0.46	0.014		0.018
b1	0.19		0.25	0.007		0.010
C		0.5			0.020	
c1	45° (typ.)					
D (1)	8.55		8.75	0.336		0.344
E	5.8		6.2	0.228		0.244
e		1.27			0.050	
e3		7.62			0.300	
F (1)	3.8		4.0	0.150		0.157
G	4.6		5.3	0.181		0.208
L	0.5		1.27	0.020		0.050
M			0.68			0.027
S	8° (max.)					

Note : (1) D and F do not include mold flash or protrusions - Mold flash or protrusions shall not exceed 0.15mm (.066 inc) ONLY FOR DATA BOOK.

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