

Automotive High-Side TMOS Driver

The MC33198 is a high-side TMOS driver, dedicated to automotive applications. It is used in conjunction with an external power MOSFET for high-side drive applications. The device can drive and protect a large variety of MOSFETs. The device has a CMOS compatible input control, charge pump to drive the MOSFET gate, and fault detection circuitry based on programmable V_{DS} monitoring to detect shorted loads. It also includes a programmable timer function to eliminate undesired switch off due to inrush currents, and a status pin which reports the output status of both on and off MOSFET states. The device uses few external components and offers an economical solution to large current high side switches. It also has PWM capability up to 1kHz.

Features

- Designed for Automotive High Side Driver Application
- Works with a Wide Variety of N-Channel Power MOSFETs
- PWM Capability
- On Board Charge Pump Capable of Charging 25nF in less than 1ms with No External Components Required
- Drive Inductive Load with No External Clamp Circuitry Required
- CMOS Logic Compatible Input Control
- TMOS Over Current and Short Circuit Protection
- Fault Output to Report an MOSFET Overcurrent Condition
- Output Status Available when MOSFET is On or Off
- Extended Temperature Range from -40°C to 125°C
- Protected Against Automotive Transients with few External Components
- Overvoltage and Undervoltage Shutdown
- Pb-Free Packaging Designated by Suffix Code EF

33198

HIGH-SIDE TMOS DRIVER



**D SUFFIX
 EF SUFFIX (PB-FREE)
 98ASB42564B
 8-PIN SOICN**

ORDERING INFORMATION		
Device	Temperature Range (T _A)	Package
MC33198D	-40°C to 125°C	8 SOICN
MCZ33198EF/R2		

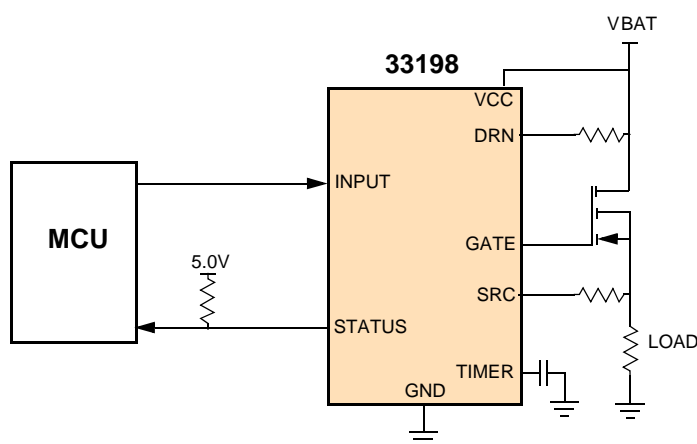


Figure 1. 33198 Simplified Application Diagram

INTERNAL BLOCK DIAGRAM

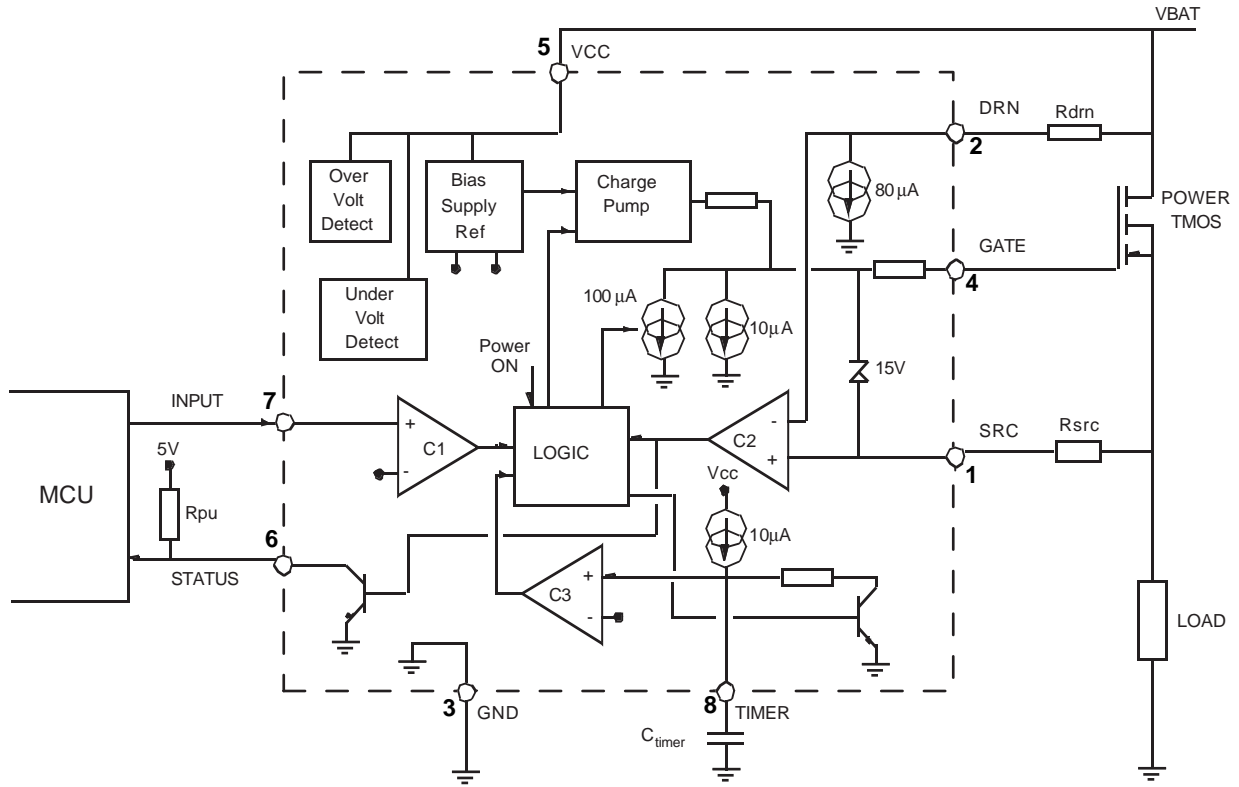


Figure 2. 33198 Simplified Internal Block Diagram and Typical Application

PIN CONNECTIONS

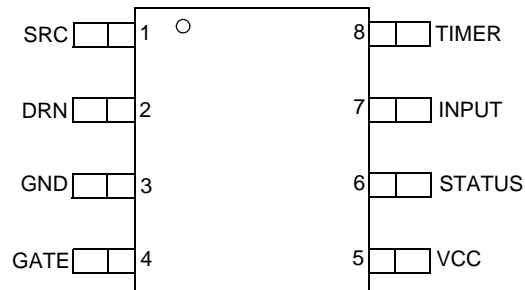


Figure 3. 33198 Pin Connections

Table 1. 33198 Pin Definitions

Pin Number	Pin Name	Formal Name	Definition
1	SRC	Source	Input to detect MOSFET/load status
2	DRN	Drain	Input to set overvoltage threshold
3	GND	Ground	Ground for the device
4	GATE	Gate	Output to control the gate of external MOSFET
5	VCC	VCC	Power for the device
6	STATUS	Status	Output signal for MOSFET status
7	INPUT	Input	Control input
8	TIMER	Timer	Inrush Current detection delay timer input

ELECTRICAL CHARACTERISTICS

MAXIMUM RATINGS

Table 2. Maximum Ratings

All voltages are with respect to ground unless otherwise noted. Exceeding these ratings may cause a malfunction or permanent damage to the device.

Ratings	Symbol	Value	Unit
ELECTRICAL RATINGS			
Power Supply Voltage	V_{CC}	- 0,6 to 60	V
TMOS Source Voltage	V_{SRC}	- 0,6 to 60	V
Comparator Threshold	V_{DRN}	- 0,6 to 60	V
Gate Output Voltage	V_{GATE}	- 0,6 to 25	V
Input Voltage	V_{IN}	- 0,6 to 25	V
Status	V_{ST}	- 0,6 to 10	V
ESD Voltage Capability ⁽¹⁾	V_{ESD}	+/-2000	V
THERMAL RATINGS			
Storage Temperature	T_{STG}	-55 to +150	°C
Operating Junction Temperature	T_J	-40 to +150	°C
THERMAL RESISTANCE			
Thermal Resistance J/A	R_J	145	°C
Peak Package Reflow Temperature During Reflow ^{(2), (3)}	T_{PPRT}	Note 3	°C

Notes

- ESD testing is performed in accordance with the Human Body Model (HBM) ($C_{ZAP} = 100 \text{ pF}$, $R_{ZAP} = 1500 \text{ }\Omega$), the Machine Model (MM) ($C_{ZAP} = 200 \text{ pF}$, $R_{ZAP} = 0 \text{ }\Omega$), and the Charge Device Model (CDM), Robotic ($C_{ZAP} = 4.0\text{pF}$).
- Pin soldering temperature limit is for 10 seconds maximum duration. Not designed for immersion soldering. Exceeding these limits may cause malfunction or permanent damage to the device.
- Freescale's Package Reflow capability meets Pb-free requirements for JEDEC standard J-STD-020C. For Peak Package Reflow Temperature and Moisture Sensitivity Levels (MSL), Go to www.freescale.com, search by part number [e.g. remove prefixes/suffixes and enter the core ID to view all orderable parts. (i.e. MC33xxxD enter 33xxx), and review parametrics.

STATIC ELECTRICAL CHARACTERISTICS

Table 3. Static Electrical Characteristics

Characteristics noted under conditions $7.0\text{ V} \leq V_{\text{SUP}} \leq 20\text{ V}$, $-40^\circ\text{C} \leq T_A \leq 125^\circ\text{C}$, $\text{GND} = 0\text{ V}$ unless otherwise noted. Typical values noted reflect the approximate parameter means at $T_A = 25^\circ\text{C}$ under nominal conditions unless otherwise noted.

Characteristic	Symbol	Min	Typ	Max	Unit
SRC PIN 1					
Leakage Current	$I_{\text{L_SRC}}$	-10	-	10	μA
DRN PIN 2					
Threshold Current	I_{THR}	54	81	102	μA
DRN Leakage, Input Off, VCC Pin Open	I_{LEAK}	-	-	10	μA
GATE PIN 4					
Output On Voltage at 1ms (Charge Pump ON)	V_{ON}	$V_{\text{CC}} + 7.0$		$V_{\text{CC}}+15$	V
Turn Off Current with NO Over V_{DS} condition and $V_{\text{OUT}} > 0.5\text{V}$ with Over V_{DS} condition and $V_{\text{OUT}} > 0.5\text{V}$	I_{OUTN} I_{OUTW}	70 5.0	110 10	150 15	μA μA
Output Off Voltage. (Charge Pump OFF and VCC Pin Open)	V_{OFF}	0.0	-	0.9	V
Gate Discharge Current. (VCC Pin Open)	I_{OFF}	-	5.0	-	μA
Turn On Time $C_{\text{I}} = 25\text{nF}$; $7.0\text{V} < V_{\text{CC}} < 10\text{V}$; $V_{\text{OUT}} > V_{\text{CC}}+7.0$ $C_{\text{I}} = 25\text{nF}$; $10\text{V} < V_{\text{CC}} < 20\text{V}$; $V_{\text{OUT}} > V_{\text{CC}}+10$	T_{ON}	- -	- -	1.0 1.0	ms
VCC PIN 5					
Supply Voltage Range	V_{CC}	7.0	-	20	V
Quiescent Supply Current ; $I_{\text{N}} = 0\text{V}$ at $V_{\text{CC}} = 7.0\text{V}$ at $V_{\text{CC}} = 20\text{V}$	I_{CCQ}	- -	1.8 2.8	4.0 6.0	mA
Supply Current ; $I_{\text{N}} = 5.0\text{V}$	I_{CC}	1.0	-	35	mA
Over Voltage Threshold	V_{OV}	22	28	34	V
Under Voltage Threshold	V_{UR}	-	6.0	7.0	V
STATUS PIN 6					
Output Voltage @ $I = 1\text{mA}$	V_{OL}	0.1	0.4	1.5	V
INPUT Pin 7					
Input Low Voltage	V_{IL}	-	-	1.5	V
Input High Voltage	V_{IH}	3.5	-	-	V
Input Hysteresis	V_{HYS}	0.8	-	-	V
Input Pull Down Resistor. $V_{\text{IN}} > 11\text{V}$	R_{IN}	20	36	100	$\text{k}\Omega$
Open Input Voltage	V_{IOP}	-	-	1.0	V

Table 3. Static Electrical Characteristics (continued)

Characteristics noted under conditions $7.0\text{ V} \leq V_{\text{SUP}} \leq 20\text{ V}$, $-40^\circ\text{C} \leq T_A \leq 125^\circ\text{C}$, $\text{GND} = 0\text{ V}$ unless otherwise noted. Typical values noted reflect the approximate parameter means at $T_A = 25^\circ\text{C}$ under nominal conditions unless otherwise noted.

Characteristic	Symbol	Min	Typ	Max	Unit
TIMER PIN 8					
Timer Current	I_{TIME}	7.0	10	14	μA
On Threshold	V_{HTH}	5.2	5.5	5.8	V
Discharge Current @ $V_{\text{PIN8}} = 5.0\text{V}$	I_{DISCH}	2.0	5.0	10	mA
Saturation Voltage @ $I_{\text{PIN8}} = 1\text{mA}$	V_{SAT}	-	0.15	0.4	V

DYNAMIC ELECTRICAL CHARACTERISTICS

Table 4. Dynamic Electrical Characteristics

Characteristics noted under conditions $7.0\text{ V} \leq V_{\text{SUP}} \leq 18\text{ V}$, $-40^\circ\text{C} \leq T_A \leq 125^\circ\text{C}$, $\text{GND} = 0\text{ V}$ unless otherwise noted. Typical values noted reflect the approximate parameter means at $T_A = 25^\circ\text{C}$ under nominal conditions unless otherwise noted.

Parameter	V _{CC} = 7.0V	V _{CC} = 14V	V _{CC} = 21V	Unit
TYPICAL RISE TIME (T_R) VERSUS GATE EXTERNAL CAPACITOR LOAD AND SUPPLY VOLTAGE (REFER TO Figure 4)				
C = 1.0nF	15	7.0	10	μs
C = 3.0nF	60	25	40	μs
C = 10nF	140	80	90	μs
C = 30nF	730	270	340	μs
TYPICAL FALL TIME (T_F) VERSUS GATE EXTERNAL CAPACITOR LOAD AND SUPPLY VOLTAGE (REFER TO Figure 4)				
C = 1.0nF	150	230	280	μs
C = 3.0nF	430	800	950	μs
C = 10nF	1200	2300	2750	μs
C = 30nF	4800	8000	9200	μs

TIMING DIAGRAMS

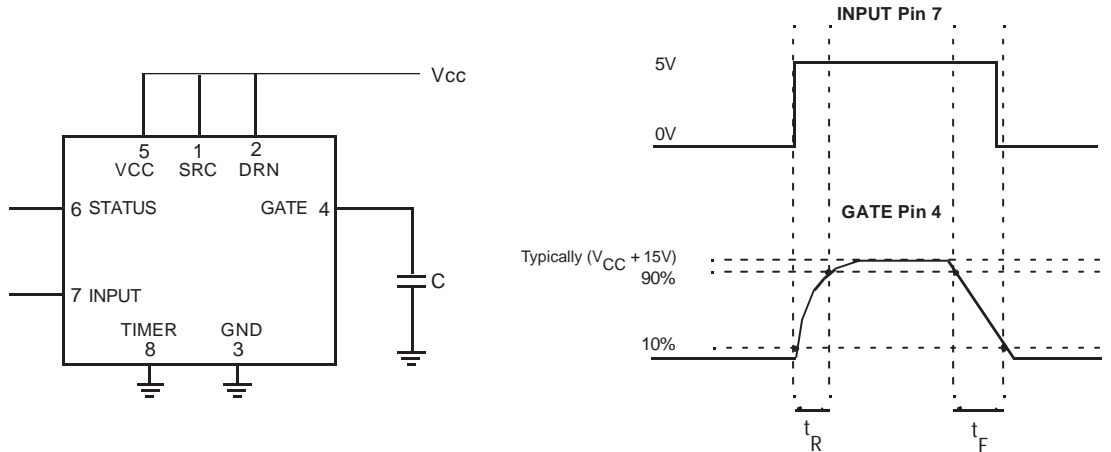


Figure 4. Timing Measurements Test Schematic

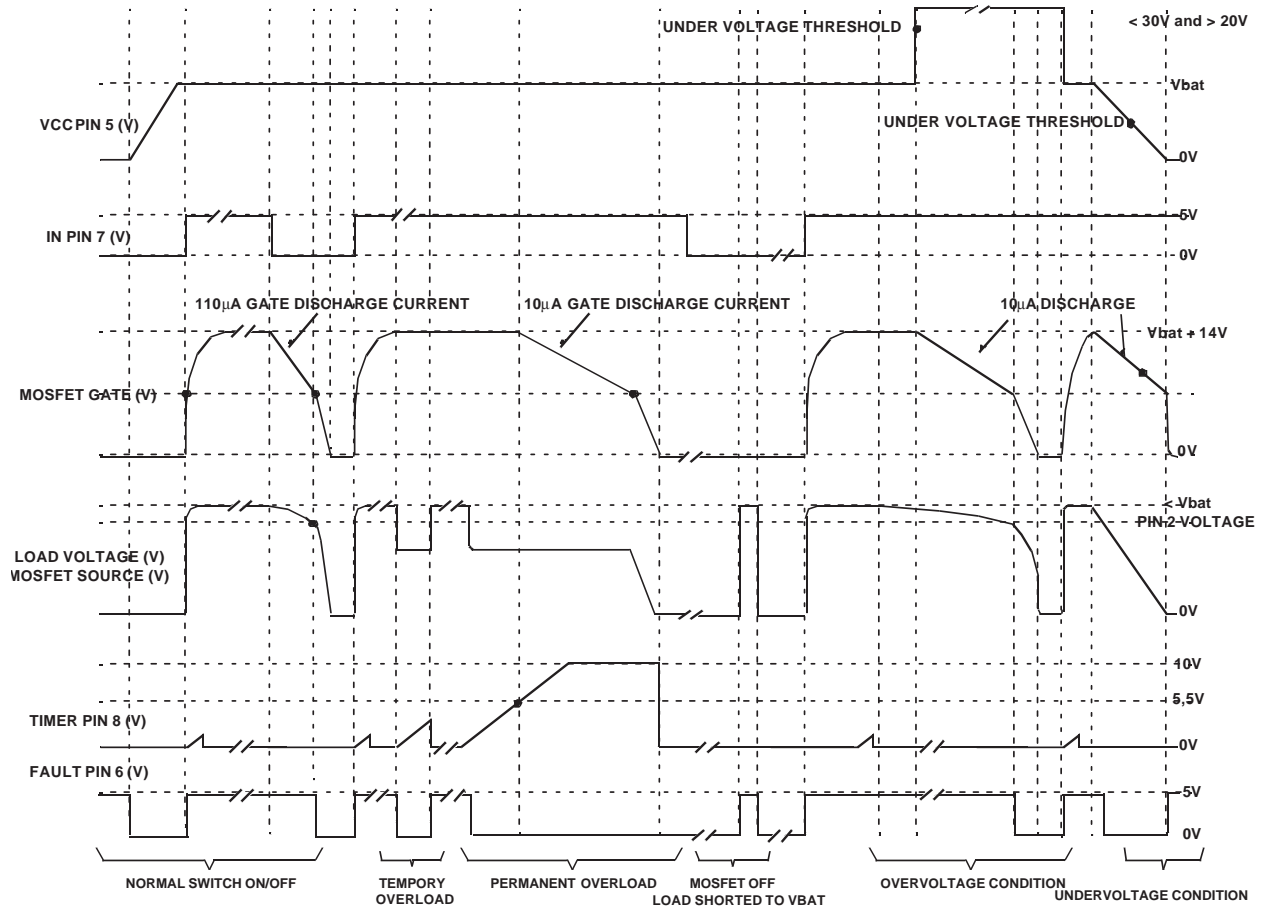
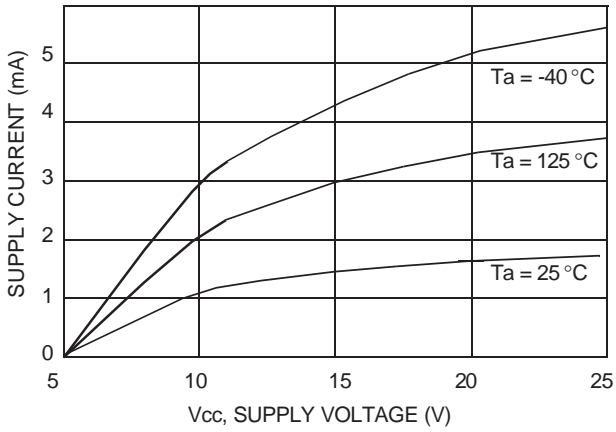


Figure 5. Descriptive Waveform Diagram

ELECTRICAL PERFORMANCE CURVES



**Figure 6. Supply Current versus Supply Voltage.
Pin 7 = 0V**

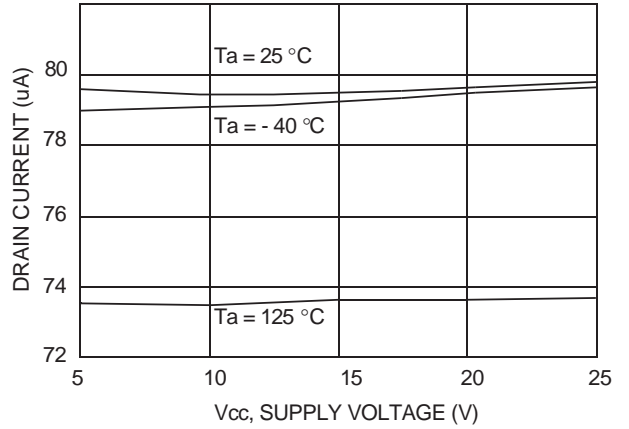
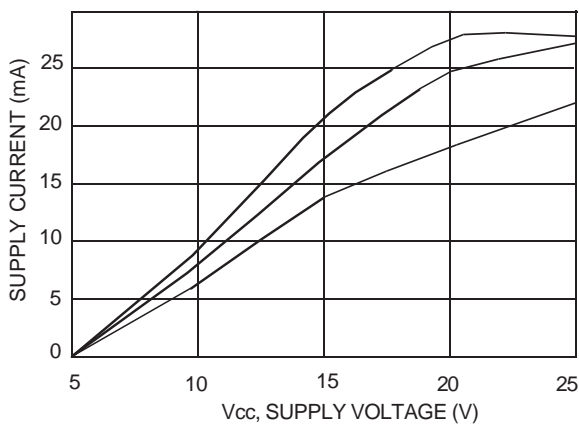


Figure 9. Drain Current versus Supply Voltage



**Figure 7. Supply Current versus Supply Voltage.
Pin 7 = 5.0V**

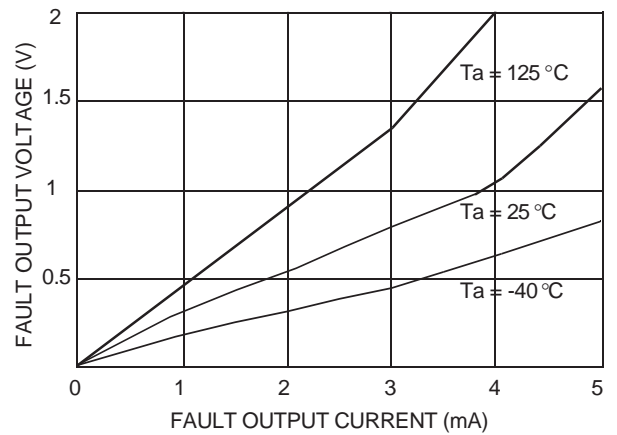


Figure 10. Fault Output Voltage versus Current

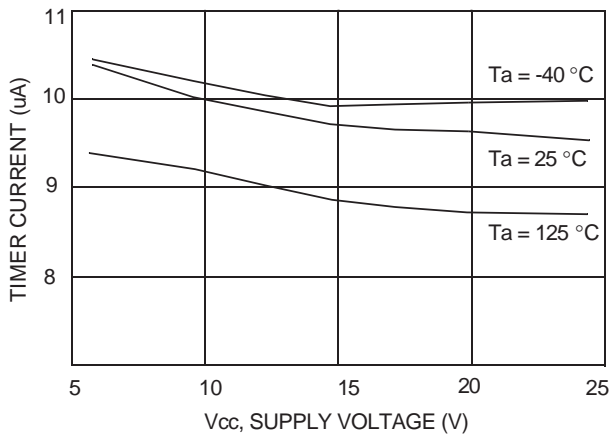


Figure 8. Time Current versus Supply Voltage

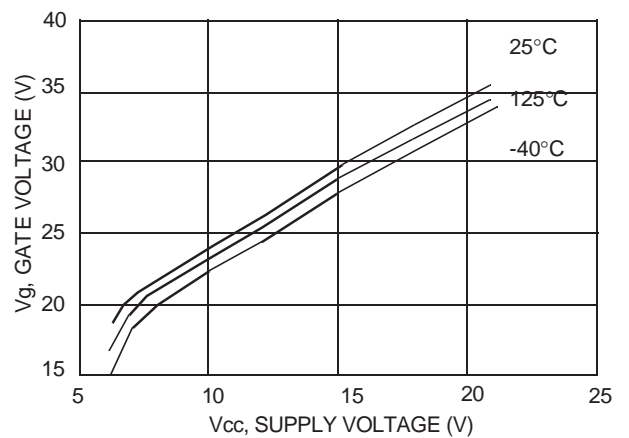


Figure 11. Gate Voltage versus Voltage

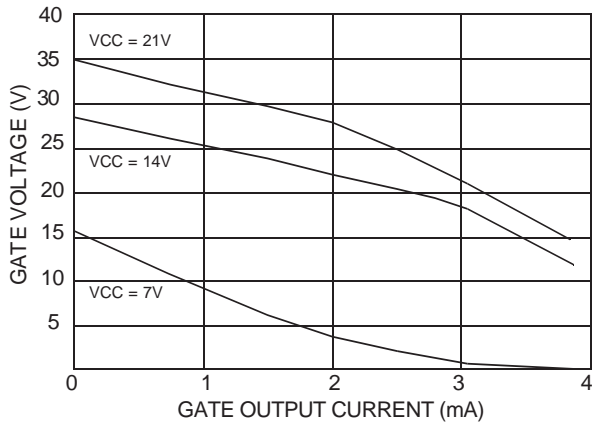


Figure 12. Gate Voltage versus Gate Output Current.
 $T_A = 25^\circ\text{C}$.

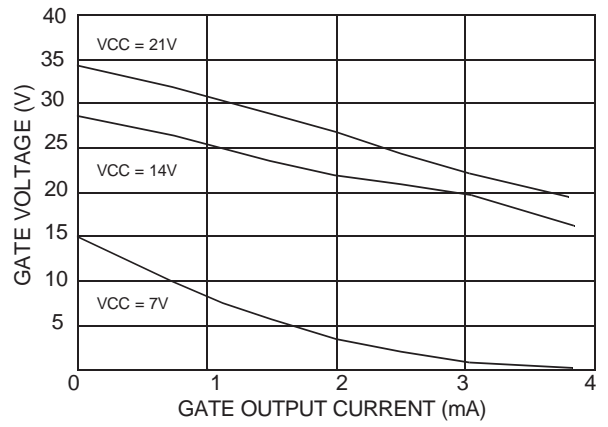


Figure 14. Gate Voltage versus Gate Output Current.
 $T_A = 40^\circ\text{C}$.

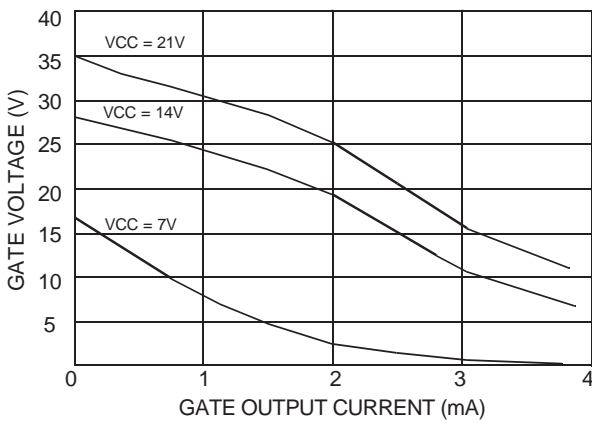


Figure 13. Gate Voltage versus Gate Output Current.
 $T_A = 125^\circ\text{C}$.

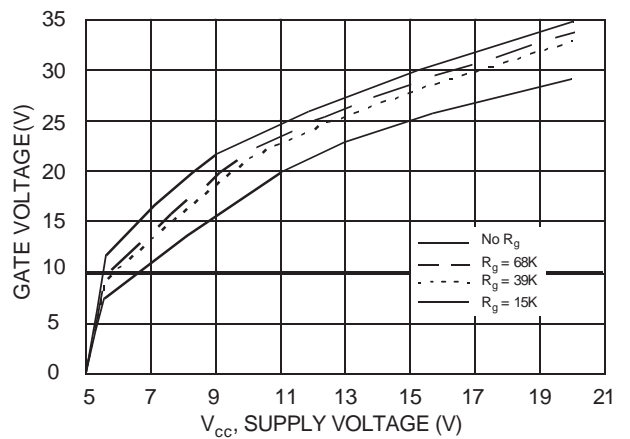


Figure 15. Gate Voltage versus V_{CC} and R_G at
 $T_A = 25^\circ\text{C}$.

FUNCTIONAL DESCRIPTION

INTRODUCTION

The MC33198 is a high side TMOS driver, dedicated to automotive applications. It is used in conjunction with an external power MOSFET for high side drive applications. The device can drive and protect a large variety of MOSFETs. The device has a CMOS compatible input control, charge pump to drive the MOSFET gate, and fault detection circuitry based on programmable V_{DS} monitoring to detect shorted loads. It also includes a programmable timer function to eliminate undesired switch off due to inrush currents, and a status pin which reports the output status of both on and off MOSFET states. The device uses few external components, and offers an economical solution to large current high side switches. It also has PWM capability up to 1kHz.

POWER SUPPLY

The MC33198 can be supplied from the battery line. It is designed with a 60V technology, making it able to sustain up to 60V transient pulses. In the off state, with pin 7 low, the supply current can be up to 5.0mA, and in operation, pin 7 high, the current up to 25mA. The device has an undervoltage detection and shutdown near 7.0V. Below this value the MOSFET is turned off. There is also a 25V overvoltage detection which switches off the output pin 4 to protect both the MOSFET and the load when V_{CC} is higher than 25V.

CHARGE PUMP

The device incorporates a self running charge pump with an internal capacitor and is connected at Gate pin 4. To prevent oscillation, a serial resistor can be added. The charge pump is able to charge a 25nF capacitor in less than 1ms. This allows the MC33198 to have a rapid response time and to drive the external TMOS gate very quickly, allowing fast switching on of the load. The device has an internal 15V zener diode between pin 4 and 1, to clamp the Gate-to-Source voltage and protect the MOSFET gate oxide from destruction. See [Dynamic Electrical Characteristics on page 7](#) for details.

BAND GAP AND REFERENCE CURRENTS

The MC33198 has an internal band gap reference voltage which generates all the internal thresholds. This band gap is also used to generate internal reference currents necessary for proper operation of the device. These currents are :

Pin 2 : Drain current (typically 80mA).

Pin 4 : High and low gate discharge currents (typically 100mA and 10mA).

Pin 8 : Timer charge current (10mA typical).

All these currents are derived from the same reference voltage and internal resistor. Their accuracy and variability is approximately $\pm 25\%$ over the full temperature and voltage range. In addition, a passive pull down current of 5.0mA

maintains the gate of the MOSFET below 0.9V when the device has no supply, ensuring that the MOSFET remains off. This passive pulldown current is operating even if device VCC (pin 5) is not powered up.

INPUT CIRCUITRY

The Input pin (pin 7) of the device is CMOS compatible and can be directly connected to a microcontroller. The input current is determined by an internal pull down resistor, typically 36k Ω . A hysteresis of 0.8 V minimum is present at this input.

OUTPUT STATUS

The device has a status output (pin 6) which has an open collector structure. This pin is used to report the MOSFET overload condition or the LOAD status when the MOSFET is off. The device Pin 1 (Source) is compared to a programmable threshold at Pin 2, in both the on and off state of the MOSFET. This allows the detection of the MOSFET over V_{DS} or over load conditions when the MOSFET is on and the load short to VBAT monitoring, when the MOSFET is in the off state. This status pin is normally connected to a pull-up resistor and a micro input, and can drive up to 1.0mA.

TIMER

The Timer pin (pin 8) is used in conjunction with an external capacitor to create a delay between the overload detection and the shutdown of the MOSFET. In case of overload, the internal current source pin 8 will charge the capacitor. When the voltage at pin 8 reaches the 5.5V threshold, the internal C3 comparator will be triggered and switch off the output to protect the MOSFET. The fault and the MOSFET turn off condition are latched and are reset by switching the input off and on. The delay between the overload detection and actual MOSFET turn off is used to allow a temporary overload which will prevent the system from switching off during possible inrush currents or transients.

MOSFET PROTECTION AND OUTPUT VOLTAGE MONITORING

The MC33198 has the ability to sense the output MOSFET source voltage and compare it to a predetermined threshold. This threshold is programmable, using the internal reference current of 80mA and an external resistor connected at pin 2 (DRN). The device can monitor the output load voltage, as well as protect the MOSFET in case of overload.

The overload detection threshold must be adapted to the MOSFET itself depending on the load to be driven and the thermal capability of the MOSFET. In practice, the maximum acceptable V_{DS} of the MOSFET should be determined and based upon the MOSFET maximum power dissipation.

In addition, the pin 8 capacitor value should be calculated to allow inrush current.

SOURCE (PIN1) AND DRAIN (PIN2) FUNCTIONALITY

These two pins are used to sense the MOSFET and load conditions. Pin 2 is connected to the internal pull down current source of 80mA and to the C2 comparator. An external resistor connected between pin 2 and VBAT creates a voltage drop across this resistor. The voltage drop will be the MOSFET maximum acceptable drain to source voltage and the C2 comparator threshold.

Pin 1 is connected to the MOSFET source pin. Two different cases should be considered, MOSFET on or off :

When the MOSFET is on and working under normal conditions, the V_{DS} should be less than the voltage developed at pin 2. So, the C2 comparator output is low and the status is high. No current will flow through the pin 8 capacitor.

If the MOSFET encounters an overload or if the load is shorted to Gnd, the voltage at the source will cross the pin 2 voltage and go below this pin 2 voltage, thereby turning on the C2 comparator. The comparator will pull the status pin 6 low and will enable the charge of the pin 8 capacitor. When the voltage at the capacitor reaches 5.5V, the C3 comparator will switch off the MOSFET by disabling the charge pump and the 110mA current source. The MOSFET gate will be discharged only by the 10mA current source. The MOSFET is latched off and can be turned back on again by switching the input pin 7 to 0 and back to 1.

When the MOSFET is off, we have the same scheme. Under normal conditions, the load should pull the source voltage to Gnd, thus C2 comparator output is high and status pin pulled low. If the load is shorted to VBAT for instance, source pin will be higher than pin 2, The C2 output comparator is low and the status pin is high. This is summarized in [Table 5, Status Functionality](#).

Table 5. Status Functionality

INPUT PIN 7	CONDITION	LOAD SOURCE VOLTAGE	C2 OUTPUT COMP	STATUS PIN 6	TIMER PIN 8
Low	Normal	$<V_{PIN2}$	High	Low	Low
Low	Short Circuit to V_{BAT}	$>V_{PIN2}$	Low	High	Charge by 10 μ A source
High	Normal	$>V_{PIN2}$	Low	High	Low
High	Short to GND or Overload	$<V_{PIN2}$	High	Low	Charge by 10 μ A source

OPERATION WITH INDUCTIVE LOADS

The device can drive the MOSFET during inductive loads switching applications. In this case, a 1.0kW resistor should be connected between source of the MOSFET and device pin 1. The resistor will limit the current flowing into pin 1 and prevent MC33198 from damage while switching the inductive load off. The gate voltage is internally clamped at - Vbe (0.6V typical), and the V_{DS} is limited to $V_{BAT} + V_{BE} + V_{GSON}$ to prevent excessive power dissipation in the MOSFET. The load voltage is limited to $V_{BE} + V_{GSON}$ and allows a reasonable discharge current.

SWITCHING ON

The MOSFET switching on is ensured by the internal charge pump. The charge pump response time versus the MOSFET gate capacitance is shown in [Table 4, Dynamic Electrical Characteristics](#).

SWITCHING OFF

Here two cases have to be discussed: the MOSFET normally switching off, and the switching off under a fault condition. The normal switching off is done by internal pull down current sources. The value is 110mA and is in fact composed of two current sources in parallel: a 100mA and a 10mA source. The 10mA current is always connected to the gate pin 4 as shown in the [Internal Block Diagram on page 2](#).

The 100mA source can be disabled. This is the case when the MOSFET is switched off under fault conditions. The device will disable the 100mA current source and the MOSFET gate will be discharged only by a 10mA current. The time required to switch off the MOSFET will be much longer in this case, and will result in a lower overvoltage at the MOSFET, especially when the device drives high inductive loads.

OFF STATE OPERATION WITHOUT VCC CONNECTION

When pin 7 is in the low state, the MOSFET is off. If V_{BAT} is present, the gate voltage is discharged by the 110mA current source. In the case of a V_{BAT} disconnection, a self sustaining 5.0mA pull down current source is incorporated in the device, to ensure that the MOSFET gate capacitor is discharged and tied below 0.9V. In case of a VCC disconnection, input pin 7 has no effect on the gate voltage, which is maintained below 0.9V. In this case, the status pin is high. Low leakage current at pin 2 (10mA max) allows the operation with the MOSFET and MC33198 pin 2 permanently connected to the battery. V_{CC} and other functions can be switched off from the main battery line. See [Figure 18](#).

PWM OPERATION

Since the MC33198 charge pump can deliver a high current, the MOSFET gate can be charged fast enough to allow for PWM operations. The maximum PWM frequency is dependent on the MOSFET itself and mainly its gate to the source capacitor value. Depending on the PWM frequency,

the switch off time can be long, compared to the on-switching time response. This is due to the 110mA gate discharge current. To improve this parameter, a resistor can be added in parallel with the gate of the MOSFET. See [Figures 16](#) and [17](#).

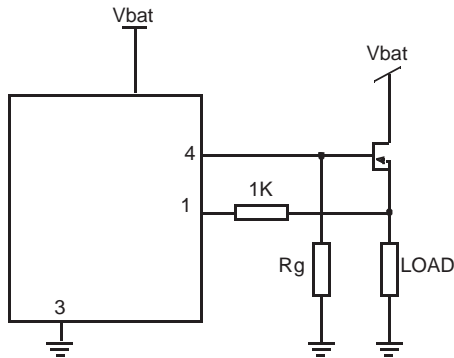


Figure 16. Schematic with R_{GATE} Resistor

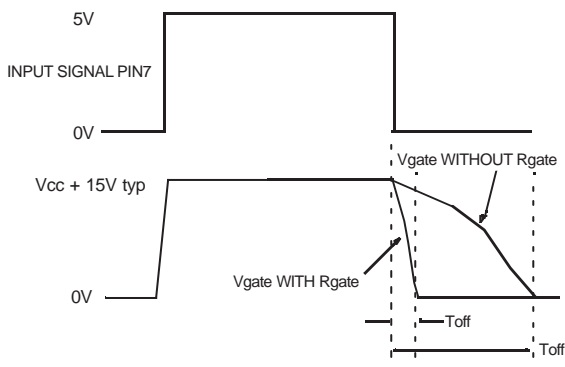


Figure 17. R_{GATE} Signal Comparison

This resistor will reduce (in some way) the charge pump output voltage available for the MOSFET, but the device will still provide enough Gate-to-Source voltage to maintain the MOSFET “on” in good conditions. The resistor will mainly act as an additional discharge current, which will reduce the switch off time of the overall application. See the [Table 6, Switching Off Characteristics with MOSFET Additional Gate Resistor](#) and [Figure 15](#), which show the pin 4 voltage depending on the additional gate resistor and the off switching time due to this resistor.

If a very low switching time is needed, the resistor has to be an extremely low value, resulting in low gate voltage not high enough to ensure proper MOSFET operation. In this case, a logic level MOSFET can be used. Logic levels will operate with V_{GS} of 5.0V, with the same performance as a standard MOSFET having a 12V V_{GS} . Care should be taken regarding the maximum gate to source voltage of a logic level MOSFET. An additional zener might be necessary to prevent gate oxide damage.

Table 6. Switching Off Characteristics with MOSFET Additional Gate Resistor

R_{GATE} (R_G)	V_{CC} (V)	V_{GATE} (V)	T_{OFF} (μ sec)
No R	7.0	16	450
	10	23	700
	14	28	750
	20	34	780
68 k Ω	7.0	14	160
	10	22	230
	14	27	230
	20	33	220
39 k Ω	7.0	13	100
	10	21	160
	14	26	160
	20	32	150
15 k Ω	7.0	11	30
	10	17.5	50
	14	24	50
	20	28.5	50

Notes

1. Time from negative edge of input signal (Pin 7) to negative edge of gate voltage (Pin 4) measured at 5V threshold.
2. Gate discharge time, not LOAD switching OFF time.L
3. TMOS used is Freescale MTP50N06, load 10 Ω resistor.

REVERSE BATTERY

The device does not sustain reverse battery operation for V_{CC} voltages greater than - 0.6V in magnitude. In application, pin 5 should be protected from reverse battery by connecting a diode in series with the V_{BAT} line.

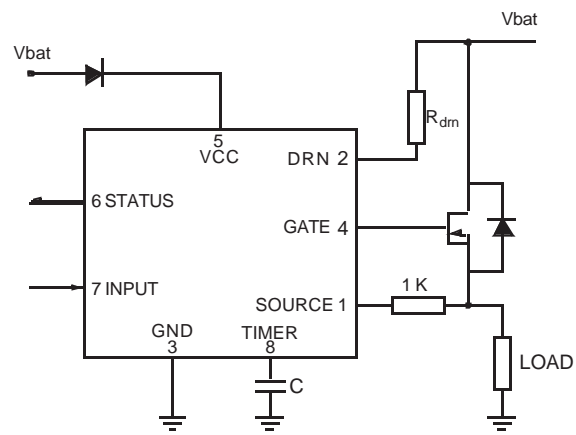


Figure 18. 33198 Reverse Battery

Pin 2, which is normally connected to a resistor, can sustain a reverse battery operation, providing that the DRN resistor is higher than 3.3K. A 1K resistor at pin 1 is also necessary to limit the reverse current flowing through the MOSFET body diode.

OPERATION

When module GND is disconnected, and if the VBAT connection is still present, pin 3 of the MC33198 goes to about 2/3 of V_{BAT} , if additional circuitry is not inserted. With R1/Q1, the Gate/Source voltage of the MOSFET is shorted as soon as pin 3 voltage rises above GND level. See [Figure 19. 33198 GND Disconnection Circuitry](#)

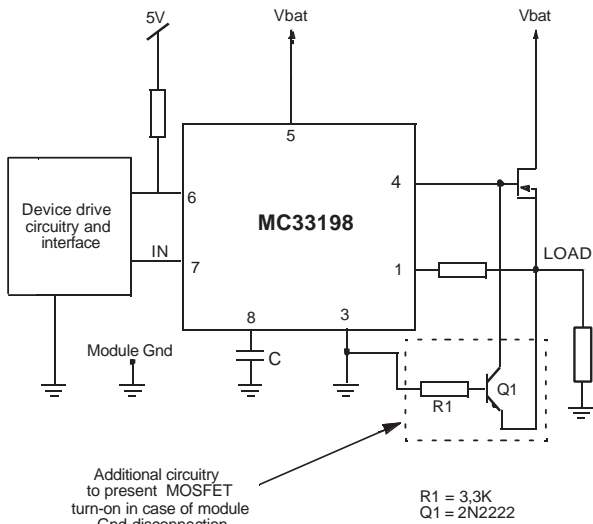


Figure 19. 33198 GND Disconnection Circuitry

REVISION HISTORY

REVISION	DATE	DESCRIPTION OF CHANGES
2.0	11/2006	<ul style="list-style-type: none">• Converted to Freescale format.• Implemented Revision History page.• Removed Comparison of the 33198 TO the 33091• Added part number MCZ33198EF (Pb-Free) to Ordering Information on page 1• Added Peak Package Reflow Temperature During Reflow ⁽²⁾, ⁽³⁾ on page 4

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