**MOTOROLA**

Low Side Protected Switch

MC3392

The MC3392 is a low side protected switch designed for use in harsh automotive applications which require the capability of handling high voltages attributed to load and field dump transients, in addition to reverse and double battery conditions. The three terminal TO–220 is intended to replace power Darlington transistors in new and existing switching applications when taking into account the CMOS input levels required by the MC3392. It offers improved functionality and ruggedness over power Darlingtons while retaining the same package and pin configuration, and can be used as a replacement in many applications using the industry standard TIP100/101 NPN power Darlington transistor.

The five–terminal TO–220 has the added feature of having a Fault output (active low) which will indicate the existence of an over temperature, over–voltage or current limit condition, including an output short to ground.

When driving a moderate load, the MC3392 performs as an extremely high gain, low saturation Darlington transistor having CMOS input levels. The primary advantage of the MC3392 over a Darlington transistor is the additional protection afforded the device and load when driving difficult or faulty loads. This device incorporates unique internal current limit and thermal protection circuitry to safeguard itself and the associated load from catastrophic failure.

The MC3392 is available in a three and five–lead TO–220 package; the five–lead having the added diagnostic feature. The full featured MC3392 is also available in a 16 pin wide body SOIC plastic power package.

- Designed for Automotive Applications
- Can Be Used as a Replacement for TIP100/101 NPN Power Darlingtons
- Drives Inductive Loads without External Clamp Circuitry
- Withstands Negative and Positive Transient Voltages
- Low ON Voltage
- CMOS Logic Compatible Input
- Over Current, Overvoltage, and Thermal Protection
- Extended Operating Temperature Range
- Fault Output

LOW SIDE PROTECTED SWITCH

SEMICONDUCTOR TECHNICAL DATA
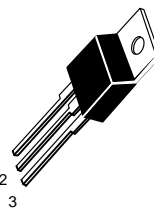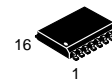

Pin 1. Input
2. Output
3. Ground

(Heatsink surface connected to Pin 3)

T SUFFIX
PLASTIC PACKAGE
CASE 221A
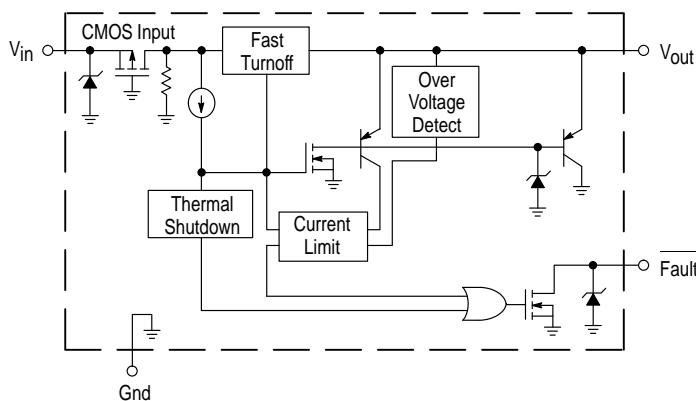(TO–220)
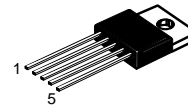
Pin 1. Input
2. Fault
3. Ground
4. NC
5. Output

T–1 SUFFIX
PLASTIC PACKAGE
CASE 314D
(TO–220)

Pin 1. NC
2. NC
3. NC
4. Output
5. Input
6. Fault
7. NC
8. NC
9–16. Ground

DW SUFFIX
PLASTIC PACKAGE
CASE 751G
SOP(8+8)L

Simplified Block Diagram

ORDERING INFORMATION

Device	Operating Temperature Range	Package
MC3392T		Plastic Power
MC3392T–1	$T_A = -40°$ to $+125°C$	Plastic Power
MC3392DW		SOP(8+8)L

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Rev 0

MC3392

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Input Voltage Range	V_{in}	− 0.5 to + 6.5	V
Output Transient Breakdown Voltage – Forward – Reverse	V_{BF} V_{BR}	+ 60 − 80	V
Short Circuit Current	I_{SC}	2.2	A
Output Avalanche Energy (Note 1)	E_{max}	60	mJ
Minimum ESD Voltage Capability (Note 2)	ESD	2000	V
Operating Junction Temperature Internally Limited (Note 3)	T_J	150	°C
Storage Temperature	T_{stg}	− 65 to +150	°C
Operating Ambient Temperature Range	T_A	− 40 to +125	°C
Thermal Resistance (Notes 4, 5) TO–220: Junction–to–Ambient Junction–to–Case SOP: Junction–to–Ambient Junction–to–Case	$R_{\theta JA}$ $R_{\theta JC}$ $R_{\theta JA}$ $R_{\theta JC}$	62.5 2.5 118 59	°C/W

NOTES: 1. Capability for both positive and negative repetitive transient pulses.
2. ESD testing performed in accordance with Human Body Model (C_{Zap} = 100 pF, R_{Zap} = 1500 Ω).
3. This device incorporates internal circuit techniques which do not allow the internal junction temperature to reach destructive temperatures.
4. The thermal resistance case is considered to be a point located near the center of the tab and plastic body of the TO–220 or a point on one of the heatsink leads (Pins 9 to 16) of the SOP.
5. The SOP thermal information is based on simulation data.

ELECTRICAL CHARACTERISTICS (Limit values are noted under conditions: − 40°C ≤ T_A ≤ +125°C. Typical denotes calculated mean value derived from 25°C parametric data, unless otherwise noted.)

Characteristics	Figure	Symbol	Min	Typ	Max	Unit
Input Control Current V_{in} = 1.0 V V_{in} = 4.0 V V_{in} = 5.0 V	3	I_{in}	 − − −	 0.2 230 260	 10 350 500	μA
Input Voltage High (On) Input Voltage Low (Off)	7	V_{IH} V_{IL}	4.0 −	2.0 2.0	− 1.0	V
Output Leakage Current +V_S = 28 V, R_L = 0	4	I_L	 −	 1.3	 100	μA
Output Short Circuit Current +V_S = 14 V, R_L = 0	5	I_{SC}	 1.0	 1.3	 2.2	A
Output On Voltage (V_{in} = 4.0 V, Note 6) I_O = 400 mA I_O = 800 mA	6	V_{OL}	 − −	 0.95 1.1	 1.1 1.8	V
Output Clamp Voltage I_O = 100 mA	8	V_{OC}	 60	 70	 80	V
Reverse Leakage Current V_{out} = −13 V	9	I_{BR}	 −	 −10	 − 30	mA
Fault Output Sink Saturation (I_{Sink} = 100 μA, V_{in} = 5.0 V)	10	$V_{DS(sat)}$	−	0.3	0.4	V
Fault Output Off–State Leakage (V_{DS} = 5.0 V)		$I_{DS(leak)}$	−	0.6	100	μA
Turn–On Time 10% to 90% of I_O (400 mA Nominal) Turn–Off Time 90% to 10% of I_O (400 mA Nominal) Propagation Delay Time Input to Output (Turn–On/Turn–Off, 50%)	11 12 –	t_r t_f t_d	 − − −	 3.3 9.7 3.0	 20 25 10	μA

NOTE: 6. I_O is defined as the output sink current.

MC3392

PIN FUNCTION DESCRIPTION

Name	Pin Number			Description
	3–Pin	**5–Pin**	**16–Pin**	
V_{in}	1	1	5	CMOS compatible input. Pins 1, 2, 3, 7, 8 no connection on 751G.
V_{out}	2	5	4	Output to load and battery, protected by a 60 V clamp against inductive load transients.
Gnd	3	3	9 to 16	Ground connection.
Fault	–	2	6	Fault output pulled low when the IC is operating in a fault state. The open drain output requires a pull–up resistor for normal operation.

Figure 1. Representative Block Diagram

Definition of Currents and Voltages. Positive current flow is defined as conventional current flow into the device. Negative current flow is defined as current flow out of the device. All voltages are referenced to ground. Both currents and voltages are specified as absolute (i.e., –10 V is greater than –1.0 V).

MC3392

Figure 2. Fault Output Timing Diagram
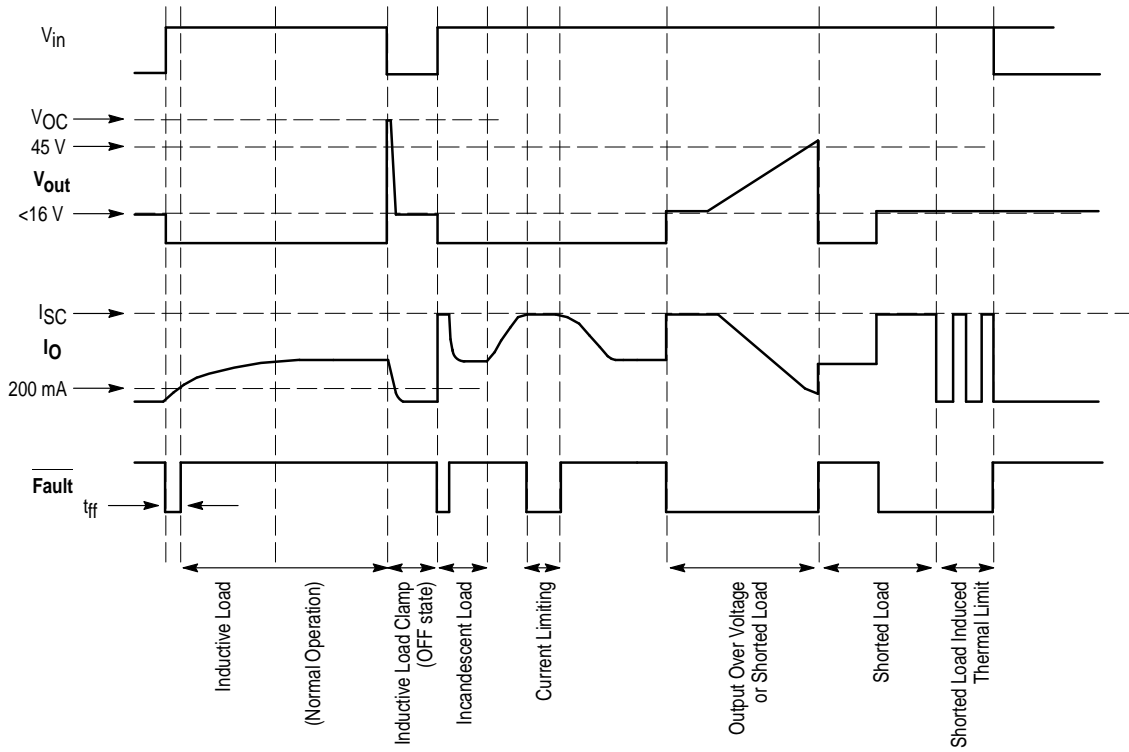
Figure 3. Input Control Current versus Input Voltage
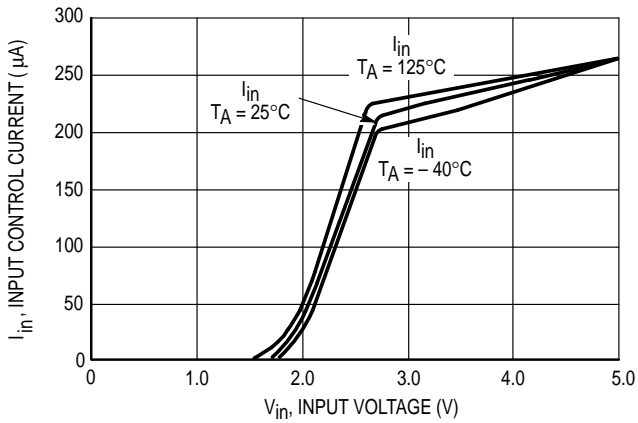
Figure 4. Output Leakage Current versus Temperature

MC3392
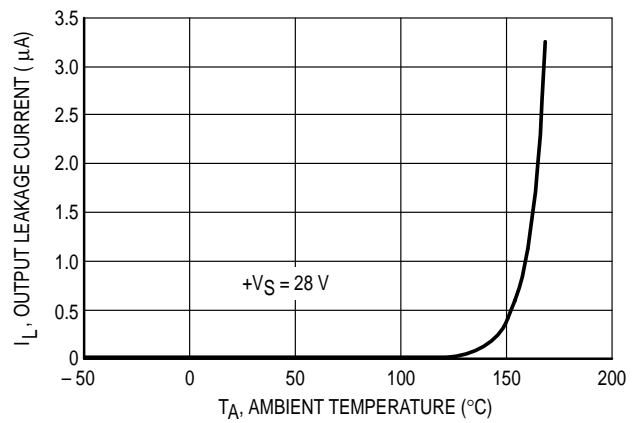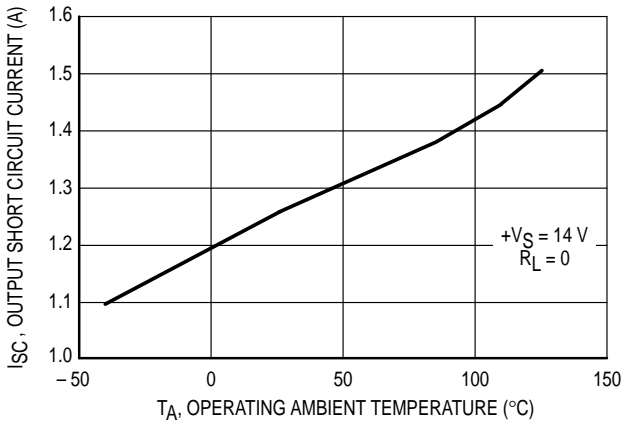
Figure 5. Output Short Circuit Current versus Temperature

I_{SC}, OUTPUT SHORT CIRCUIT CURRENT (A) vs T_A, OPERATING AMBIENT TEMPERATURE (°C)

+V$_S$ = 14 V
R$_L$ = 0

Figure 6. Output On Voltage versus Temperature

V_{On}, OUTPUT ON VOLTAGE (V) vs T_A, OPERATING AMBIENT TEMPERATURE (°C)

I_O = 800 mA

V_{in} = 4.0 V

I_O = 400 mA
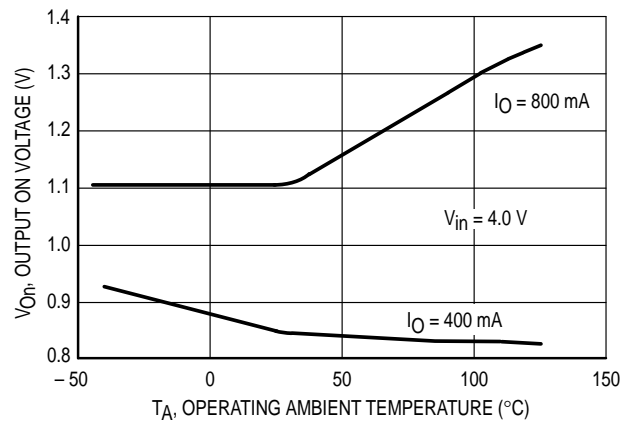
Figure 7. Input Voltage versus Temperature

V_{IH}, V_{IL}, INPUT VOLTAGE HIGH AND LOW (V) vs T_A, OPERATING AMBIENT TEMPERATURE (°C)

V_{IH}
V_{IL}
+V$_S$ = 5.0 V
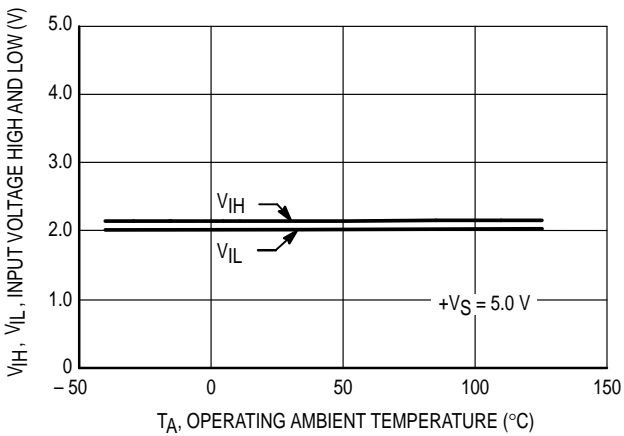
Figure 8. Output Clamp Voltage versus Temperature

V_{OC}, OUTPUT CLAMP VOLTAGE (V) vs T_A, OPERATING AMBIENT TEMPERATURE (°C)

I_O = 100 mA
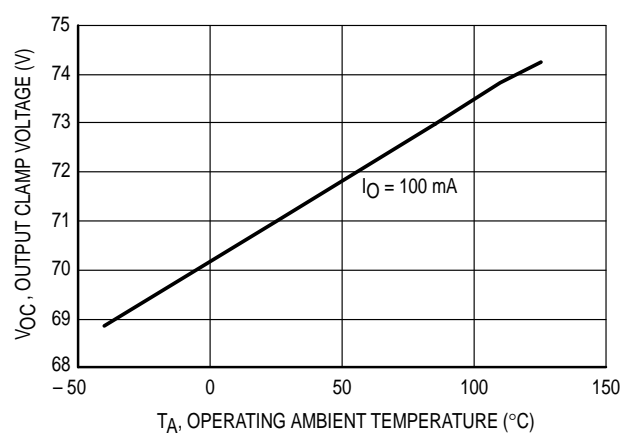
Figure 9. Reverse Breakdown Voltage versus Temperature

V_{BR}, REVERSE BREAKDOWN VOLTAGE (V) vs T_A, OPERATING AMBIENT TEMPERATURE (°C)

Transient Breakdown
Pulse Width = 1.0 ms

I_O = 20 mA
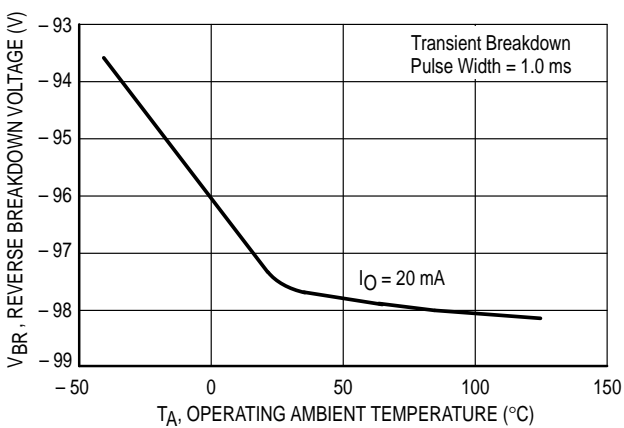
Figure 10. Fault Output Saturation versus Sink Current

$V_{DS(sat)}$, OUTPUT SATURATION (V) vs I_{Sink}, SINK CURRENT (mA)

V_{in} = 4.0 V
T_A = 25°C

V_{in} = 5.0 V
T_A = 125°C

V_{in} = 5.0 V
T_A = 25°C

V_{in} = 5.0 V
T_A = − 40°C

V_{in} = 6.0 V
T_A = 25°C

V_{out} = (short fault)
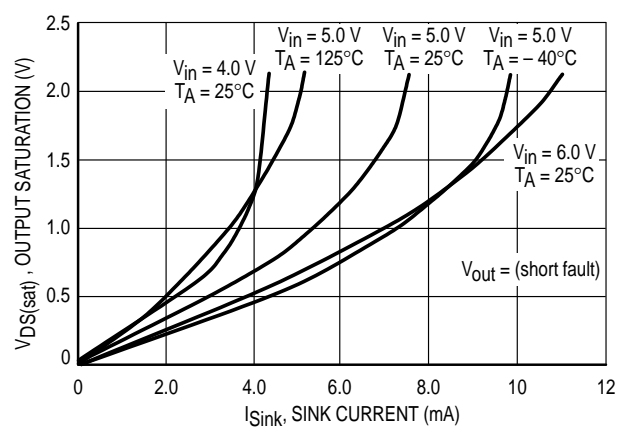
MC3392

Figure 11. Turn–On Waveform

$I_O \rightarrow$

$V_{out} \rightarrow$

760 mA

14 V

4.0 V
1.0 V

+V_S = 14 V
R_L = 17 Ω
T_A = 25°C
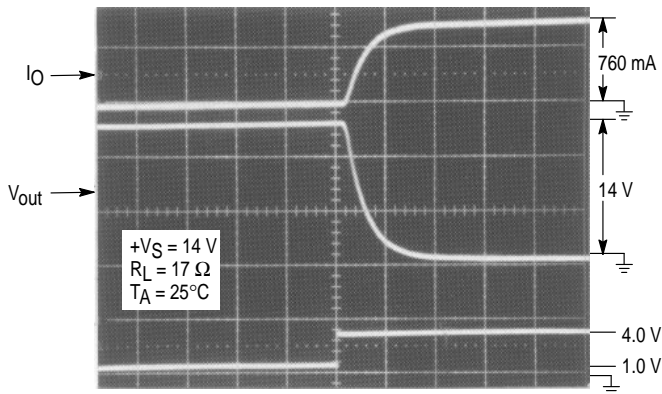
Figure 12. Turn–Off Waveform

$I_O \rightarrow$

$V_{out} \rightarrow$

$V_{in} \rightarrow$

+V_S = 14 V
R_L = 17 Ω
T_A = 25°C
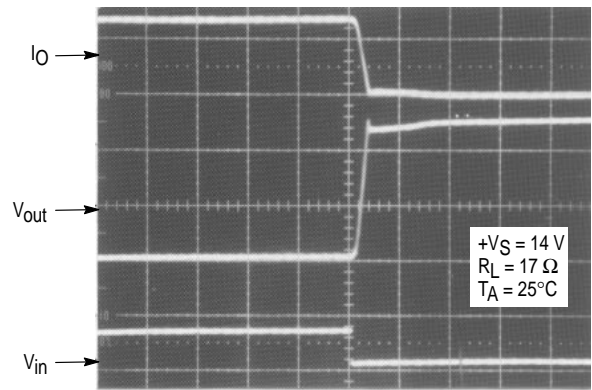
Figure 13. Output Current versus Supply Voltage

V_{in} = 4.0 V
R_L = 0
T_A = 25°C

No Heatsink

Infinite Heatsink

I_O, OUTPUT CURRENT (A) vs +V_S, SUPPLY VOLTAGE (V)
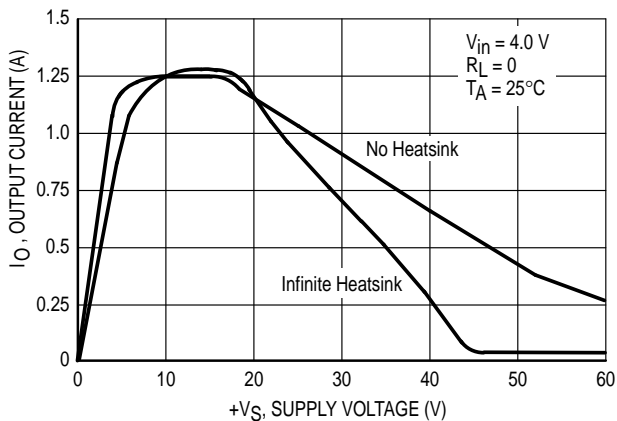
Figure 14. Maximum Load Inductance versus Output Current

E_{max} = 60 mJ

External Clamp Needed

Safe Operating Region

L_{max}, MAXIMUM LOAD INDUCTANCE (H) vs I_O, OUTPUT CURRENT (A)
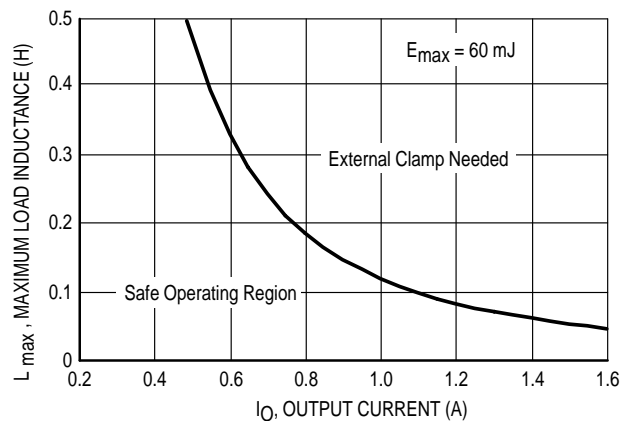
TECHNICAL DISCUSSION

Introduction

The MC3392 is a low side protected switch incorporating many features making it ideal for use in harsh automotive applications. The protection circuitry of the MC3392 protects not only itself but also the associated load from destructive voltage transients attributed to load and field dump, as well as reverse and double battery conditions found in automotive applications. The MC3392 is unique in that the protection circuitry is internal and does not require additional external protection components for its operation. This makes the device very cost effective because its application utilizes few external components, thus reducing cost and space requirements needed for the system. The MC3392 is extremely effective when used to drive solenoids, as well as incandescent lamp loads. The following description of the device's operation is in reference to the functional blocks of the Representative Block Diagram shown in Figure 1.

CMOS Input

The input of the MC3392 is CMOS compatible. Input control performs as true logic. When the input (V_{in}) is less than 1.0 V the MC3392 switch is in a high impedance or OFF state. When V_{in} is greater than 4.0 V, is in a low impedance or ON state. The switching threshold of the input is approximately 2.0 V and is graphed in Figure 7. With the input at 4.0 V, the input sink current will be approximately 250 μA. In the ON state, the internal protection circuitry is activated and all of the protection features are available for use. In the OFF state, however, it is important to note that none of the protection features are available, with the exception of the internal inductive load clamp. The input pin is afforded a minimum of 2000 V ESD protection (Human Body Model) by virtue of the 7.2 V zener diode.

Over Temperature Shutdown

Internal Thermal Shutdown Circuitry is provided to protect the MC3392 in the event the Operating Junction Temperature (T_J) exceeds 150°C. Typically, Thermal Shutdown will occur at 160° to 170°C. The thermal shutdown sense element is embedded within the output PNP (Q4) in order to afford very fast thermal coupling of Q4 to the sense element. Any rise in temperature due to the ambient is translated directly to Q4 and the sense element. If the junction temperature rises excessively above 150°C, the Thermal Shutdown circuit will turn ON, quickly pulling the gate of Q2 to ground, which pulls the base of Q4 to ground, turning it OFF. In addition, the Thermal Shutdown circuit simultaneously turns Q5 ON and with a suitable pull–up resistor at the Fault pin reports the presence of a fault (logic low). The output PNP will remain OFF until the junction temperature decreases to within the operating range at which time Thermal Shutdown turns OFF, ceasing to hold the gate of Q2 low, turning Q4 back ON. This process will repeat as long as the thermal over load exists. This mode of operation is a nondestructive safety feature of the device and will correct itself real time when the cause of over temperature is removed. A continued over temperature condition will thermally Pulse Width Modulate (PWM) the output and Fault and may be incorrectly interpreted as an oscillating load if one does not consider the simultaneous performance of the Fault pin.

Current Limit

The MC3392 protects itself against V_{out} to $+V_S$ hard shorts as well as any over current conditions by reducing the magnitude of output current (I_O) to that of the short circuit current limit value (I_{SC}). When the output current monitored by Q3 tries to exceed I_{SC}, the Current Limit circuit lowers the gate voltage of Q2, lowering the base of Q4, causing the load current through Q4 to diminish. Simultaneously, when the load current exceeds I_{SC}, Q5 will turn ON reporting a fault condition. If the output current is allowed to remain excessively high for the degree of heatsinking incorporated, and the junction temperature of the device is allowed to heat beyond 150°C, the Thermal Shutdown circuit will activate and the output will thermally PWM. Again, these modes of operation are safety features of the MC3392 and are not destructive.

Overvoltage Detect

This circuitry protects the MC3392 from V_{out} voltages in excess of 16 V by lowering the output current to a nondestructive value. With increasing V_{out} voltage (16 V < V_{out} < 45 V) the load current is reduced to below that of I_{SC} and produces a fold back current effect. As V_{out} increases in excess of 16 V, the output current decreases linearly until V_{out} exceeds 45 V. With an infinite heatsink and V_{out} > 45 V, I_O will be less than 100 mA. For the other extreme, no heatsink and V_{out} > 45 V, I_O can be expected to be less than about 400 mA. This behavior of I_O in relation to V_{out} is shown in Figure 13.

For the infinite heatsink case, the output current initially increases with increased voltage until V_{out} exceeds 16 V, thereafter the behavior is expressed as,

$$I_O = I_{SC} [1 - (V_{out} - 16 V) / 30 V]$$

Beyond 45 V, I_O is limited to less than 100 mA. Anytime the Overvoltage Detect circuit is activated, the gate of Q5 is pulled low causing Q5 to turn ON to report the fault at the Fault pin.

Inductive Load Clamp

The MC3392 has an internal inductive load clamp for protection against flyback voltages imposed on the output pin in excess of 70 V. The incorporated zener clamp can quickly dissipate up to 60 milli–Joules of inductive flyback energy. Figure 14 shows the maximum inductive load versus load current that the clamp can handle safely. As an example (using Figure 14), if operating the MC3392 to drive a 0.33 H inductor, the maximum load current should be adjusted to 600 mA or less. If the load current is too high for the inductor used, some series resistance can be added to the load to limit the current. If this is not possible, an external clamp must be used to facilitate handling the higher energy. When using an external clamp, the external clamp voltage must be less than 60 V so as to override the internal clamp. The output clamp offers protection for the output when the MC3392 is in the OFF state. During the ON state, other protection features (Overvoltage, Current, and Temperature) are available to protect the output.

Fault Logic

The Fault is comprised of an internal open drain FET requiring an external pull–up resistor. Typically, a 5.0 k pull–up resistor to a +5.0 V supply is satisfactory. The Fault pin is afforded a minimum of 2000 V ESD protection (Human Body Model) by virtue of the 7.2 V zener diode. The Fault will report a fault (logic low state) whenever the MC3392 experiences a fault condition. Conditions producing a fault are: I_O > 1.3 A (over current/shorted load); T_J > 150°C (over temperature); and V_{out} > 16 V (overvoltage).

If the device goes into Thermal Shutdown, caused by environmental overheating (not resulting from another fault condition), the Fault and V_{out} will thermally PWM as the MC3392 repeatedly heats to shut off, cools, and again turns on. If a current limit fault causes the device to go into Thermal Shutdown, the output will oscillate while the Fault remains pulled low. There is no thermal hysteresis designed in to control the PWM effect and this fault mode of operation is not destructive.

Fast Turn–Off

This circuitry enhances the MC3392 turn–off performance. Whenever V_{in} goes to a logic low state, V_{out} is held in an OFF state for approximately 15 μs. During fast turn–off, less than 30 mA of current is allowed to flow producing an abrupt turn–off. This turn–off characteristic can be seen in Figure 12, a photograph of the typical turn–off waveform.

APPLICATIONS INFORMATION

Solenoid Driver

The MC3392 can be used to drive a variety of solenoid applications similar to that of Figure 15. For example; driving a solenoid having an inductance of 73.8 mH and a resistance of 95 Ω from a 12 V supply will cause 240 mA of sink current to flow with the MC3392 in the ON state. The resulting current value is within the normal load current operating region and will not produce a fault. Load current is paramount in any design using the MC3392 and must be less than I_{SC} for acceptable operation. If the load current is greater than I_{SC}, a current limit fault state will exist. Operation in this state is not destructive as the device will turn off if the Junction Temperature (T_J) rises above 150°C. When the Junction Temperature cools below 150°C the device will again turn–on, with a repeat of the cycle. Careful design to acceptable load current limits should be insured for satisfactory operation of an application.

Figure 15. Solenoid Driver
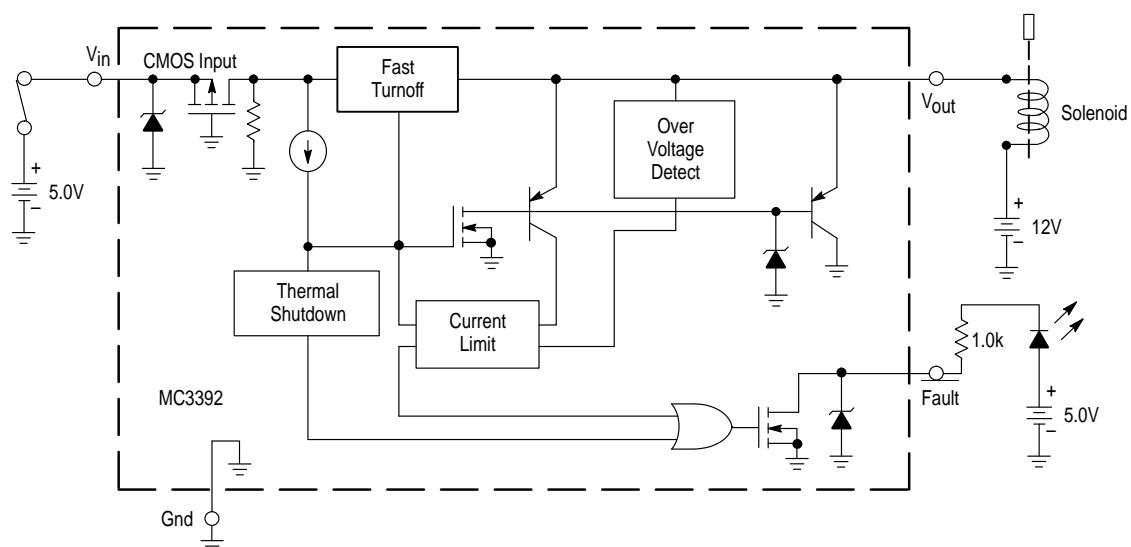
MC3392

Instrument Panel Lamp Dimmer Control

The MC3392 can be used to control the dimming function associated with instrument panel lamps. The brightness of incandescent lamps can be varied by pulse width modulating the input of the MC3392. The modulating signal for the MC3392 can be obtained directly from a microprocessor or, as in Figure 16, from an MC1455 timer. The MC1455 timer is configured as a free–running clock having both frequency and duty cycle control. The typical timer frequency is approximately 80 Hz when the frequency potentiometer is adjusted to 1.0 k. This frequency was chosen so as to avoid any perceptible lamp flicker. The duty cycle potentiometer

controls the duty cycle over a range of approximately 3.0% to 97%; When at 3.0% duty cycle, the lamps are essentially off; When at 97% duty cycle, the lamps are essentially full lit. Six incandescent lamps are shown in this application drawing 720 mA total current. Similar applications can be used to drive a variety of lamp loads. The total load current is the primary factor of consideration when driving lamp loads. The total value of I_O must be less than I_{SC}.

Another convenient aspect of this application is the LED. The LED can be used to denote the existence of a system fault (overvoltage, current limiting, or thermal shutdown).
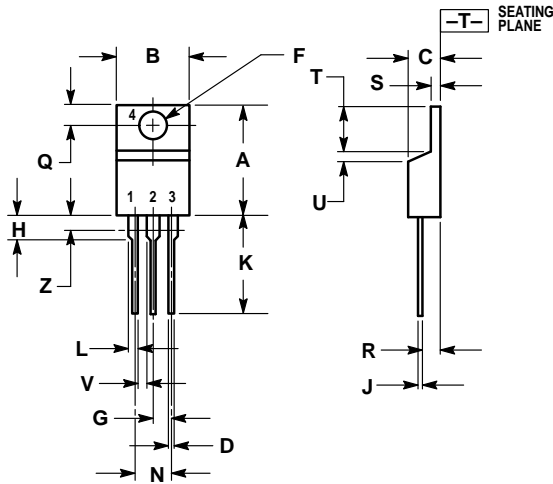
Figure 16. Instrument Panel Lamp Dimmer Control
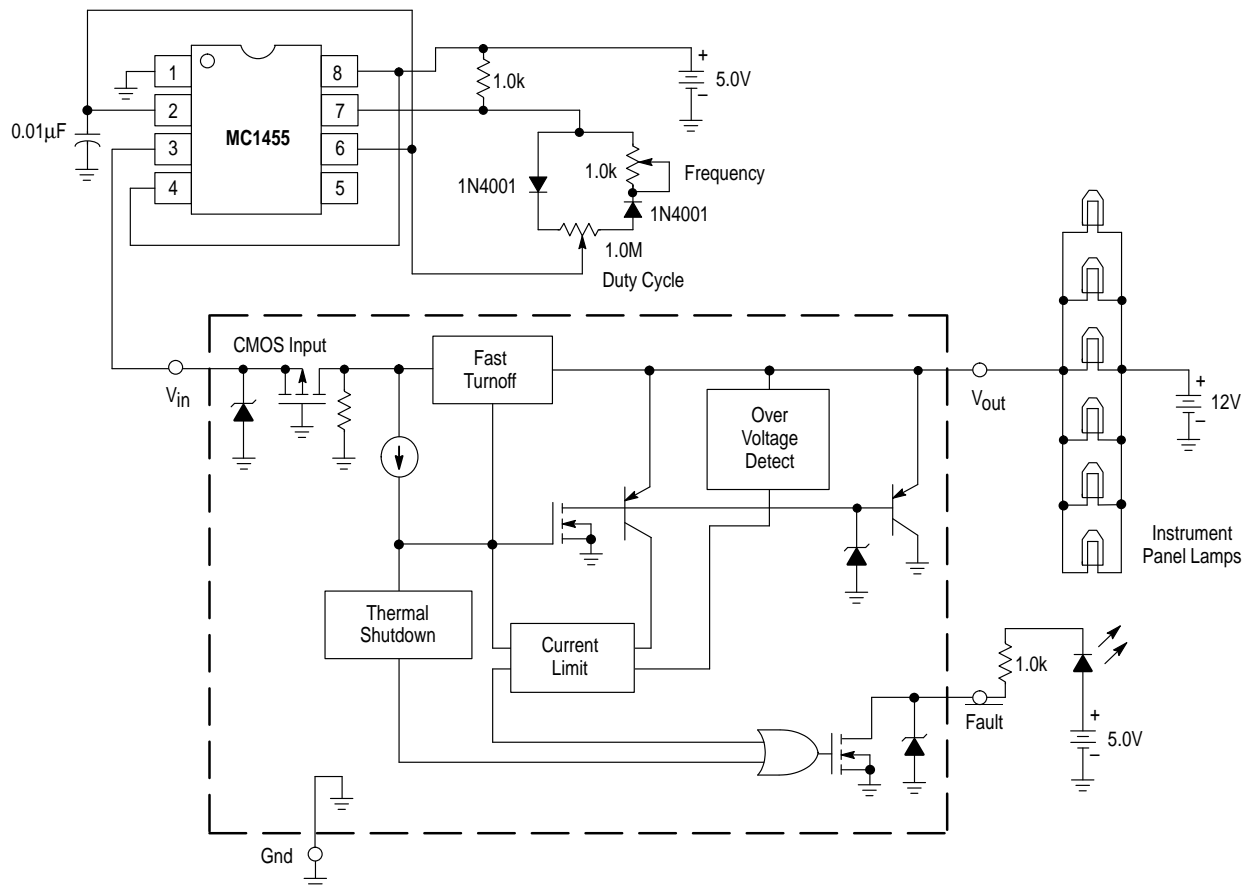
MC3392

OUTLINE DIMENSIONS

T SUFFIX
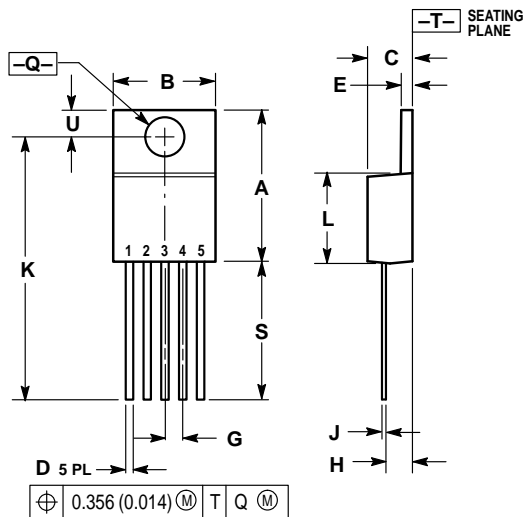PLASTIC PACKAGE
CASE 221A–06
(TO–220)
ISSUE Y

NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: INCH.
3. DIMENSION Z DEFINES A ZONE WHERE ALL BODY AND LEAD IRREGULARITIES ARE ALLOWED.

DIM	INCHES MIN	INCHES MAX	MILLIMETERS MIN	MILLIMETERS MAX
A	0.570	0.620	14.48	15.75
B	0.380	0.405	9.66	10.28
C	0.160	0.190	4.07	4.82
D	0.025	0.035	0.64	0.88
F	0.142	0.147	3.61	3.73
G	0.095	0.105	2.42	2.66
H	0.110	0.155	2.80	3.93
J	0.018	0.025	0.46	0.64
K	0.500	0.562	12.70	14.27
L	0.045	0.060	1.15	1.52
N	0.190	0.210	4.83	5.33
Q	0.100	0.120	2.54	3.04
R	0.080	0.110	2.04	2.79
S	0.045	0.055	1.15	1.39
T	0.235	0.255	5.97	6.47
U	0.000	0.050	0.00	1.27
V	0.045	—	1.15	—
Z	—	0.080	—	2.04

T–1 SUFFIX
PLASTIC PACKAGE
CASE 314D–03
(TO–220)
ISSUE D

NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: INCH.
3. DIMENSION D DOES NOT INCLUDE INTERCONNECT BAR (DAMBAR) PROTRUSION. DIMENSION D INCLUDING PROTRUSION SHALL NOT EXCEED 10.92 (0.043) MAXIMUM.

DIM	INCHES MIN	INCHES MAX	MILLIMETERS MIN	MILLIMETERS MAX
A	0.572	0.613	14.529	15.570
B	0.390	0.415	9.906	10.541
C	0.170	0.180	4.318	4.572
D	0.025	0.038	0.635	0.965
E	0.048	0.055	1.219	1.397
G	0.067 BSC		1.702 BSC	
H	0.087	0.112	2.210	2.845
J	0.015	0.025	0.381	0.635
K	1.020	1.065	25.908	27.051
L	0.320	0.365	8.128	9.271
Q	0.140	0.153	3.556	3.886
U	0.105	0.117	2.667	2.972
S	0.543	0.582	13.792	14.783

⊕ | 0.356 (0.014) Ⓜ | T | Q Ⓜ

MC3392

OUTLINE DIMENSIONS

DW SUFFIX
PLASTIC PACKAGE
CASE 751G–02
SOP(8+8)L
ISSUE A
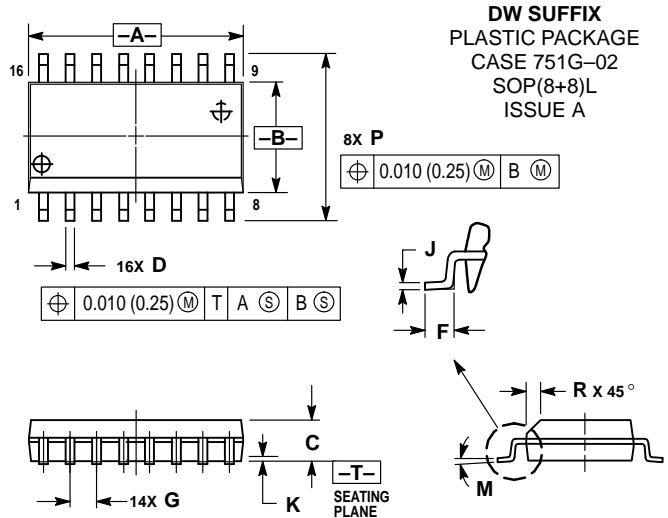
NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: MILLIMETER.
3. DIMENSIONS A AND B DO NOT INCLUDE MOLD PROTRUSION.
4. MAXIMUM MOLD PROTRUSION 0.15 (0.006) PER SIDE.
5. DIMENSION D DOES NOT INCLUDE DAMBAR PROTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL BE 0.13 (0.005) TOTAL IN EXCESS OF D DIMENSION AT MAXIMUM MATERIAL CONDITION.

DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	10.15	10.45	0.400	0.411
B	7.40	7.60	0.292	0.299
C	2.35	2.65	0.093	0.104
D	0.35	0.49	0.014	0.019
F	0.50	0.90	0.020	0.035
G	1.27 BSC		0.050 BSC	
J	0.25	0.32	0.010	0.012
K	0.10	0.25	0.004	0.009
M	0 °	7 °	0 °	7 °
P	10.05	10.55	0.395	0.415
R	0.25	0.75	0.010	0.029

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