

# Automotive Quad Low Side Driver

The MC33385 is a Quad Low Side Driver fully protected switch. This device is a general purpose Low Side Driver but has been especially designed to operate in engine management application as injector driver or automotive gear box. It is interfaced directly with a microcontroller for parallel control of the load and the individual output diagnostic is done through a SPI. The diagnostic logic recognizes 4 failure types at each output stage the overcurrent, the short to GND, the openload and the over-temperature.

- RDSON of 250mΩ per Output at 25°C
- Supplied from the main 5V Vcc
- Input CMOS Compatible
- Diagnostic through SPI
- Nominal Current of 2A per Output
- Current Limitation at 3A with Automatic Turn Off
- Output Internally Clamped at 50V typ for Inductive Load Drive
- Junction to Case Thermal Resistance of 4.4°C/W
- Individual Output over Temperature Shutdown

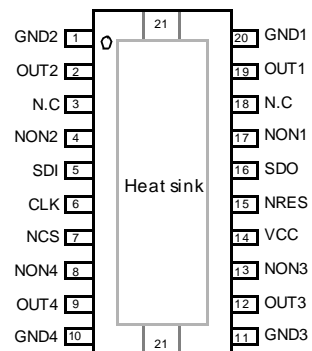
## QUAD LOW SIDE DRIVER

SEMICONDUCTOR  
TECHNICAL DATA



DH SUFFIX  
HSOP20 PACKAGE

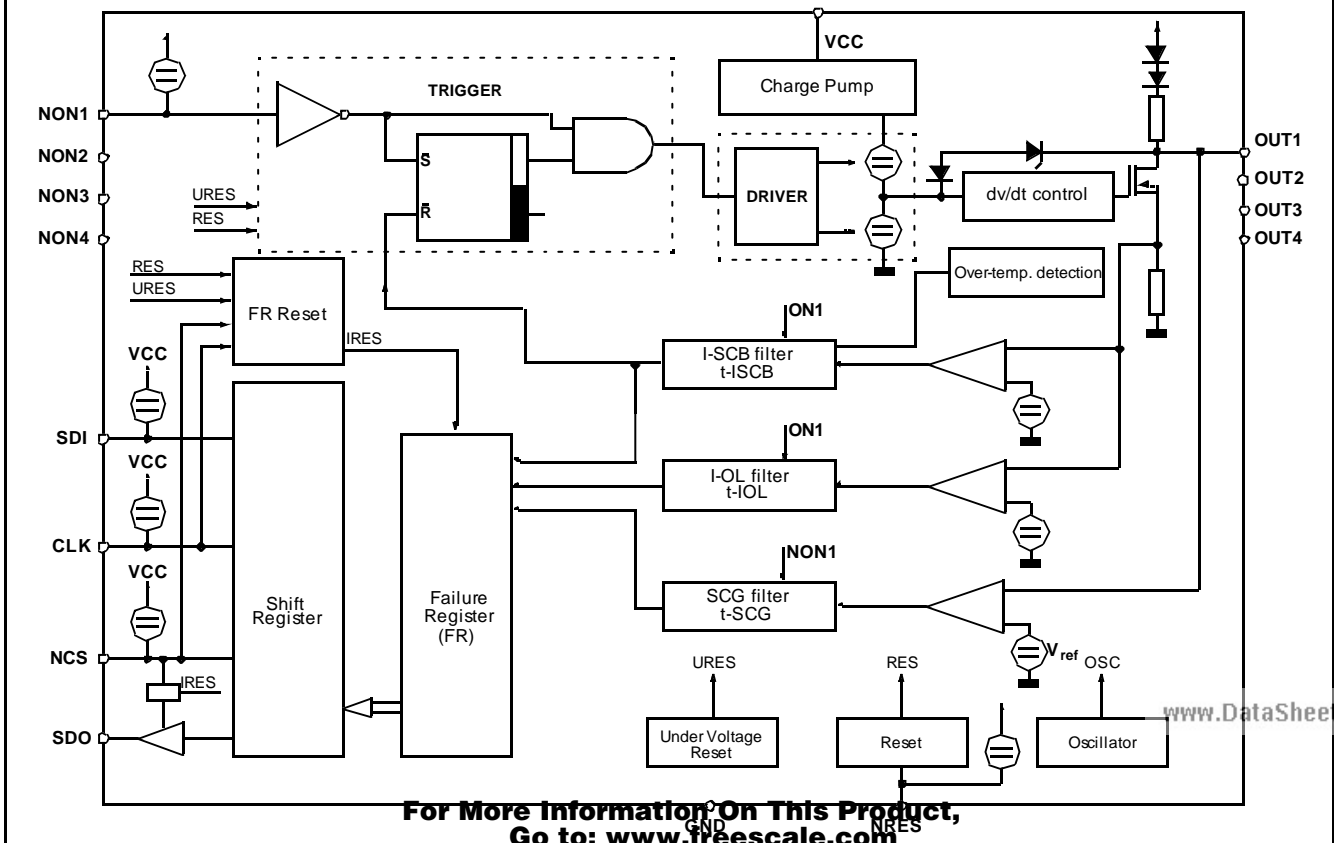
### PIN ASSIGNMENT



### ORDERING INFORMATION

| Device    | Temperature Range | Package |
|-----------|-------------------|---------|
| MC33385DH | -40°C to +125°C   | HSOP20  |

### Simplified Block Diagram



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MC33385

**Freescale Semiconductor, Inc.****MAXIMUM RATINGS**  $T_J = -40^{\circ}\text{C}$  up to  $150^{\circ}\text{C}$ 

| Ratings | Symbols | Min | Max | Unit |
|---------|---------|-----|-----|------|
|---------|---------|-----|-----|------|

**SUPPLY VOLTAGE**

|               |          |       |   |   |
|---------------|----------|-------|---|---|
| Voltage Range | $V_{CC}$ | - 0.3 | 7 | V |
|---------------|----------|-------|---|---|

**OUTPUTS : 1...4**

|   |            |       |              |            |
|---|------------|-------|--------------|------------|
| Continuous Output Voltage (With no reverse current) | $V_{out}$  | - 0.3 | 45           | V          |
| Continuous Current                                  | $I_{outc}$ |       | 2.5          | A          |
| Peak Output Current                                 | $I_{outp}$ | - 10  | $I_{SCBmax}$ | A          |
| Clamped Energy at the Switching OFF (See figure 6)  | $W_{OFF}$  |       | 70           | mJ for 1ms |

**INPUTS**

|                                |          |       |                |    |
|--------------------------------|----------|-------|----------------|----|
| Input Voltage (Inputs)         | $V_{IN}$ | - 0.3 | $V_{CC} + 0.3$ | V  |
| Input Protection Diode Current | $I_{IN}$ | - 20  | 1              | mA |

**OUTPUTS : SDO**

|                                |       |       |                |    |
|--------------------------------|-------|-------|----------------|----|
| Input Voltage (Outputs)        | $V_o$ | - 0.3 | $V_{CC} + 0.3$ | V  |
| Input Protection Diode Current | $I_o$ | - 20  | 1              | mA |

**THERMAL RATINGS**

|  |            |      |     |                    |
|--|------------|------|-----|--------------------|
| Operating Junction Temperature   | $T_J$      | - 40 | 150 | $^{\circ}\text{C}$ |
| Thermal Resistance : Junction-case (One powerstage in use)                       | $R_{thjc}$ |      | 4.5 | K/W                |
| Thermal Resistance : Junction-ambient (Device soldered on printed circuit board) | $R_{thja}$ |      | 50  | K/W                |

**RANGE OF FUNCTIONALITY**  $T_{case} = -40^{\circ}\text{C}$  up to  $125^{\circ}\text{C}$ 

| Ratings | Symbols | Min | Max | Unit |
|---------|---------|-----|-----|------|
|---------|---------|-----|-----|------|

**SUPPLY VOLTAGE**

|                      |          |     |     |   |
|----------------------|----------|-----|-----|---|
| Supply Voltage Range | $V_{CC}$ | 4.5 | 5.5 | V |
|----------------------|----------|-----|-----|---|

**JUNCTION TEMPERATURE**

|   |          |      |     |                    |
|---|----------|------|-----|--------------------|
| Junction Temperature Continuous (Continuous)  | $T_{j1}$ | - 40 | 150 | $^{\circ}\text{C}$ |
| Junction Temperature Dynamical (Time limited) | $T_{j2}$ |      | 185 | $^{\circ}\text{C}$ |

**OUTPUT CURRENT**

|                      |           |  |              |  |
|----------------------|-----------|--|--------------|--|
| Output Current Range | $I_{out}$ |  | $I_{SCBmax}$ |  |
|----------------------|-----------|--|--------------|--|

**RESET BEHAVIOUR**

|  |             |             |      |   |
|--|-------------|-------------|------|---|
| Reset Changeable (at NRES-Pin)   | $V_{CC}$    | $V_{CCRES}$ | 5.5  | V |
| Undervoltage Reset (Independent of NRES)<br>Active for $V_{CC} = 0\text{V}$ to $V_{CCPRO}$ | $V_{CCRES}$ | 3.35        | 3.95 | V |

**UNDERVOLTAGE PROTECTION**

|   |             |     |     |   |
|---|-------------|-----|-----|---|
| Protection active for $V_{CC}=0\text{V}$ to $V_{CCpro}$ | $V_{CCPRO}$ | 1.5 | 4.0 | V |
|---|-------------|-----|-----|---|

**OVER TEMPERATURE**

|                                 |           |     |     |                    |
|---------------------------------|-----------|-----|-----|--------------------|
| Temperature Detection Threshold | $T_{OFF}$ | 155 | 185 | $^{\circ}\text{C}$ |
|---------------------------------|-----------|-----|-----|--------------------|

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2

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## ELECTRICAL CHARACTERISTICS $T_{CASE} = -40^{\circ}$ up to $+125^{\circ}C$ and $V_{CC} = 4.5V$ up to $5.5V$

| Parameters | Symbol | Min | Typ | Max | Unit |
|------------|--------|-----|-----|-----|------|
|------------|--------|-----|-----|-----|------|

### SUPPLY CURRENT

|  |                              |  |  |           |          |
|--|------------------------------|--|--|-----------|----------|
| Standby Current (without load) (NON1...NON4 = High Level)<br>$5.15V \geq V_{CC}$<br>$5.5V \geq V_{CC}$ | $I_{ccSTB1}$<br>$I_{ccSTB2}$ |  |  | 6<br>7    | mA<br>mA |
| Operating Mode (For $5.15V \geq V_{CC}$ ) (Iout 1...4) = 2A  | $I_{ccOPM}$                  |  |  | 17        | mA       |
| $\Delta I_{cc}$ During Reverse Output Current<br>(Iout = -5A on one output)                            | $\Delta I_{cc}$              |  |  | 100<br>50 | mA<br>mA |

### INPUTS

|   |            |                    |  |                    |         |
|---|------------|--------------------|--|--------------------|---------|
| NONx, NCS, CLK, NRES, SDI   |            |                    |  |                    |         |
| Low Threshold   | VINL       | -0.3               |  | $0.2 \cdot V_{CC}$ | V       |
| High Threshold  | VINH       | $0.7 \cdot V_{CC}$ |  | $V_{CC} + 0.3$     | V       |
| Hysteresis  | $V_{hyst}$ | 0.85               |  |                    | V       |
| Input Current ( $V_{in} = V_{CC}$ )                                     | IIN        |                    |  | 10                 | $\mu A$ |
| Input Current ( $V_{CC} > V_{RES}$ & $0V < V_{IN} < 0.9 \cdot V_{CC}$ ) | IIN        | -100               |  | -20                | $\mu A$ |
| Input Frequency (NON1 to NON4)  | fIN        | 0                  |  | 1000               | Hz      |

### SERIAL DATA OUTPUT

|   |       |                |  |     |         |
|---|-------|----------------|--|-----|---------|
| High Output Level (ISDO = -2mA)                               | VSDOH | $V_{CC} - 0.4$ |  |     | V       |
| Low Output Level (ISDO = 3.2mA)                               | VSDOL |                |  | 0.4 | V       |
| Tristate Leakage Current (NCS = HIGH, VSDO = 0V to $V_{CC}$ ) | ISDOL | -10            |  | 10  | $\mu A$ |

### OUTPUTS (Out 1...4)

|  |              |             |    |             |            |
|--|--------------|-------------|----|-------------|------------|
| Average Output Current   | $I_{outa}$   | 2.5         |    |             | A          |
| Output Peak Current  | $I_{outp}$   | ISCBmax     |    |             | A          |
| Leakage Current 1 (NON = High, $V_{out} = 25V$ , $V_{CC} = 5V$ ) | $I_{outL1}$  |             |    | 10          | $\mu A$    |
| Leakage Current 2 (NON = High, $V_{out} = 16V$ , $V_{CC} = 1V$ ) | $I_{outL2}$  |             |    | 10          | $\mu A$    |
| Output Clamp Voltage (Iout = 1A)                                 | $V_{clp}$    | 45          | 50 | 58          | V          |
| Matching Clamp Voltage (Between two outputs)                     | $V_{dpm}$    | $V_{clp-1}$ |    | $V_{clp+1}$ | V          |
| Clamped Energy at the Switching OFF (See graph 6)                | $W_{OFF}$    | 50          |    |             | mJ for 1ms |
| On Resistance (Iout = 2A, $T_j = 150^{\circ}C$ , NON = LOW)      | RDSON        |             |    | 500         | m $\Omega$ |
| Output Low Voltage Limitation (Iout = 150mA)                     | $V_{outlim}$ | 65          |    | 220         | mV         |
| Output Capacitance (Guaranteed by design)                        | Cout         |             |    | 350         | pF         |

### OUTPUTS TIMING

|   |                |          |        |         |                          |
|---|----------------|----------|--------|---------|--------------------------|
| Positive Output Voltage Ramp (with inductive load)<br>$V_{out} = 4V \dots 16V$<br>$V_{out} = 16V \dots V_{clp}$ | OVRp1<br>OVRp2 | 2<br>3.5 | 3<br>6 | 5<br>10 | V/ $\mu s$<br>V/ $\mu s$ |
| Negative Output Voltage Ramp (25%... 75%)   | OVRn           | 1.75     | 3      | 4       | V/ $\mu s$               |
| Internal Switch-on-Time Charge Pump<br>(NON = LOW... $V_{Gate} = 0.9 \cdot V_{Bat}$ )                           | $t_{dCP}$      |          |        | 40      | $\mu s$                  |
| Turn ON Delay<br>(NON = 50%, $V_{out} = 0.9 \cdot V_{Bat}$ )  | $t_{dON}$      | 1        | 2.5    | 5       | $\mu s$                  |

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3

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## ELECTRICAL CHARACTERISTICS $T_{CASE} = -40^{\circ}$ up to $+125^{\circ}C$ and $V_{CC} = 4.5V$ up to $5.5V$

| Parameters   | Symbol                     | Min | Typ      | Max      | Unit               |
|--|----------------------------|-----|----------|----------|--------------------|
| Turn OFF Delay<br>(NON = 50%, $V_{out} = 0.1 * V_{Bat}$ )<br>(NON = 50%, $V_{out} = 4V$ )                          | $t_{dOFFa}$<br>$t_{dOFFb}$ |     | 1<br>4.7 | 3<br>7.5 | $\mu s$<br>$\mu s$ |
| Undervoltage Protection<br>Max ON time after a output voltage ramp from 0V to 25V at $V_{CC} = 0V \dots V_{CCpro}$ | $t_{rpON}$                 |     |          | 100      | $\mu s$            |
| Matching Turn ON Delay<br>(NON = 50%, $V_{out} = 0.9 * V_{Bat}$ )  | $t_{mON}$                  | - 3 |          | 3        | $\mu s$            |
| Rise time Turn OFF<br>(10% - 90% of $V_{dp}$ )   | $t_{rOFF}$                 |     | 8.5      | 12       |                    |

### OUTPUTS REVERSE DIODE

|  |                        |             |  |            |        |
|--|------------------------|-------------|--|------------|--------|
| Reverse Output Current   | $I_{RD}$               | 2,5         |  |            | A      |
| Reverse Peakcurrent (Note 1 and 2)                                 | $I_{RDP}$              | 5           |  |            | A      |
| Reverse Voltage Drop<br>- $I_{out} = - 5A$<br>- $I_{out} = - 2,5A$ | $V_{RD1}$<br>$V_{RD2}$ | 1.0<br>0.85 |  | 1.7<br>1.7 | V<br>V |

### POWERSTAGE PROTECTION

|                          |             |      |  |      |         |
|--------------------------|-------------|------|--|------|---------|
| Short Current Limit      | $I_{SCB}$   | 3.0  |  | 5    | A       |
| Short Circuit Delay Time | $t_{SCB}$   | 0.2  |  | 2    | $\mu s$ |
| $V_{CC}$ Undervoltage    | $V_{CCmin}$ | 3.35 |  | 3.95 | V       |

### DIAGNOSTIC

|  |           |                |  |                |             |
|--|-----------|----------------|--|----------------|-------------|
| Short to GND Threshold Voltage for $I_{OUT} \leq 2A$ | $V_{REF}$ | $0.390xV_{CC}$ |  | $0.435xV_{CC}$ | V           |
| Short to GND Filter Time                             | $T_{SCG}$ | 140            |  | 250            | $\mu s$     |
| Open Load Threshold Current                          | $I_{OL}$  | 10             |  | 50             | mA          |
| Open Load Filter Time                                | $t_{OL}$  | 140            |  | 250            | $\mu s$     |
| Pull-up Resistor                                     | $R_{OL}$  | 2.0            |  | 8.0            | k $\Omega$  |
| Temperature Detection Threshold                      | $T_{OFF}$ | 155            |  | 185            | $^{\circ}C$ |

**NOTES 1&2:** For  $t \leq 2ms$ . Max. reverse current is limited to - 10A (for all outputs together)

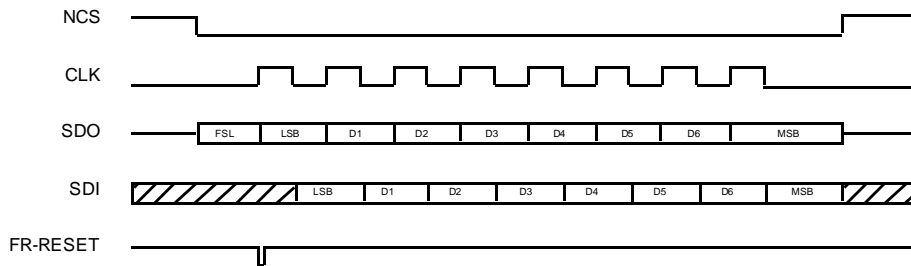
### SERIAL DIAGNOSTIC LINK : Load Capacitor at SDI and SDO = 100pF

|   |      |     |  |     |     |
|---|------|-----|--|-----|-----|
| Clock Frequency (50% duty cycle)                              | clk  | 3   |  |     | MHz |
| Minimum Time CLK = HIGH                                       | tclh | 100 |  |     | ns  |
| Minimum Time CLK = LOW  | tcll | 100 |  |     | ns  |
| Propagation Delay (CLF Data at SDO valid)                     | tpcl |     |  | 100 | ns  |
| NCS = LOW to Data at SDO Valid                                | tpcl |     |  | 100 | ns  |
| CLK Low Before NCS Low<br>(Setup time CLK to NCS change H/L)  | tscl | 100 |  |     | ns  |
| CLK Change L/H after NCS = Low                                | thcl | 100 |  |     | ns  |
| SDI Input Set up Time<br>(CLK change H/Lafter SDI data valid) | tscl | 20  |  |     | ns  |
| SDI Input Hold Time (SDI data hold after CLK change H/L)      | thcl |     |  | 20  | ns  |
| CLK Low Before NCS High                                       | tscl | 150 |  |     | ns  |
| CLK High After NCS High                                       | thcl | 150 |  |     | ns  |

| Parameters  | Symbol     | Min | Typ | Max | Unit |
|---|------------|-----|-----|-----|------|
| NCSL/H ti Output Data Flout                             | tpchdz     |     |     | 100 | ns   |
| Capacitance at SDI, SDO, CLK, CS                        | tpcld      |     |     | 10  | pF   |
| NCS Filtertime (Pulses $\leq t_{fNCS}$ will be ignored) | $t_{fNCS}$ | 10  |     | 40  | ns   |

### DIAGNOSTIC REGISTER AND SPI TIMING

Figure1- Timing Diagram to Read the Diagnostic Register



NOTE : FR -RESET means Reset failure storage (internal signal)

Figure2 - Diagnostic Failure Register Structure

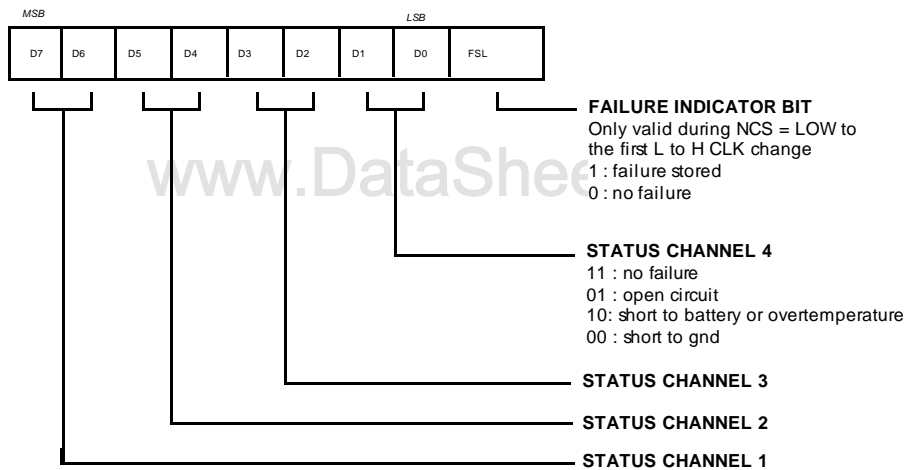
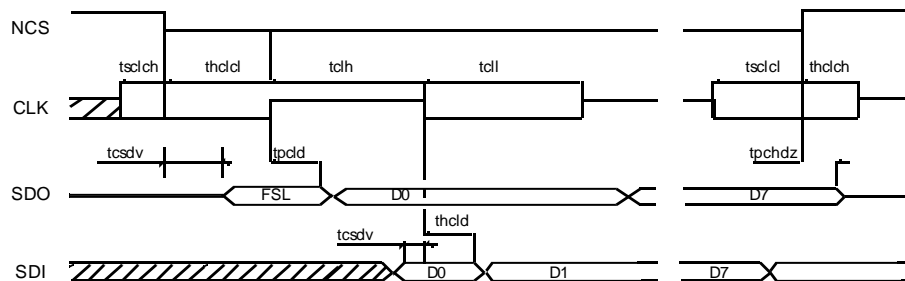
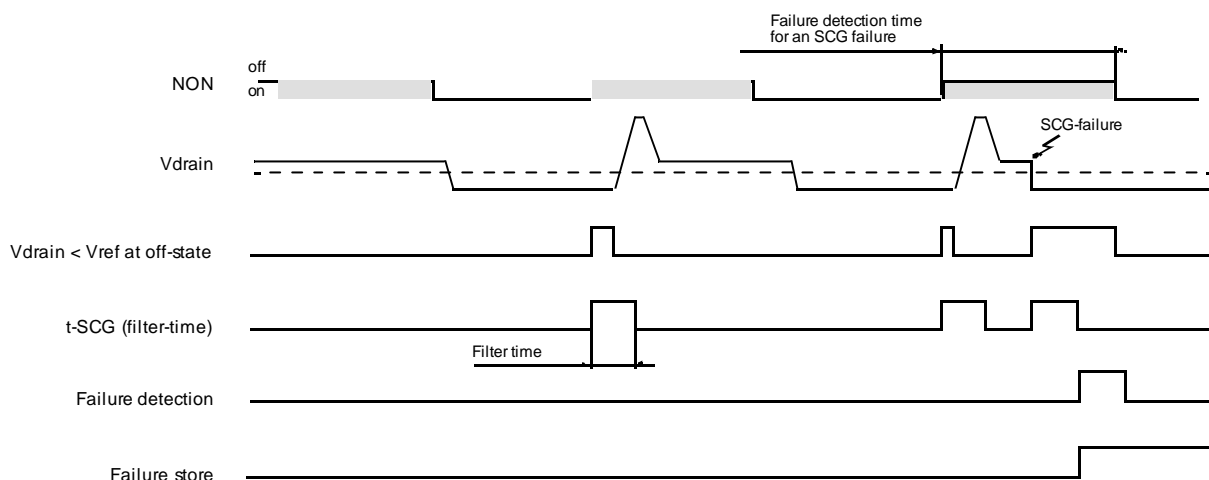


Figure3- Serial Interface Timing

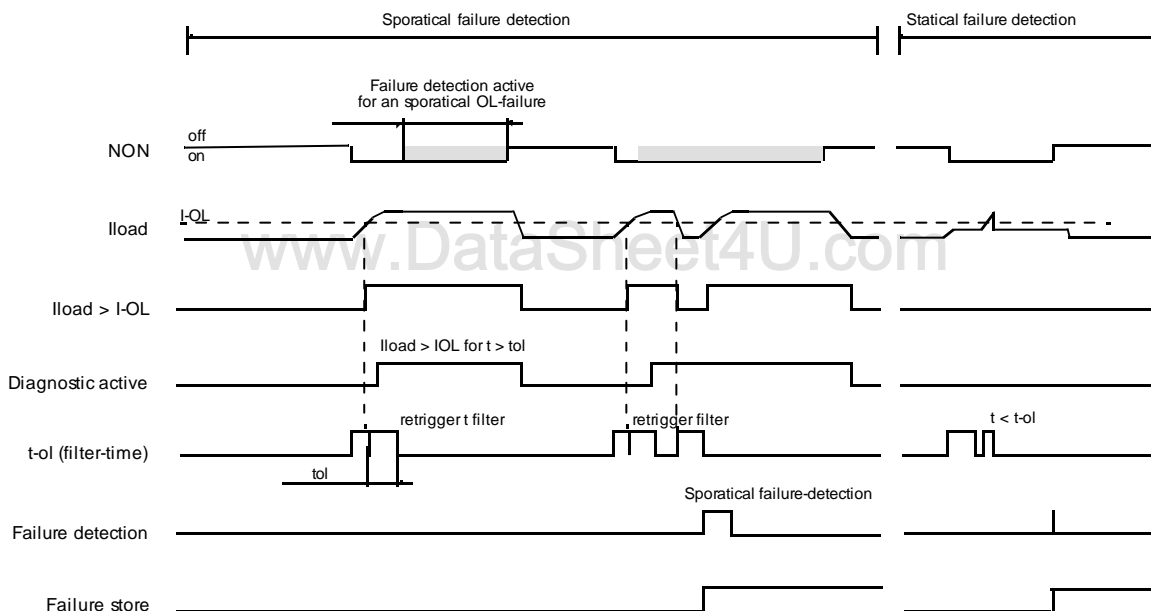


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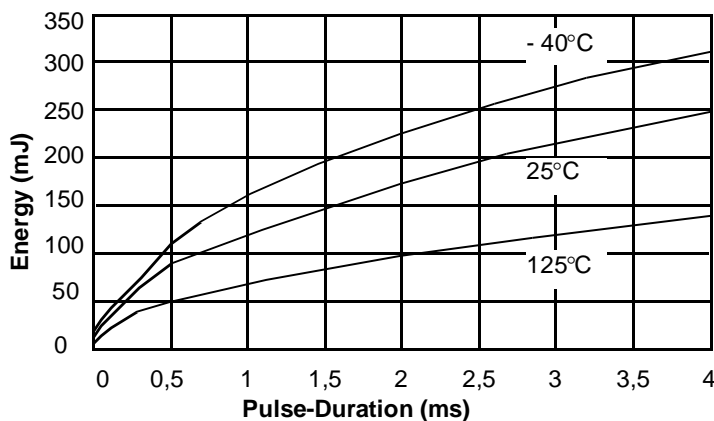
**Figure 4 - Diagram to Short-Circuit to GND Failure (SCG-Failure) Detection**



**Figure 5- Diagram to Open Load Failure (OL-Failure) Detection**



**Figure 6- Max Clamp- Energy Specification**



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## Introduction

The device is a Quad Low Side Driver driven by four CMOS input stages. Each output power transistor is protected against short to  $V_{BAT}$  and by a zener clamp against overvoltage.

A diagnostic logic recognizes four failure types at the output stage : overcurrent, short to GND, open-load and overtemperature.

The failures are individually stored in a byte which can be read out via a serial interface (SPI).

## Output Stage Control

Each of the four output stages is switched ON and OFF by an individual control line (NON-Input). The logic level of the control line is CMOS compatible. The output transistors are switched off when the inputs are not connected.

## Power Transistors

Each of the four output stages has its own zener clamp. This causes a voltage limitation at the power transistors when inductive loads are switched off. Drain voltage ramp occurring when output is switched on or off, is within defined limits. Output transistors can be connected in parallel to increase current capability. In this case, the associated inputs should be connected together.

## Short-Circuit and Overtemperature Protection

If the output current increases above the short current limit for a time longer than  $t_{SCB}$  or if the temperature increases above  $T_{OFF}$  then the power transistor is immediately switched off. It remains switched off until the control signal on the NON-Input is switched off and on again.

## Diagnostics

Following failures at the output stage are recognized :

- Short -Circuit to  $V_{BAT}$  or overtemp..... = SCB (Highest priority)
- Short -Circuit to GND..... = SCG
- Open Load..... = OL (Lowest priority)

The SCB failure is recognized by an overcurrent (current above the short current limit) or an overtemperature.

If the current through the output stage is lower than the IOL-reference, after a filter time an OL failure will be recognized. This measurement is active while the powerstage is switched on.

The SCG failure will recognize when the drain voltage is lower than the OL reference limit, while the output stage is switched off. All four outputs have an independent overtemperature detection and shutdown. All failures are stored in individual registers.

They can be read by the microprocessor via the serial interface. There is no failure detected if the powerstage control time is shorter than the filter time.

## Diagnostic Interface

The communication between the microprocessor and the failure register runs via the SPI link. If there is a failure stored in the failure register, the first bit of the shift register is set to a high level. With the H/L change on the NCS pin the first bit of the diagnostic shift register will be transmitted to the SDO output. The SDO output is the serial output from the diagnostic shift register and it is tristated when the NCS pin is high. The CLK pin clocks the diagnostic shift register. New SDO data will appear on every rising edge of this pin and new SDI data will be latched on every CLK' s falling edge into the shift register. With the first positive pulse of the CLK, the failure register will be cleared. There is no bus collision at a small spike at the NCS. The CLK is always LOW while the NCS-signal is changing.

## Reset

There are two different reset functions realised :

Under voltage reset : as long as the  $V_{CC}$  voltage is lower than  $V_{CCRES}$ , the powerstages are switched off and the failure-register are reseted.

Reset pin : as long as the NRES-pin is low, following circuits are reseted :

- Powerstages
- Failure register

## Undervoltage Protection

At low  $V_{CC}$  voltage, the device remains switched off even if there is a voltage ramp at the OUT pin.

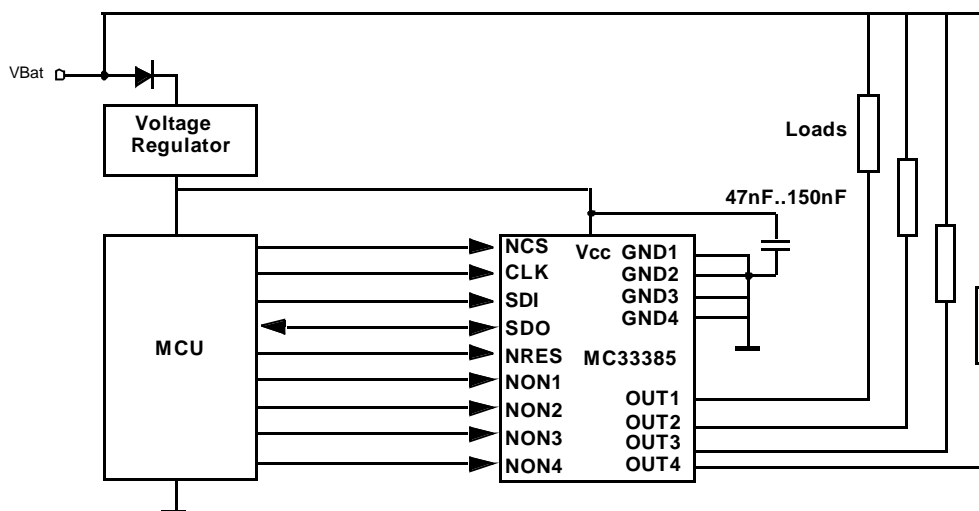
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This device is dedicated to automotive applications such as engine managements systems, automatic gear box... It interfaces between the microcontroller and the actuors of the system.

The loads can be only resistive or resistive and inductive such as injectors, EGR valves...etc... Following is an example of application schematic, see figure below.

Figure7- Typical Application



### PINS FUNCTION DESCRIPTION

| Pin No. | Function | Description                                      |
|---------|----------|--|
| 1       | GND2     | Ground 2   |
| 2       | OUT2     | Output Channel 2                                 |
| 3       |          | NC   |
| 4       | NON2     | Input Control Signal for Channel 2               |
| 5       | SDI      | Serial Data Input                                |
| 6       | CLK      | Clock Line for Serial Interface                  |
| 7       | NCS      | Chip Select for Serial Interface                 |
| 8       | NON4     | Input Control Signal for Channel 4               |
| 9       | OUT4     | Output Channel 4                                 |
| 10      | GND4     | Ground 4   |
| 11      | GND3     | Ground 3   |
| 12      | OUT3     | Output Channel 3                                 |
| 13      | NON3     | Input Control Signal for Channel 3               |
| 14      | Vcc      | 5V Power Supply                                  |
| 15      | NRES     | Reset Input                                      |
| 16      | SDO      | Data Output of Serial Interface                  |
| 17      | NON1     | Input Control Signal Channel 1                   |
| 18      |          | NC   |
| 19      | OUT1     | Output Channel 1                                 |
| 20      | GND1     | Ground 1   |
|         | Case     | Connected to the PCB Ground for Thermal Purposes |

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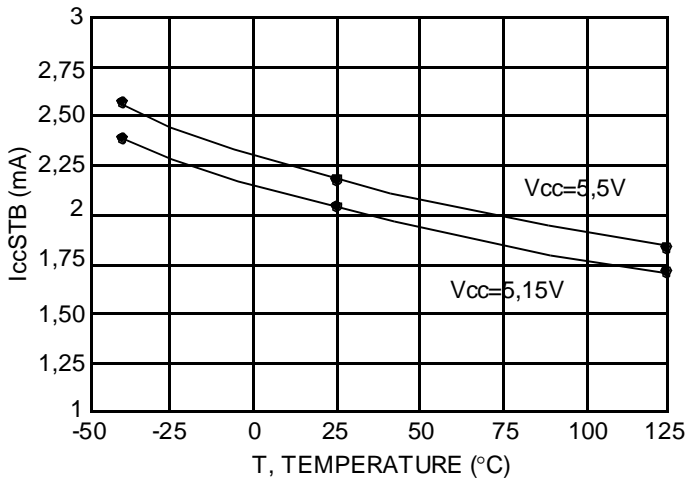
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8

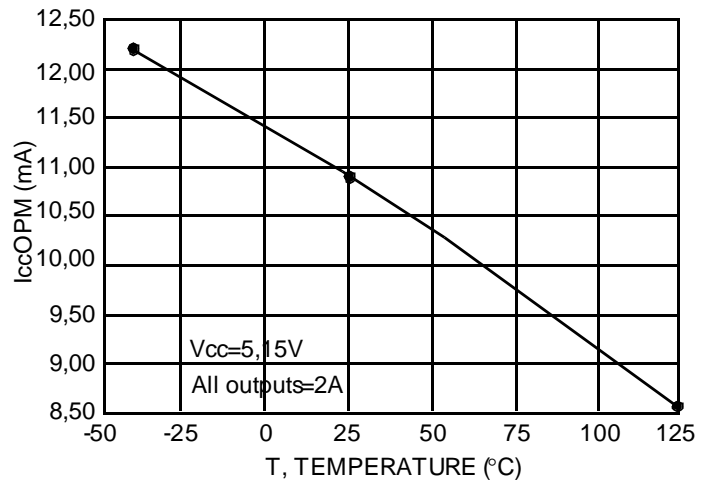


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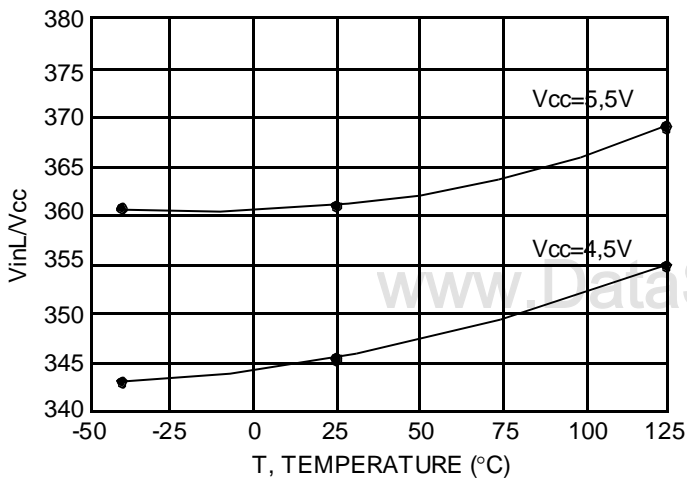
**Figure8- Standby Current versus Temperature**



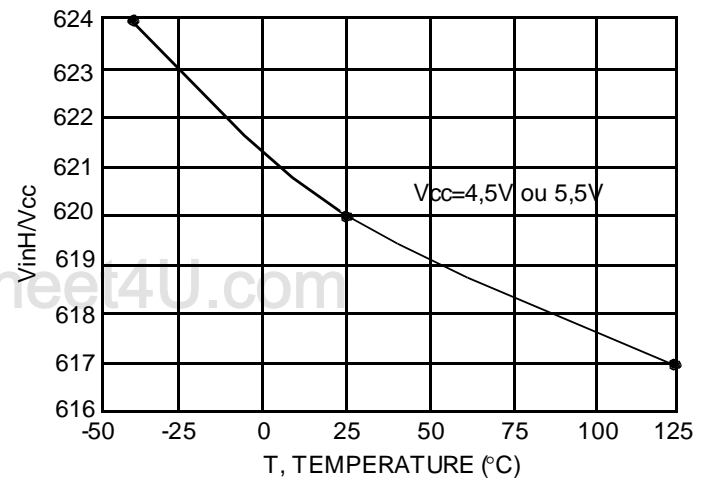
**Figure9- Operating Mode Current versus Temperature**



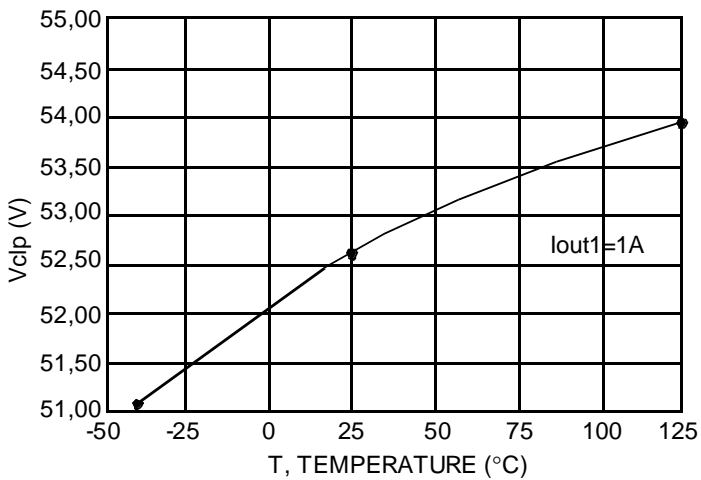
**Figure10- Low Threshold Input Voltage versus Temperature**



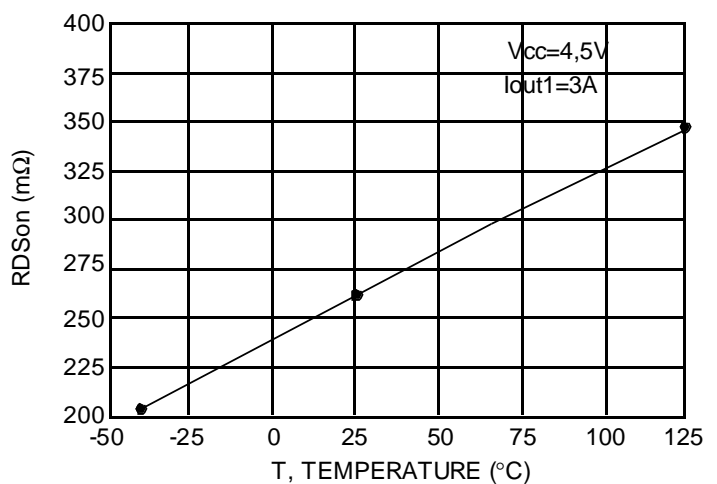
**Figure11- High Threshold Input Voltage versus Temperature**



**Figure12- Output Clamp Voltage versus Temperature**

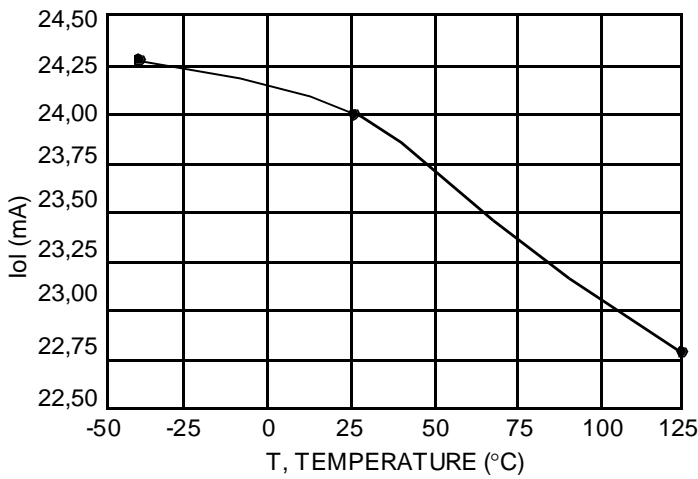


**Figure13 - RdsOn versus Temperature**

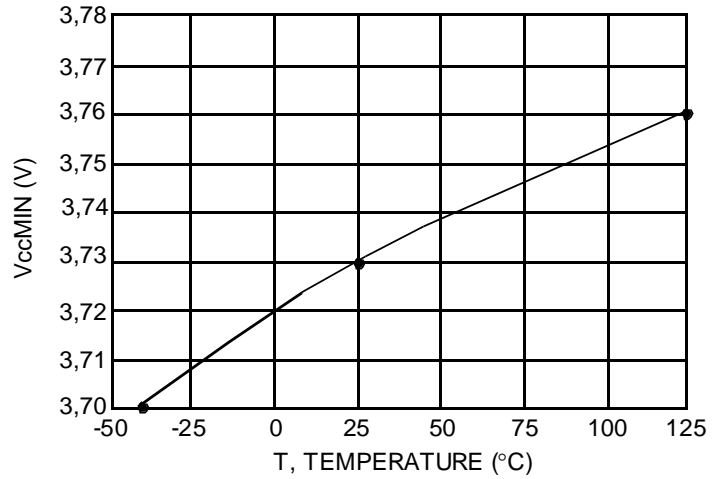


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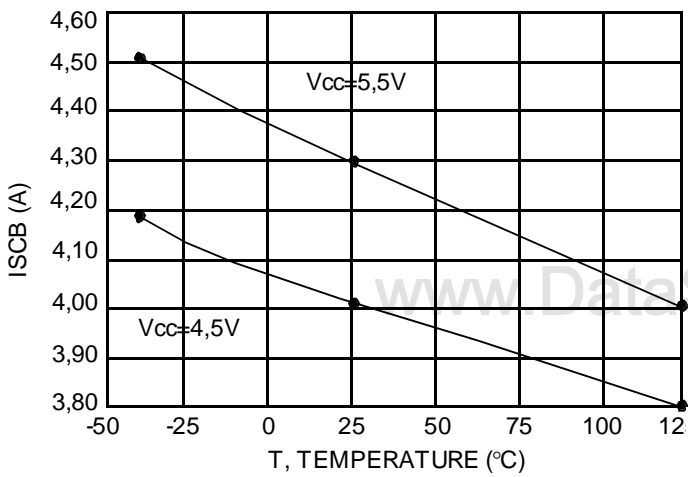
**Figure14- Open Load versus Temperature**



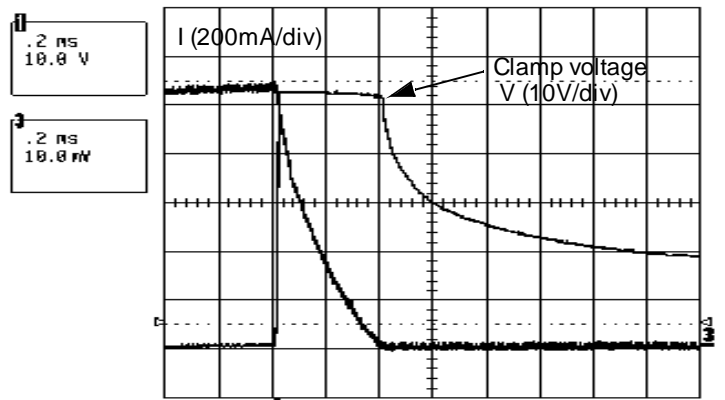
**Figure15- Vcc Undervoltage versus Temperature**



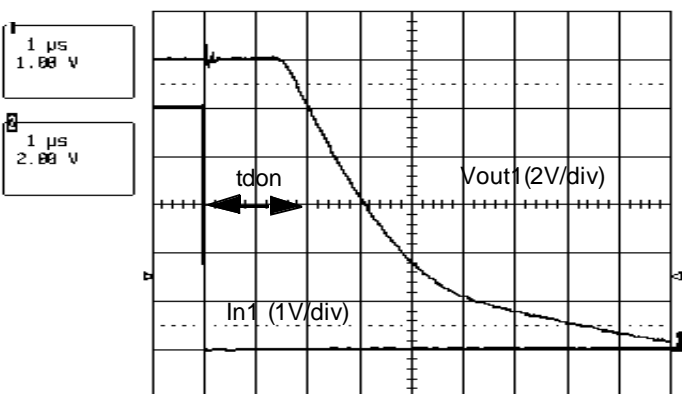
**Figure16- Short Current Limit versus Temperature**



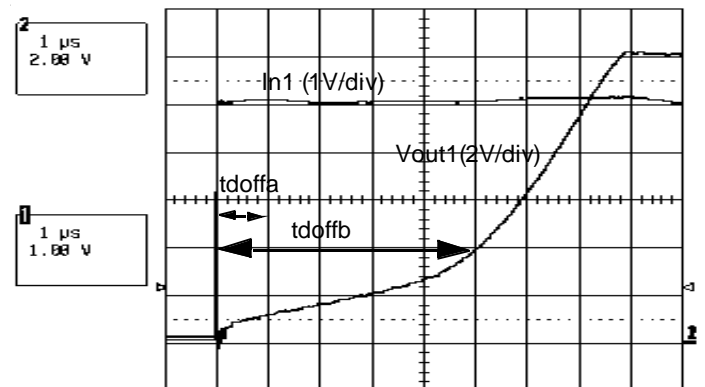
**Figure17- Inductive Switching**



**Figure18- Turn on Delay**

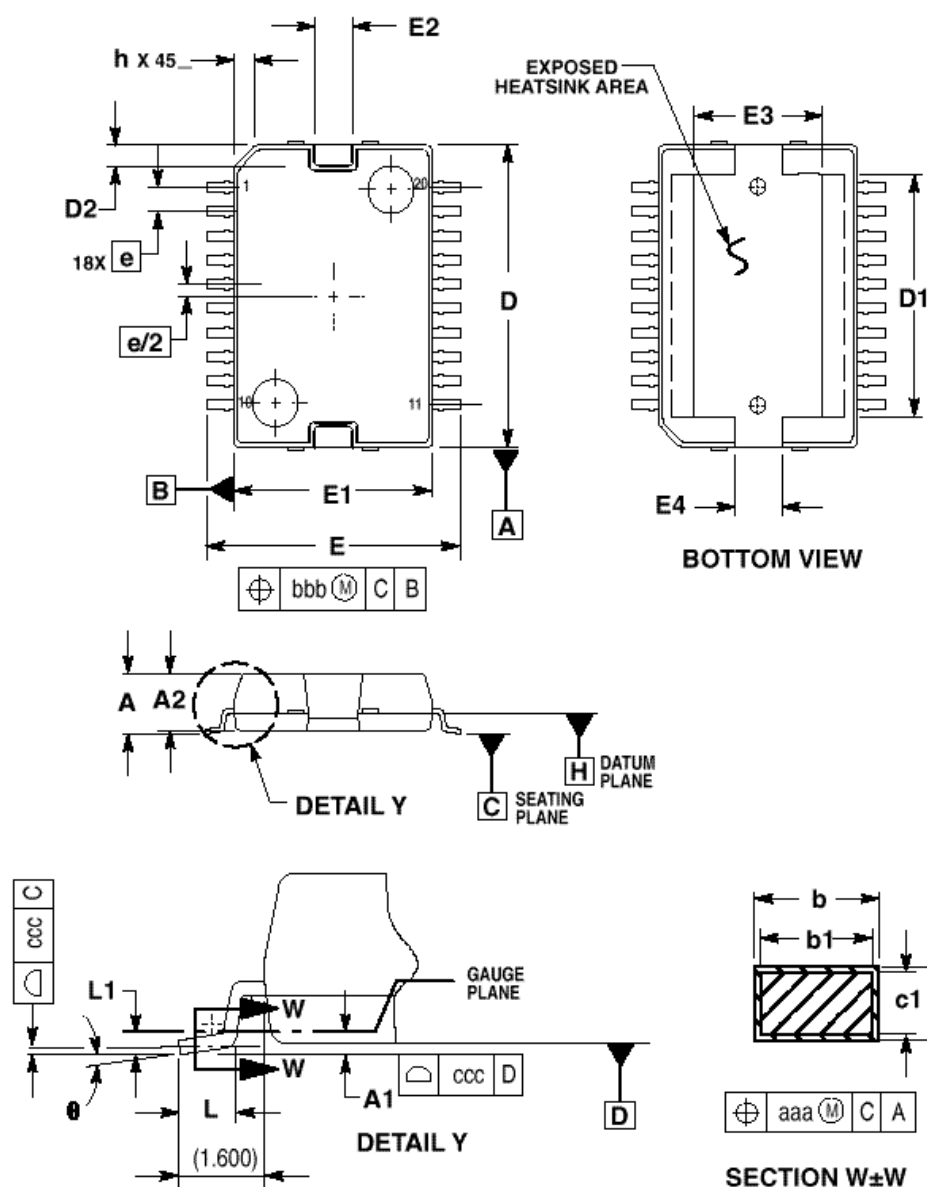


**Figure19- Turn off Delay**



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## CASE OUTLINES



## NOTES:

1. CONTROLLING DIMENSION: MILLIMETER.
2. DIMENSIONS AND TOLERANCES PER ASME Y14.5M, 1994.
3. DATUM PLANE  $\pm H$  IS LOCATED AT BOTTOM OF LEAD AND IS COINCIDENT WITH THE LEAD WHERE THE LEAD EXITS THE PLASTIC BODY AT THE BOTTOM OF THE PARTING LINE.
4. DIMENSIONS D AND E1 DO NOT INCLUDE MOLD PROTRUSION. ALLOWABLE PROTRUSION IS 0.150 PER SIDE. DIMENSIONS D AND E1 DO INCLUDE MOLD MISMATCH AND ARE DETERMINED AT DATUM PLANE  $\pm H$ .
5. DIMENSION b DOES NOT INCLUDE DAMBAR PROTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL BE 0.178 TOTAL IN EXCESS OF THE b DIMENSION AT MAXIMUM MATERIAL CONDITION.
6. DATUMS  $\pm A$  AND  $\pm B$  TO BE DETERMINED AT DATUM PLANE  $\pm H$ .
7. DIMENSION D DOES NOT INCLUDE TIEBAR PROTRUSIONS. ALLOWABLE TIEBAR PROTRUSIONS ARE 0.150 PER SIDE.

| DIM | MILLIMETERS |        |
|-----|-------------|--------|
|     | MIN         | MAX    |
| A   | 3.100       | 3.350  |
| A1  | 0.050 BSC   |        |
| A2  | 3.100       | 3.250  |
| D   | 15.800      | 16.000 |
| D1  | 12.270      | 12.470 |
| D2  | 0.900       | 1.100  |
| E   | 13.950      | 14.450 |
| E1  | 10.900      | 11.100 |
| E2  | 2.500       | 2.700  |
| E3  | 7.000       | 7.200  |
| E4  | 2.700       | 2.900  |
| L   | 0.840       | 1.100  |
| L1  | 0.350 BSC   |        |
| b   | 0.400       | 0.520  |
| b1  | 0.400       | 0.482  |
| c   | 0.230       | 0.310  |
| c1  | 0.230       | 0.280  |
| e   | 1.270 BSC   |        |
| h   | ***         | 1.100  |
| ⌀   | 0           | 8      |
| aaa | 0.200       |        |
| bbb | 0.200       |        |
| ccc | 0.100       |        |

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