

## Quad High Side Switch (Quad 35mΩ)

The 33874 is one in a family of devices designed for low-voltage automotive and industrial lighting and motor control applications. Its four low  $R_{DS(ON)}$  MOSFETs (four 35m $\Omega$ ) can control the high sides of four separate resistive or inductive loads.

Programming, control, and diagnostics are accomplished using a 16-bit SPI interface. Additionally, each output has its own parallel input for pulse-width modulation (PWM) control if desired. The 33874 allows the user to program via the SPI the fault current trip levels and duration of acceptable lamp inrush or motor stall intervals. Such programmability allows tight control of fault currents and can protect wiring harnesses and circuit boards as well as loads.

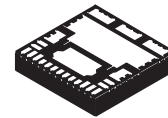
The 33874 is packaged in a power-enhanced 12x12 nonlead Power QFN package with exposed tabs.

## Features

- Quad 35mΩ high side switches (at 25°C)
- Operating voltage range of 6.0V to 27V with standby current < 5.0μA
- SPI control of over-current limit, over-current fault blanking time, output OFF open load detection, output ON/OFF control, watchdog timeout, slew rates, and fault status reporting
- SPI status reporting of over-current, open and shorted loads, over-temperature, under-voltage and over-voltage shutdown, fail-safe pin status, and program status
- Analog current feedback with selectable ratio
- Analog board temperature feedback
- Enhanced -16V reverse polarity  $V_{PWR}$  protection
- Pb-free packaging designated by suffix code PNA

**33874**

## HIGH SIDE SWITCH



**PNA SUFFIX (PB\_FREE)**  
**98ART10510D**  
**24-PIN PQFN (12 x 12)**

## ORDERING INFORMATION

| Device         | Temperature Range (T <sub>A</sub> ) | Package |
|----------------|-------------------------------------|---------|
| MC33874BPNA/R2 | -40°C to 125°C                      | 24 PQFN |

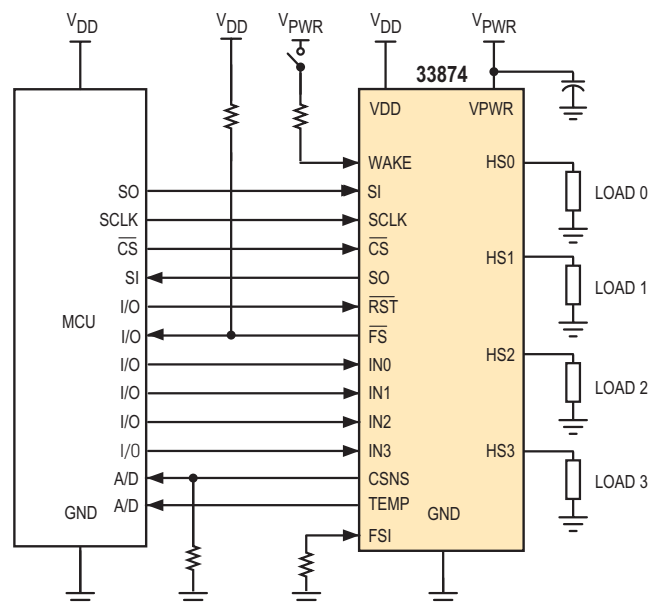


**Figure 1. 33874 Simplified Application Diagram**

\* This document contains certain information on a new product.  
Specifications and information herein are subject to change without notice.

## INTERNAL BLOCK DIAGRAM

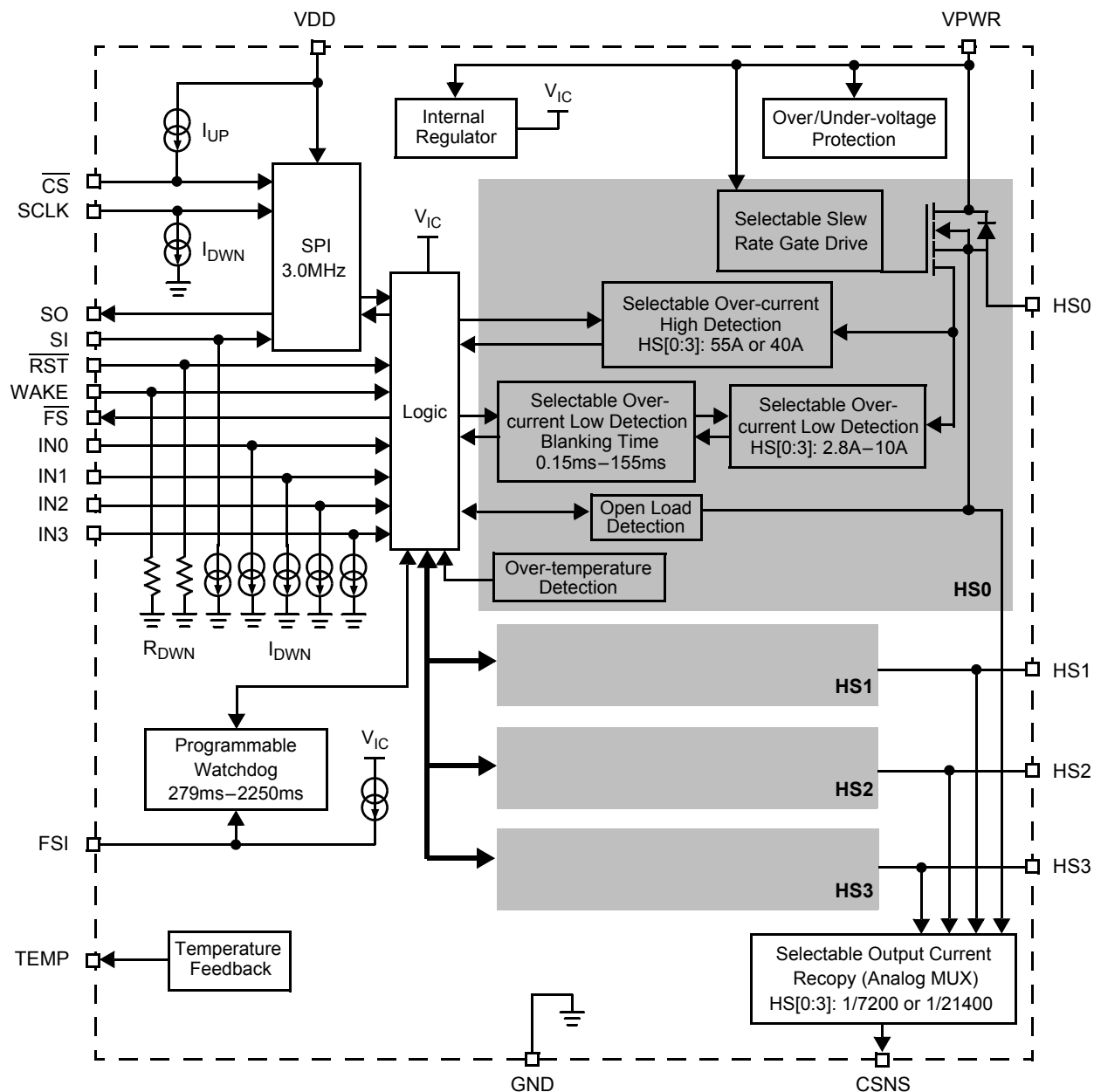


Figure 2. 33874 Simplified Internal Block Diagram

## PIN CONNECTIONS

### Transparent Top View of Package

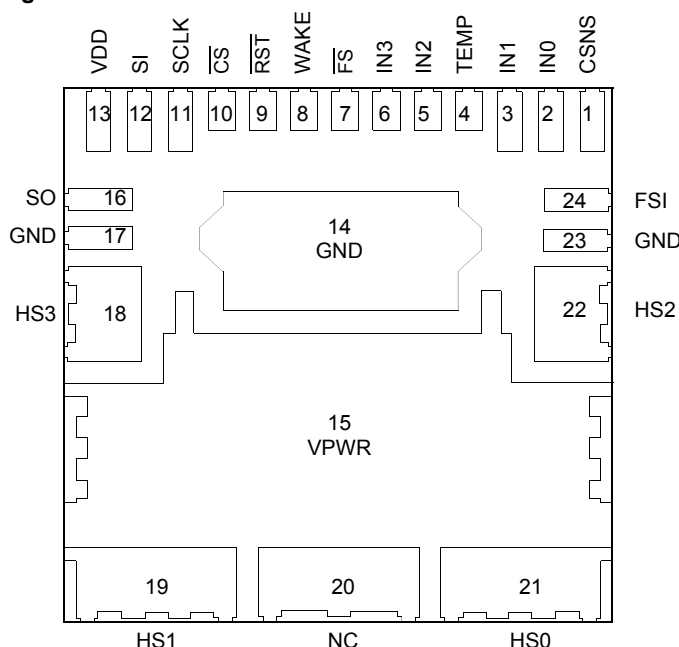


**Figure 3. 33874 Pin Connections**

**Table 1. 33874 Pin Definitions**

A functional description of each pin can be found in the Functional Pin Description section beginning on [page 15](#).

| Pin Number       | Pin Name                 | Pin Function | Formal Name                   | Definition                                                                                                                                                   |
|------------------|--------------------------|--------------|-------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1                | CSNS                     | Output       | Output Current Monitoring     | The Current Sense pin sources a current proportional to the designated HS0:HS3 output.                                                                       |
| 2<br>3<br>5<br>6 | IN0<br>IN1<br>IN2<br>IN3 | Input        | Parallel Inputs               | The IN0:IN3 high side input pins are used to directly control HS0:HS3 high side output pins, respectively.                                                   |
| 4                | TEMP                     | Output       | Temperature Feedback          | This pin reports an analog value proportional to the temperature of the GND flag (pins 14, 17, 23). It is used by the MCU to monitor board temperature.      |
| 7                | $\overline{FS}$          | Output       | Fault Status (Active Low)     | This pin is an open drain configured output requiring an external pull-up resistor to VDD for fault reporting.                                               |
| 8                | WAKE                     | Input        | Wake                          | This input pin controls the device mode and watchdog timeout feature if enabled.                                                                             |
| 9                | $\overline{RST}$         | Input        | Reset                         | This input pin is used to initialize the device configuration and fault registers, as well as place the device in a low-current Sleep Mode.                  |
| 10               | $\overline{CS}$          | Input        | Chip Select (Active Low)      | This input pin is connected to a chip select output of a master microcontroller (MCU).                                                                       |
| 11               | SCLK                     | Input        | Serial Clock                  | This input pin is connected to the MCU providing the required bit shift clock for SPI communication.                                                         |
| 12               | SI                       | Input        | Serial Input                  | This pin is a command data input pin connected to the SPI Serial Data Output of the MCU or to the SO pin of the previous device of a daisy-chain of devices. |
| 13               | VDD                      | Power        | Digital Drain Voltage (Power) | This pin is an external voltage input pin used to supply power to the SPI circuit.                                                                           |

**Table 1. 33874 Pin Definitions (continued)**

A functional description of each pin can be found in the Functional Pin Description section beginning on [page 15](#).

| Pin Number           | Pin Name                 | Pin Function | Formal Name           | Definition                                                                                                                                |
|----------------------|--------------------------|--------------|-----------------------|-------------------------------------------------------------------------------------------------------------------------------------------|
| 14, 17, 23           | GND                      | Ground       | Ground                | These pins are the ground for the logic and analog circuitry of the device.                                                               |
| 15                   | VPWR                     | Power        | Positive Power Supply | This pin connects to the positive power supply and is the source of operational power for the device.                                     |
| 16                   | SO                       | Output       | Serial Output         | This output pin is connected to the SPI Serial Data Input pin of the MCU or to the SI pin of the next device of a daisy-chain of devices. |
| 18<br>19<br>21<br>22 | HS3<br>HS1<br>HS0<br>HS2 | Output       | High Side Outputs     | Protected 35mΩ high side power output pins to the load.                                                                                   |
| 20                   | NC                       | N/A          | No Connect            | This pin may not be connected.                                                                                                            |
| 24                   | FSI                      | Input        | Fail-safe Input       | The value of the resistance connected between this pin and ground determines the state of the outputs after a watchdog timeout occurs.    |

## 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 |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------|---------------------------|------|
| <b>ELECTRICAL RATINGS</b>                                                                                                                                   |                                    |                           |      |
| Operating Voltage Range<br>Steady-State                                                                                                                     | $V_{PWR(SS)}$                      | -16 to 41                 | V    |
| $V_{DD}$ Supply Voltage                                                                                                                                     | $V_{DD}$                           | -0.3 to 5.5               | V    |
| Input/Output Voltage <sup>(1)</sup>                                                                                                                         | See note <sup>(1)</sup>            | -0.3 to 7.0               | V    |
| SO Output Voltage <sup>(1)</sup>                                                                                                                            | $V_{SO}$                           | -0.3 to $V_{DD}+0.3$      | V    |
| WAKE Input Clamp Current                                                                                                                                    | $I_{CL(WAKE)}$                     | 2.5                       | mA   |
| CSNS Input Clamp Current                                                                                                                                    | $I_{CL(CSNS)}$                     | 10                        | mA   |
| HS [0:3] Voltage<br>Positive<br>Negative                                                                                                                    | $V_{HS}$                           | 41<br>-16                 | V    |
| Output Current <sup>(2)</sup>                                                                                                                               | $I_{HS[0:3]}$                      | 11                        | A    |
| Output Clamp Energy <sup>(3)</sup>                                                                                                                          | $E_{CL[0:3]}$                      | 85                        | mJ   |
| ESD Voltage <sup>(4)</sup><br>Human Body Model (HBM)<br>Charge Device Model (CDM)<br>Corner Pins (1, 13, 19, 21)<br>All Other Pins (2-12, 14-18, 20, 22-24) | $V_{ESD}$                          | ±2000<br><br>±750<br>±500 | V    |
| <b>THERMAL RATINGS</b>                                                                                                                                      |                                    |                           |      |
| Operating Temperature<br>Ambient<br>Junction                                                                                                                | $T_A$<br>$T_J$                     | -40 to 125<br>-40 to 150  | °C   |
| Storage Temperature                                                                                                                                         | $T_{STG}$                          | -55 to 150                | °C   |
| Thermal Resistance <sup>(5)</sup><br>Junction to Case<br>Junction to Ambient                                                                                | $R_{\theta JC}$<br>$R_{\theta JA}$ | <1.0<br>30                | °C/W |
| Peak Pin Reflow Temperature During Solder Mounting <sup>(6)</sup>                                                                                           | $T_{SOLDER}$                       | Note 6                    | °C   |

## Notes

- Exceeding voltage limits on IN[0:3],  $\overline{RST}$ , FSI, CSNS, TEMP, SI, SO, SCLK,  $\overline{CS}$ , or  $\overline{FS}$  pins may cause a malfunction or permanent damage to the device.
- Continuous high side output current rating so long as maximum junction temperature is not exceeded. Calculation of maximum output current using package thermal resistance is required.
- Active clamp energy using single-pulse method ( $L = 2\text{mH}$ ,  $R_L = 0\Omega$ ,  $V_{PWR} = 14\text{V}$ ,  $T_J = 150^\circ\text{C}$  initial).
- ESD testing is performed in accordance with the Human Body Model ( $C_{ZAP} = 100\text{pF}$ ,  $R_{ZAP} = 1500\Omega$ ), Charge Device Model (CDM), Robotic ( $C_{ZAP} = 4.0\text{pF}$ ).
- Device mounted on a 2s2p test board per JEDEC JESD51-2.
- Freescale's Package Reflow capability meets Sn-Pb-free requirements for JEDEC standard J-STD-020A. For Peak Package Reflow Temperature and Moisture Sensitivity Levels (MSL), Go to [www.freescale.com](http://www.freescale.com), search by part number [e.g. remove prefixes/suffixes and enter the core ID to view all orderable parts. (i.e. MC33xxx enter 33xxx)], and review parametrics.

### STATIC ELECTRICAL CHARACTERISTICS

**Table 3. Static Electrical Characteristics**

Characteristics noted under conditions  $6.0V \leq V_{PWR} \leq 27V$ ,  $4.5V \leq V_{DD} \leq 5.5V$ ,  $-40^{\circ}C \leq T_A \leq 125^{\circ}C$ ,  $GND = 0V$ , unless otherwise noted. Typical values noted reflect the approximate parameter means at  $T_A = 25^{\circ}C$  under nominal conditions, unless otherwise noted.

| Characteristic                                                                                                                      | Symbol           | Min    | Typ      | Max        | Unit    |
|-------------------------------------------------------------------------------------------------------------------------------------|------------------|--------|----------|------------|---------|
| <b>POWER INPUT (VPWR, VDD)</b>                                                                                                      |                  |        |          |            |         |
| Battery Supply Voltage Range<br>Fully Operational                                                                                   | $V_{PWR}$        | 6.0    | –        | 27         | V       |
| $V_{PWR}$ Operating Supply Current<br>Outputs ON, HS[0:3] open                                                                      | $I_{PWR(ON)}$    | –      | –        | 20         | mA      |
| $V_{PWR}$ Supply Current<br>Outputs OFF, Open Load Detection Disabled, WAKE > $0.7 \times V_{DD}$ ,<br>$RST = V_{LOGIC\ HIGH}$      | $I_{PWR(SBY)}$   | –      | –        | 5.0        | mA      |
| Sleep State Supply Current ( $V_{PWR} = 14V$ , $\overline{RST} < 0.5V$ , WAKE < 0.5V)<br>$T_A = 25^{\circ}C$<br>$T_A = 85^{\circ}C$ | $I_{PWR(SLEEP)}$ | –<br>– | 1.0<br>– | 10<br>50   | $\mu A$ |
| $V_{DD}$ Supply Voltage                                                                                                             | $V_{DD(ON)}$     | 4.5    | 5.0      | 5.5        | V       |
| $V_{DD}$ Supply Current<br>No SPI Communication<br>3.0MHz SPI Communication <sup>(7)</sup>                                          | $I_{DD(ON)}$     | –<br>– | –<br>–   | 1.0<br>5.0 | mA      |
| $V_{DD}$ Sleep State Current                                                                                                        | $I_{DD(SLEEP)}$  | –      | –        | 5.0        | $\mu A$ |
| Over-voltage Shutdown Threshold                                                                                                     | $V_{OV}$         | 28     | 32       | 36         | V       |
| Over-voltage Shutdown Hysteresis                                                                                                    | $V_{OVHYS}$      | 0.2    | 0.8      | 1.5        | V       |
| Under-voltage Shutdown Threshold <sup>(8)</sup>                                                                                     | $V_{UV}$         | 4.75   | 5.25     | 5.75       | V       |
| Under-voltage Hysteresis <sup>(9)</sup>                                                                                             | $V_{UVHYS}$      | –      | 0.25     | –          | V       |
| Under-voltage Power-ON Reset                                                                                                        | $V_{UVPOR}$      | –      | –        | 4.75       | V       |

**Notes**

7. Not guaranteed in production.
8. The under-voltage fault condition is reported to SPI register as long as the external  $V_{DD}$  supply is within specification and the  $V_{PWR}$  voltage level does not go below the under-voltage Power-ON Reset threshold.
9. This applies when the under-voltage fault is not latched (IN = [0:3]).

**Table 3. Static Electrical Characteristics (continued)**

Characteristics noted under conditions  $6.0V \leq V_{PWR} \leq 27V$ ,  $4.5V \leq V_{DD} \leq 5.5V$ ,  $-40^{\circ}C \leq T_A \leq 125^{\circ}C$ ,  $GND = 0V$ , unless otherwise noted. Typical values noted reflect the approximate parameter means at  $T_A = 25^{\circ}C$  under nominal conditions, unless otherwise noted.

| Characteristic                                                                                                                                                                                                            | Symbol                                                                                                       | Min                                                  | Typ                                                 | Max                                                  | Unit      |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------|------------------------------------------------------|-----------------------------------------------------|------------------------------------------------------|-----------|
| <b>OUTPUTS (HS0, HS1, HS2, HS3)</b>                                                                                                                                                                                       |                                                                                                              |                                                      |                                                     |                                                      |           |
| Output Drain-to-Source ON Resistance ( $I_{HS} = 5.0A$ , $T_A = 25^{\circ}C$ )<br>$V_{PWR} = 6.0V$<br>$V_{PWR} = 10V$<br>$V_{PWR} = 13V$                                                                                  | $R_{DS(ON)}$                                                                                                 | –<br>–<br>–                                          | –<br>–<br>–                                         | 55<br>35<br>35                                       | $m\Omega$ |
| Output Drain-to-Source ON Resistance ( $I_{HS} = 5.0A$ , $T_A = 150^{\circ}C$ )<br>$V_{PWR} = 6.0V$<br>$V_{PWR} = 10V$<br>$V_{PWR} = 13V$                                                                                 | $R_{DS(ON)}$                                                                                                 | –<br>–<br>–                                          | –<br>–<br>–                                         | 94<br>60<br>60                                       | $m\Omega$ |
| Output Source-to-Drain ON Resistance <sup>(10)</sup><br>$I_{HS} = 1.0A$ , $T_A = 25^{\circ}C$ , $V_{PWR} = -12V$                                                                                                          | $R_{SD(ON)}$                                                                                                 | –                                                    | –                                                   | 70                                                   | $m\Omega$ |
| Output Overcurrent High Detection Levels ( $9.0V \leq V_{PWR} \leq 16V$ )<br>SOCH = 0<br>SOCH = 1                                                                                                                         | $I_{OCH0}$<br>$I_{OCH1}$                                                                                     | 44<br>32                                             | 55<br>40                                            | 66<br>48                                             | A         |
| Overcurrent Low Detection Levels ( $9.0V \leq V_{PWR} \leq 16V$ )<br>SOCL[2:0] : 000<br>SOCL[2:0] : 001<br>SOCL[2:0] : 010<br>SOCL[2:0] : 011<br>SOCL[2:0] : 100<br>SOCL[2:0] : 101<br>SOCL[2:0] : 110<br>SOCL[2:0] : 111 | $I_{OCL0}$<br>$I_{OCL1}$<br>$I_{OCL2}$<br>$I_{OCL3}$<br>$I_{OCL4}$<br>$I_{OCL5}$<br>$I_{OCL6}$<br>$I_{OCL7}$ | 8.0<br>7.1<br>6.3<br>5.6<br>4.6<br>3.8<br>3.1<br>2.2 | 10<br>8.9<br>7.9<br>7.0<br>5.8<br>4.8<br>3.9<br>2.8 | 12<br>10.7<br>9.5<br>8.5<br>7.0<br>5.8<br>4.7<br>3.4 | A         |
| Current Sense Ratio ( $9.0V \leq V_{PWR} \leq 16V$ , $CSNS \leq 4.5V$ )<br>DICR D2 = 0<br>DICR D2 = 1                                                                                                                     | $C_{SR0}$<br>$C_{SR1}$                                                                                       | –<br>–                                               | 1/7200<br>1/21400                                   | –<br>–                                               | –         |
| Current Sense Ratio ( $C_{SR0}$ ) Accuracy<br>Output Current<br>2.0A to 10A                                                                                                                                               | $C_{SR0\_ACC}$                                                                                               | –17                                                  | –                                                   | 17                                                   | %         |

## Notes

10. Source-Drain ON Resistance (Reverse Drain-to-Source ON Resistance) with negative polarity  $V_{PWR}$ .

**Table 3. Static Electrical Characteristics (continued)**

Characteristics noted under conditions  $6.0V \leq V_{PWR} \leq 27V$ ,  $4.5V \leq V_{DD} \leq 5.5V$ ,  $-40^{\circ}C \leq T_A \leq 125^{\circ}C$ ,  $GND = 0V$ , unless otherwise noted. Typical values noted reflect the approximate parameter means at  $T_A = 25^{\circ}C$  under nominal conditions, unless otherwise noted.

| Characteristic                                                                  | Symbol           | Min | Typ | Max | Unit        |
|---------------------------------------------------------------------------------|------------------|-----|-----|-----|-------------|
| <b>OUTPUTS (HS0, HS1, HS2, HS3) (continued)</b>                                 |                  |     |     |     |             |
| Current Sense Ratio ( $C_{SR1}$ ) Accuracy<br>Output Current<br>10A to 20A      | $C_{SR1\_ACC}$   | -19 | –   | 19  | %           |
| Current Sense Clamp Voltage<br>CSNS Open; $I_{HS[0:3]} = 11A$                   | $V_{CL(CSNS)}$   | 4.5 | 6.0 | 7.0 | V           |
| Open Load Detection Current <sup>(11)</sup>                                     | $I_{OLDC}$       | 30  | –   | 100 | $\mu A$     |
| Output Fault Detection Threshold<br>Output Programmed OFF                       | $V_{OFD(THRES)}$ | 2.0 | 3.0 | 4.0 | V           |
| Output Negative Clamp Voltage<br>$0.5A \leq I_{HS[0:3]} \leq 2.0A$ , Output OFF | $V_{CL}$         | -20 | –   | -16 | V           |
| Over-temperature Shutdown <sup>(12)</sup>                                       | $T_{SD}$         | 155 | 175 | 190 | $^{\circ}C$ |
| Over-temperature Shutdown Hysteresis <sup>(12)</sup>                            | $T_{SD(HYS)}$    | 5.0 | –   | 20  | $^{\circ}C$ |

Notes

11. Output OFF Open Load Detection Current is the current required to flow through the load for the purpose of detecting the existence of an open load condition when the specific output is commanded OFF.
12. Guaranteed by process monitoring. Not production tested.

**Table 3. Static Electrical Characteristics (continued)**

Characteristics noted under conditions  $6.0V \leq V_{PWR} \leq 27V$ ,  $4.5V \leq V_{DD} \leq 5.5V$ ,  $-40^{\circ}C \leq T_A \leq 125^{\circ}C$ ,  $GND = 0V$ , unless otherwise noted. Typical values noted reflect the approximate parameter means at  $T_A = 25^{\circ}C$  under nominal conditions, unless otherwise noted.

| Characteristic                                                                                                                                                                                                                                                                    | Symbol               | Min                  | Typ                        | Max                   | Unit            |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------|----------------------|----------------------------|-----------------------|-----------------|
| <b>CONTROL INTERFACE (SCLK, SI, SO, IN[0:3], <math>\overline{RST}</math>, WAKE, <math>\overline{FS}</math>, <math>\overline{CS}</math>, FSI)</b>                                                                                                                                  |                      |                      |                            |                       |                 |
| Input Logic High-voltage <sup>(13)</sup>                                                                                                                                                                                                                                          | $V_{IH}$             | $0.7 V_{DD}$         | –                          | –                     | V               |
| Input Logic Low-voltage <sup>(13)</sup>                                                                                                                                                                                                                                           | $V_{IL}$             | –                    | –                          | $0.2 V_{DD}$          | V               |
| Input Logic Voltage Hysteresis <sup>(14)</sup>                                                                                                                                                                                                                                    | $V_{IN(HYS)}$        | 100                  | 850                        | 1200                  | mV              |
| Input Logic Pull-down Current (SCLK, SI, IN[0:3], $V_{IN} > 0.2 \times V_{DD}$ )                                                                                                                                                                                                  | $I_{DWN}$            | 5.0                  | –                          | 20                    | $\mu A$         |
| $\overline{RST}$ Input Voltage Range                                                                                                                                                                                                                                              | $V_{\overline{RST}}$ | 4.5                  | 5.0                        | 5.5                   | V               |
| SO, $\overline{FS}$ Tri-State Capacitance <sup>(14)</sup>                                                                                                                                                                                                                         | $C_{SO}$             | –                    | –                          | 20                    | pF              |
| Input Logic Pull-down Resistor ( $\overline{RST}$ ) and WAKE                                                                                                                                                                                                                      | $R_{DWN}$            | 100                  | 200                        | 400                   | k $\Omega$      |
| Input Capacitance <sup>(15)</sup>                                                                                                                                                                                                                                                 | $C_{IN}$             | –                    | 4.0                        | 12                    | pF              |
| Wake Input Clamp Voltage <sup>(16)</sup><br>$I_{CL(WAKE)} < 2.5mA$                                                                                                                                                                                                                | $V_{CL(WAKE)}$       | 7.0                  | –                          | 14                    | V               |
| Wake Input Forward Voltage<br>$I_{CL(WAKE)} = -2.5mA$                                                                                                                                                                                                                             | $V_{F(WAKE)}$        | -2.0                 | –                          | -0.3                  | V               |
| SO High-state Output Voltage<br>$I_{OH} = 1.0mA$                                                                                                                                                                                                                                  | $V_{SOH}$            | $0.8 V_{DD}$         | –                          | –                     | V               |
| $\overline{FS}$ , SO Low-state Output Voltage<br>$I_{OL} = -1.6mA$                                                                                                                                                                                                                | $V_{SOL}$            | –                    | 0.2                        | 0.4                   | V               |
| SO Tri-state Leakage Current<br>$\overline{CS} \geq 0.7 \times V_{DD}$ , $0 < V_{SO} < V_{DD}$                                                                                                                                                                                    | $I_{SO(LEAK)}$       | -5.0                 | 0                          | 5.0                   | $\mu A$         |
| Input Logic Pull-up Current <sup>(17)</sup><br>$\overline{CS}$ , $V_{IN} < 0.7 \times V_{DD}$                                                                                                                                                                                     | $I_{UP}$             | 5.0                  | –                          | 20                    | $\mu A$         |
| FSI Input pin External Pull-down Resistance <sup>(18)</sup><br>FSI Disabled, HS[0:3] state according to direct inputs state and SPI<br>INx_SPI bits and A/O_s bit<br>FSI Enabled, HS[0:3] OFF<br>FSI Enabled, HS0 ON, HS[1:3] OFF<br>FSI Enabled, HS0 and HS2 ON, HS1 and HS3 OFF | $R_{FS}$             | –<br>6.0<br>15<br>40 | 0<br>6.5<br>17<br>Infinite | 1.0<br>7.0<br>19<br>– | k $\Omega$      |
| Temperature Feedback<br>$T_A = 25^{\circ}C$                                                                                                                                                                                                                                       | $T_{FEED}$           | 3.8                  | 3.9                        | 4.0                   | V               |
| Temperature Feedback Derating                                                                                                                                                                                                                                                     | $DT_{FEED}$          | -7.2                 | -7.5                       | -7.8                  | mV/ $^{\circ}C$ |

**Notes**

- Upper and lower logic threshold voltage range applies to SI,  $\overline{CS}$ , SCLK,  $\overline{RST}$ , IN[0:3], and WAKE input signals. The WAKE and  $\overline{RST}$  signals may be supplied by a derived voltage referenced to  $V_{PWR}$ .
- No hysteresis on FSI and wake pins. Parameter is guaranteed by process monitoring but is not production tested.
- Input capacitance of SI,  $\overline{CS}$ , SCLK,  $\overline{RST}$ , and WAKE. This parameter is guaranteed by process monitoring but is not production tested.
- The current must be limited by a series resistance when using voltages  $> 7.0V$ .
- Pull-up current is with  $\overline{CS}$  OPEN.  $\overline{CS}$  has an active internal pull-up to VDD.
- The selection of the RFS must take into consideration the tolerance, temperature coefficient and lifetime duration to assure that the resistance value will always be within the desired (specified) range.

## DYNAMIC ELECTRICAL CHARACTERISTICS

**Table 4. Dynamic Electrical Characteristics**

Characteristics noted under conditions  $6.0V \leq V_{PWR} \leq 27V$ ,  $4.5V \leq V_{DD} \leq 5.5V$ ,  $-40^{\circ}C \leq T_A \leq 125^{\circ}C$ ,  $GND = 0V$ , unless otherwise noted. Typical values noted reflect the approximate parameter means at  $T_A = 25^{\circ}C$  under nominal conditions, unless otherwise noted.

| Characteristic                                                                                                               | Symbol                                                                           | Min                    | Typ                    | Max                   | Unit       |
|------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------|------------------------|------------------------|-----------------------|------------|
| <b>POWER OUTPUT TIMING (HS0, HS1, HS2, HS3)</b>                                                                              |                                                                                  |                        |                        |                       |            |
| Output Rising Slow Slew Rate A (DICR D3 = 0) <sup>(19)</sup><br>$9.0V < V_{PWR} < 16V$                                       | SR <sub>RA_SLOW</sub>                                                            | 0.1                    | 0.3                    | 0.75                  | V/ $\mu$ s |
| Output Rising Slow Slew Rate B (DICR D3 = 0) <sup>(20)</sup><br>$9.0V < V_{PWR} < 16V$                                       | SR <sub>RB_SLOW</sub>                                                            | 0.015                  | 0.05                   | 0.15                  | V/ $\mu$ s |
| Output Rising Fast Slew Rate A (DICR D3 = 1) <sup>(19)</sup><br>$9.0V < V_{PWR} < 16V$                                       | SR <sub>RA_FAST</sub>                                                            | 0.5                    | 1.5                    | 3.0                   | V/ $\mu$ s |
| Output Rising Fast Slew Rate B (DICR D3 = 1) <sup>(20)</sup><br>$9.0V < V_{PWR} < 16V$                                       | SR <sub>RB_FAST</sub>                                                            | 0.025                  | 0.3                    | 1.0                   | V/ $\mu$ s |
| Output Falling Slow Slew Rate A (DICR D3 = 0) <sup>(19)</sup><br>$9.0V < V_{PWR} < 16V$                                      | SR <sub>FA_SLOW</sub>                                                            | 0.1                    | 0.3                    | 0.75                  | V/ $\mu$ s |
| Output Falling Slow Slew Rate B (DICR D3 = 0) <sup>(20)</sup><br>$9.0V < V_{PWR} < 16V$                                      | SR <sub>FB_SLOW</sub>                                                            | 0.015                  | 0.05                   | 0.15                  | V/ $\mu$ s |
| Output Falling Fast Slew Rate A (DICR D3 = 1) <sup>(19)</sup><br>$9.0V < V_{PWR} < 16V$                                      | SR <sub>FA_FAST</sub>                                                            | 0.5                    | 1.5                    | 3.0                   | V/ $\mu$ s |
| Output Falling Fast Slew Rate B (DICR D3 = 1) <sup>(20)</sup><br>$9.0V < V_{PWR} < 16V$                                      | SR <sub>FB_FAST</sub>                                                            | 0.025                  | 0.3                    | 1.0                   | V/ $\mu$ s |
| Output Turn-ON Delay Time in Slow Slew Rate <sup>(21)</sup><br>DICR = 0                                                      | t <sub>DLY_SLOW(ON)</sub>                                                        | 2.0                    | 30                     | 200                   | $\mu$ s    |
| Output Turn-ON Delay Time in Fast Slew Rate <sup>(21)</sup><br>DICR = 1                                                      | t <sub>DLY_FAST(ON)</sub>                                                        | 1.0                    | 6.0                    | 100                   | $\mu$ s    |
| Output Turn-OFF Delay Time in Slow Slew Rate Mode <sup>(22)</sup><br>DICR = 0                                                | t <sub>DLY_SLOW(OFF)</sub>                                                       | 40                     | 200                    | 800                   | $\mu$ s    |
| Output Turn-OFF Delay Time in Fast Slew Rate Mode <sup>(22)</sup><br>DICR = 1                                                | t <sub>DLY_FAST(OFF)</sub>                                                       | 20                     | 50                     | 400                   | $\mu$ s    |
| Over-current Low Detection Blanking Time<br>OCLT[1:0]: 00<br>OCLT[1:0]: 01 <sup>(23)</sup><br>OCLT[1:0]: 10<br>OCLT[1:0]: 11 | t <sub>OCL0</sub><br>t <sub>OCL1</sub><br>t <sub>OCL2</sub><br>t <sub>OCL3</sub> | 108<br>—<br>55<br>0.08 | 155<br>—<br>75<br>0.15 | 202<br>—<br>95<br>0.3 | ms         |

**Notes**

- Rise and Fall Slew Rates A measured across a  $5.0\Omega$  resistive load at high side output =  $0.5V$  to  $V_{PWR} - 3.5V$  (see [Figure 4](#), page 12). These parameters are guaranteed by process monitoring.
- Rise and Fall Slew Rates B measured across a  $5.0\Omega$  resistive load at high side output =  $0.5V$  to  $V_{PWR} - 3.5V$  (see [Figure 4](#)). These parameters are guaranteed by process monitoring.
- Turn-ON delay time measured from rising edge of any signal (IN[0:3], SCLK,  $\overline{CS}$ ) that would turn the output ON to  $V_{HS[0:3]} = 0.5V$  with  $R_L = 5.0\Omega$  resistive load.
- Turn-OFF delay time measured from falling edge of any signal (IN[0:3], SCLK,  $\overline{CS}$ ) that would turn the output OFF to  $V_{HS[0:3]} = V_{PWR} - 0.5V$  with  $R_L = 5.0\Omega$  resistive load.
- This logical bit is not defined. Do not use.

**Table 4. Dynamic Electrical Characteristics (continued)**

Characteristics noted under conditions  $6.0V \leq V_{PWR} \leq 27V$ ,  $4.5V \leq V_{DD} \leq 5.5V$ ,  $-40^{\circ}C \leq T_A \leq 125^{\circ}C$ ,  $GND = 0V$ , unless otherwise noted. Typical values noted reflect the approximate parameter means at  $T_A = 25^{\circ}C$  under nominal conditions, unless otherwise noted.

| Characteristic                                              | Symbol       | Min  | Typ  | Max  | Unit    |
|-------------------------------------------------------------|--------------|------|------|------|---------|
| <b>POWER OUTPUT TIMING (HS0, HS1, HS2, HS3) (continued)</b> |              |      |      |      |         |
| Over-current High Detection Blanking Time                   | $t_{OCH}$    | 1.0  | 5.0  | 20   | $\mu s$ |
| $\overline{CS}$ to CSNS Valid Time <sup>(24)</sup>          | $t_{CNSVAL}$ | –    | –    | 10   | $\mu s$ |
| Watchdog Timeout <sup>(25)</sup>                            |              |      |      |      | ms      |
| WD[1:0] : 00                                                | $t_{WDTO0}$  | 446  | 558  | 725  |         |
| WD[1:0] : 01                                                | $t_{WDTO1}$  | 223  | 279  | 363  |         |
| WD[1:0] : 10                                                | $t_{WDTO2}$  | 1800 | 2250 | 2925 |         |
| WD[1:0] : 11                                                | $t_{WDTO3}$  | 900  | 1125 | 1463 |         |
| Direct Input Switching Frequency (DICR D3 = 0)              | $f_{PWM}$    | –    | 300  | –    | Hz      |

**SPI INTERFACE CHARACTERISTICS ( $\overline{RST}$ ,  $\overline{CS}$ , SCLK, SI, SO)**

|                                                                                                                               |                     |   |    |     |         |
|-------------------------------------------------------------------------------------------------------------------------------|---------------------|---|----|-----|---------|
| Maximum Frequency of SPI Operation                                                                                            | $f_{SPI}$           | – | –  | 3.0 | MHz     |
| Required Low-state Duration for $\overline{RST}$ <sup>(26)</sup>                                                              | $t_{WRST}$          | – | 50 | 350 | ns      |
| Rising Edge of $\overline{CS}$ to Falling Edge of $\overline{CS}$ (Required Setup Time) <sup>(27)</sup>                       | $t_{\overline{CS}}$ | – | –  | 300 | ns      |
| Rising Edge of $\overline{RST}$ to Falling Edge of $\overline{CS}$ (Required Setup Time) <sup>(27)</sup>                      | $t_{ENBL}$          | – | –  | 5.0 | $\mu s$ |
| Falling Edge of $\overline{CS}$ to Rising Edge of SCLK (Required Setup Time) <sup>(27)</sup>                                  | $t_{LEAD}$          | – | 50 | 167 | ns      |
| Required High-state Duration of SCLK (Required Setup Time) <sup>(27)</sup>                                                    | $t_{WSCLKh}$        | – | –  | 167 | ns      |
| Required Low-state Duration of SCLK (Required Setup Time) <sup>(27)</sup>                                                     | $t_{WSCLKl}$        | – | –  | 167 | ns      |
| Falling Edge of SCLK to Rising Edge of $\overline{CS}$ (Required Setup Time) <sup>(27)</sup>                                  | $t_{LAG}$           | – | 50 | 167 | ns      |
| SI to Falling Edge of SCLK (Required Setup Time) <sup>(28)</sup>                                                              | $t_{SI(SU)}$        | – | 25 | 83  | ns      |
| Falling Edge of SCLK to SI (Required Setup Time) <sup>(28)</sup>                                                              | $t_{SI(HOLD)}$      | – | 25 | 83  | ns      |
| SO Rise Time<br>$C_L = 200pF$                                                                                                 | $t_{RSO}$           | – | 25 | 50  | ns      |
| SO Fall Time<br>$C_L = 200pF$                                                                                                 | $t_{FSO}$           | – | 25 | 50  | ns      |
| SI, $\overline{CS}$ , SCLK, Incoming Signal Rise Time <sup>(28)</sup>                                                         | $t_{RSI}$           | – | –  | 50  | ns      |
| SI, $\overline{CS}$ , SCLK, Incoming Signal Fall Time <sup>(28)</sup>                                                         | $t_{FSI}$           | – | –  | 50  | ns      |
| Time from Falling Edge of $\overline{CS}$ to SO Low-impedance <sup>(29)</sup>                                                 | $t_{SO(EN)}$        | – | –  | 145 | ns      |
| Time from Rising Edge of $\overline{CS}$ to SO High-impedance <sup>(30)</sup>                                                 | $t_{SO(DIS)}$       | – | 65 | 145 | ns      |
| Time from Rising Edge of SCLK to SO Data Valid <sup>(31)</sup><br>$0.2 V_{DD} \leq SO \leq 0.8 \times V_{DD}$ , $C_L = 200pF$ | $t_{VALID}$         | – | 65 | 105 | ns      |

**Notes**

24. Time necessary for the CSNS to be with  $\pm 5\%$  of the targeted value.
25. Watchdog timeout delay measured from the rising edge of WAKE or  $\overline{RST}$  from a sleep state condition, to output turn-ON with the output driven OFF and FSI floating. The values shown are for WDR setting of [00]. The accuracy of  $t_{WDTO}$  is consistent for all configured watchdog timeouts.
26.  $\overline{RST}$  low duration measured with outputs enabled and going to OFF or disabled condition.
27. Maximum setup time required for the 33874 is the minimum guaranteed time needed from the microcontroller.
28. Rise and Fall time of incoming SI,  $\overline{CS}$ , and SCLK signals suggested for design consideration to prevent the occurrence of double pulsing.
29. Time required for output status data to be available for use at SO. 1.0k $\Omega$  on pull-up on  $\overline{CS}$ .
30. Time required for output status data to be terminated at SO. 1.0k $\Omega$  on pull-up on  $\overline{CS}$ .
31. Time required to obtain valid data out from SO following the rise of SCLK.

## TIMING DIAGRAMS

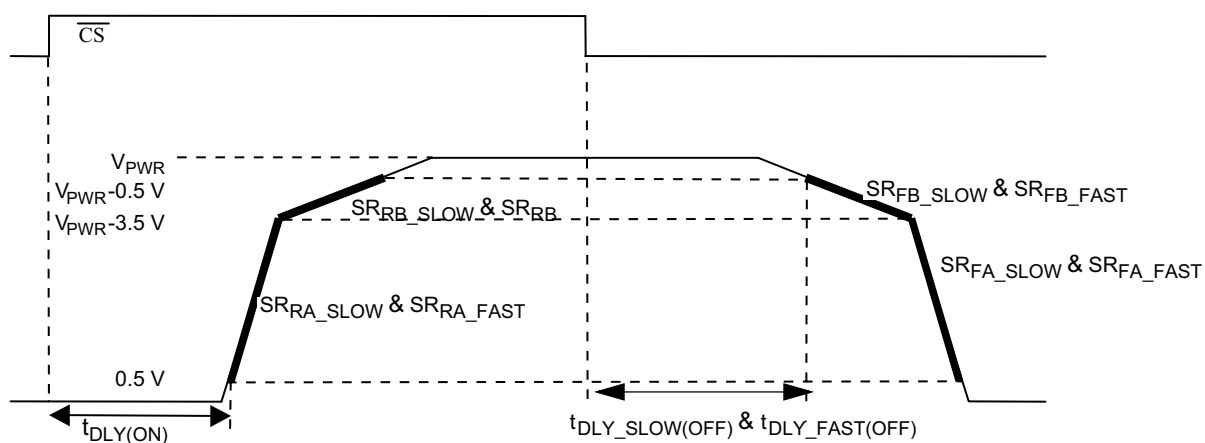


Figure 4. Output Slew Rate and Time Delays

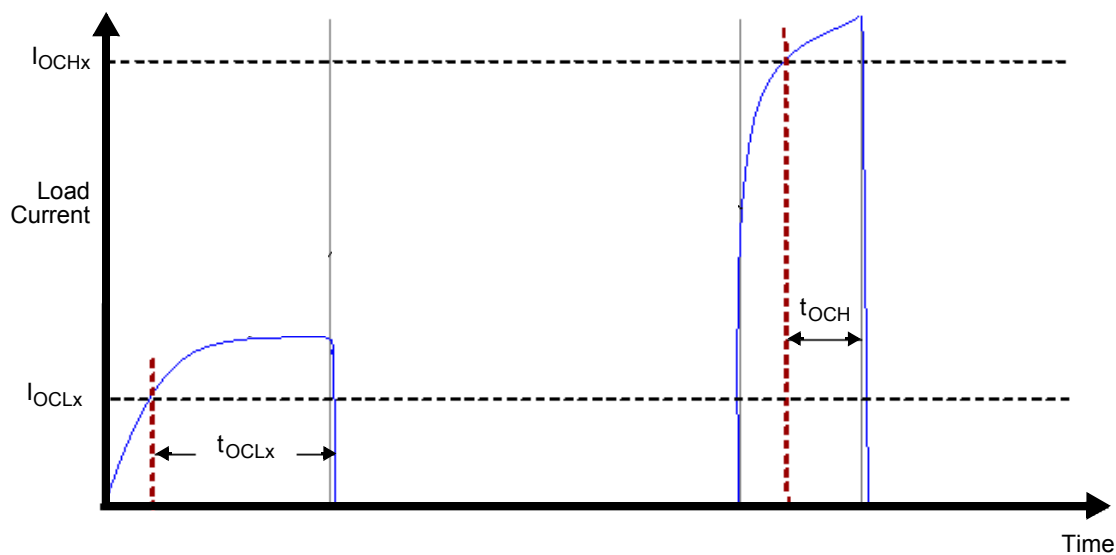


Figure 5. Over-current Shutdown

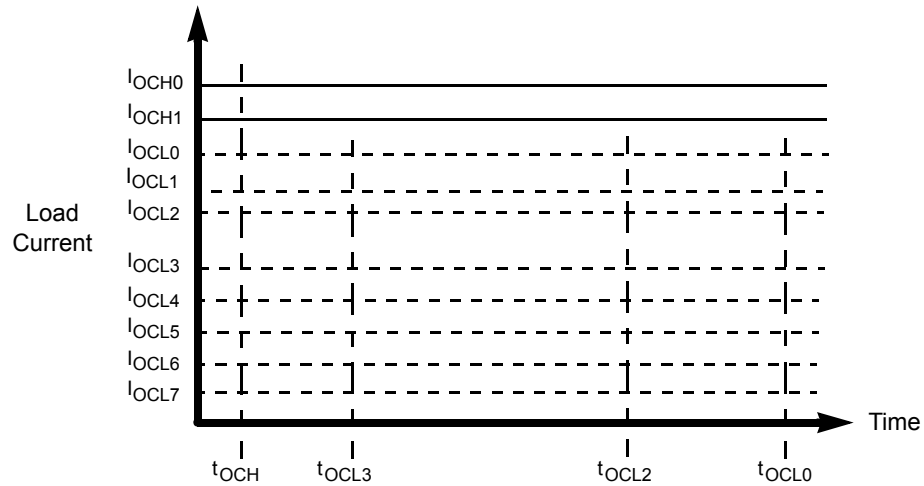


Figure 6. Over-current Low and High Detection

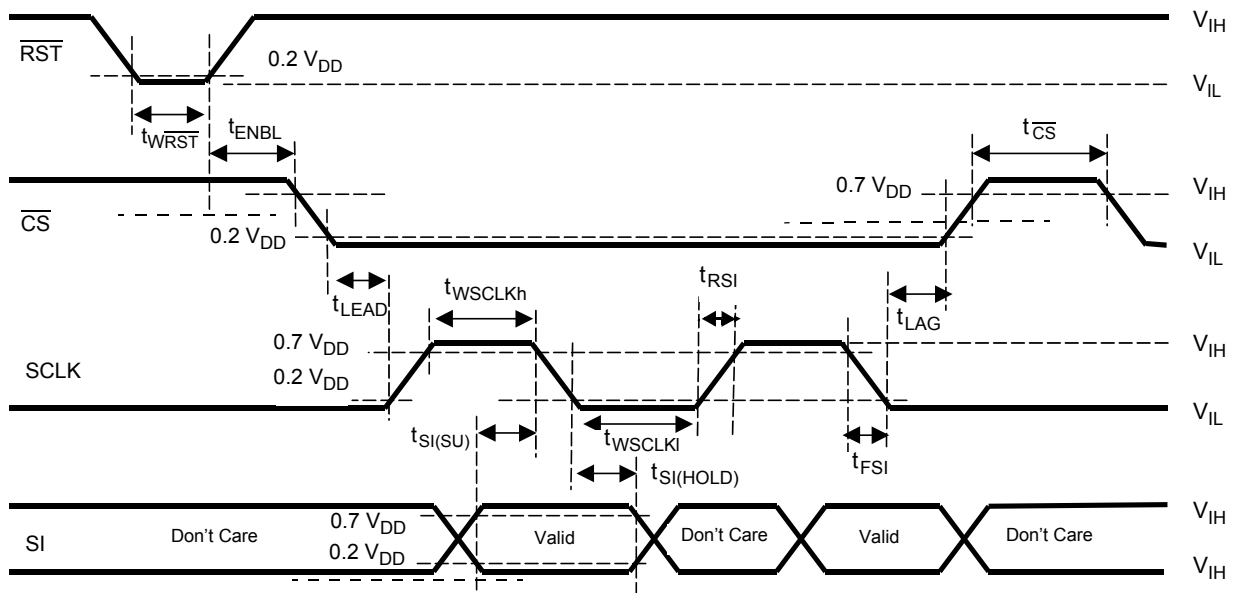


Figure 7. Input Timing Switching Characteristics

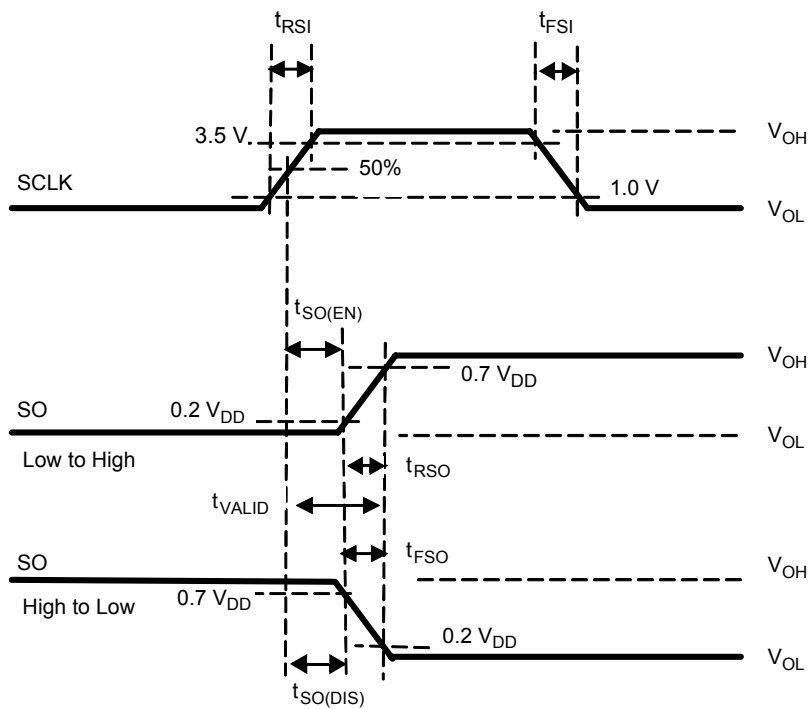


Figure 8. SCLK Waveform and Valid SO Data Delay Time

## FUNCTIONAL DESCRIPTION

### INTRODUCTION

The 33874 is one in a family of devices designed for low-voltage automotive and industrial lighting and motor control applications. Its four low  $R_{DS(ON)}$  MOSFETs (35m $\Omega$ ) can control the high sides of four separate resistive or inductive loads.

Programming, control, and diagnostics are accomplished using a 16-bit SPI interface. Additionally, each output has its own parallel input for PWM control if desired. The 33874

allows the user to program via the SPI the fault current trip levels and duration of acceptable lamp inrush or motor stall intervals. Such programmability allows tight control of fault currents and can protect wiring harnesses and circuit boards as well as loads.

The 33874 is packaged in a power-enhanced 12 x 12 nonlead PQFN package with exposed tabs.

### FUNCTIONAL PIN DESCRIPTION

#### OUTPUT CURRENT MONITORING (CSNS)

The Current Sense pin sources a current proportional to the designated HS0:HS3 output. That current is fed into a ground-referenced resistor and its voltage is monitored by an MCU's A/D. The output to be monitored is selected via the SPI. This pin can be tri-stated through the SPI.

#### SERIAL INPUTS (IN0, IN1, IN2, IN3)

The IN0:IN3 high side input pins are used to directly control HS0:HS3 high side output pins, respectively. A SPI register determines if each input is activated or if the input logic state is ORed or ANDed with the SPI instruction. These pins are to be driven with 5.0V CMOS levels, and they have an active internal pull-down current source.

#### TEMPERATURE FEEDBACK (TEMP)

This pin reports an analog voltage value proportional to the temperature of the GND. It is used by the MCU to monitor board temperature.

#### FAULT STATUS ( $\overline{FS}$ )

This pin is an open drain configured output requiring an external pull-up resistor to  $V_{DD}$  for fault reporting. If a device fault condition is detected, this pin is active LOW. Specific device diagnostic faults are reported via the SPI SO pin.

#### WAKE

This input pin controls the device mode and watchdog timeout feature if enabled. An internal clamp protects this pin from high damaging voltages when the output is current limited with an external resistor. This input has a passive internal pull-down.

#### RESET ( $\overline{RST}$ )

This input pin is used to initialize the device configuration and fault registers, as well as place the device in a low-current sleep mode. The pin also starts the watchdog timer

when transitioning from logic [0] to logic [1]. This pin should not be allowed to be logic [1] until  $V_{DD}$  is in regulation. This pin has a passive internal pull-down.

#### CHIP SELECT ( $\overline{CS}$ )

The  $\overline{CS}$  pin enables communication with the master microcontroller (MCU). When this pin is in a logic [0] state, the device is capable of transferring information to, and receiving information from, the MCU. The 33874 latches in data from the Input Shift registers to the addressed registers on the rising edge of  $\overline{CS}$ . The device transfers status information from the power output to the Shift register on the falling edge of  $\overline{CS}$ . The SO output driver is enabled when  $\overline{CS}$  is logic [0].  $\overline{CS}$  should transition from a logic [1] to a logic [0] state only when SCLK is a logic [0].  $\overline{CS}$  has an active internal pull-up,  $I_{UP}$ .

#### SERIAL CLOCK (SCLK)

The SCLK pin clocks the internal shift registers of the 33874 device. The serial input (SI) pin accepts data into the input shift register on the falling edge of the SCLK signal while the serial output (SO) pin shifts data information out of the SO line driver on the rising edge of the SCLK signal. It is important the SCLK pin be in a logic low state whenever  $\overline{CS}$  makes any transition. For this reason, it is recommended the SCLK pin be in a logic [0] whenever the device is not accessed ( $\overline{CS}$  logic [1] state). SCLK has an active internal pull-down. When  $\overline{CS}$  is logic [1], signals at the SCLK and SI pins are ignored and SO is tri-stated (high-impedance) (see [Figure 9](#), page 18).

#### SERIAL INPUT (SI)

This is a serial interface (SI) command data input pin. Each SI bit is read on the falling edge of SCLK. A 16-bit stream of serial data is required on the SI pin, starting with D15 to D0. The internal registers of the 33874 are configured and controlled using a 5-bit addressing scheme described in [Table 8](#), page 22. Register addressing and configuration are

described in [Table 9](#), page [22](#). The SI input has an active internal pull-down,  $I_{DWN}$ .

### DIGITAL DRAIN VOLTAGE (VDD)

This pin is an external voltage input pin used to supply power to the SPI circuit. In the event  $V_{DD}$  is lost, an internal supply provides power to a portion of the logic, ensuring limited functionality of the device.

### GROUND (GND)

This pin is the ground for the device.

### POSITIVE POWER SUPPLY (VPWR)

This pin connects to the positive power supply and is the source of operational power for the device. The  $V_{PWR}$  contact is the backside surface mount tab of the package.

### SERIAL OUTPUT (SO)

The SO data pin is a tri-stateable output from the shift register. The SO pin remains in a high-impedance state until

the  $\overline{CS}$  pin is put into a logic [0] state. The SO data is capable of reporting the status of the output, the device configuration, and the state of the key inputs. The SO pin changes state on the rising edge of SCLK and reads out on the falling edge of SCLK. Fault and input status descriptions are provided in [Table 16](#), page [26](#).

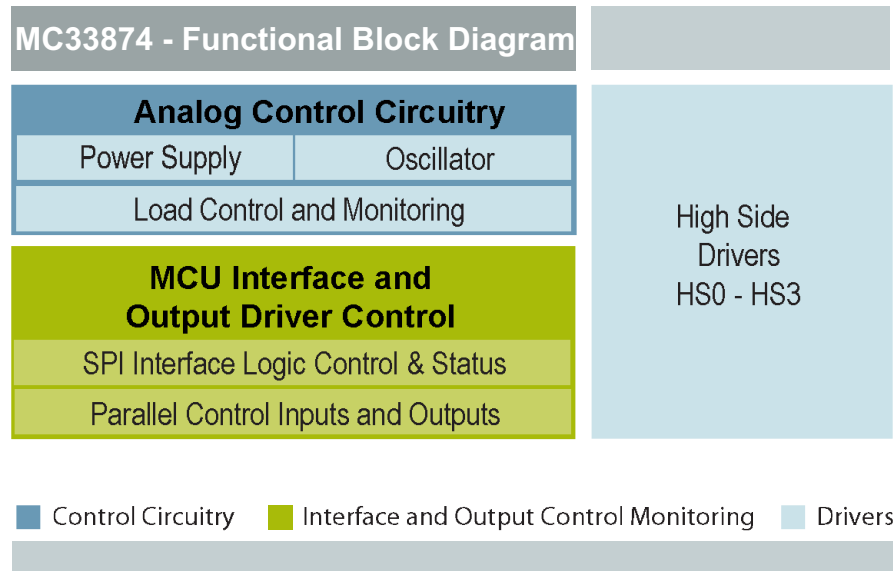
### HIGH SIDE OUTPUTS (HS3, HS1, HS0, HS2)

Protected 35mΩ high side power output pins to the load.

### FAIL-SAFE INPUT (FSI)

The value of the resistance connected between this pin and ground determines the state of the outputs after a watchdog timeout occurs. Depending on the resistance value, either all outputs are OFF or the output HSO only is ON. If the FSI pin is left to float up to a logic [1] level, then the outputs HS0 and HS2 will turn ON when in the Fail-safe state. When the FSI pin is connected to GND, the watchdog circuit and Fail-safe operation are disabled. This pin incorporates an active internal pull-up current source.

## FUNCTIONAL INTERNAL BLOCK DESCRIPTION



### ANALOG CONTROL CIRCUITRY

The 33874 is designed to operate from 6.0V to 27V on the VPWR Pin. The VPWR Pin supplies power to all internal regulators, analog and logic circuit blocks. The VDD supply is used for setting communication threshold levels and supplying power to the SPI interface logic. This IC architecture provides a very low standby current. The analog circuitry provides for over-current and over-temperature protection as well as temperature warning features.

### MCU INTERFACE AND OUTPUT CONTROL

The device is designed with 4 inputs for PWM Output driver control, if desired. MCU programming, control and

diagnostics are accomplished using the 16-bit SPI interface. Several parallel control and status lines are provided.

### HIGH-SIDE DRIVERS: HS0 – HS3

The 33874 provides high side load drive capability for 4 outputs. The  $R_{DS(ON)}$  for the output MOSFETs is 35mΩ. The outputs are protected for over-current and over-temperature. The MOSFET gate drive can be slew rate controlled using the SPI interface. There is also an open load detection feature. A ratioed value of the MOSFET output current is available to the MCU.

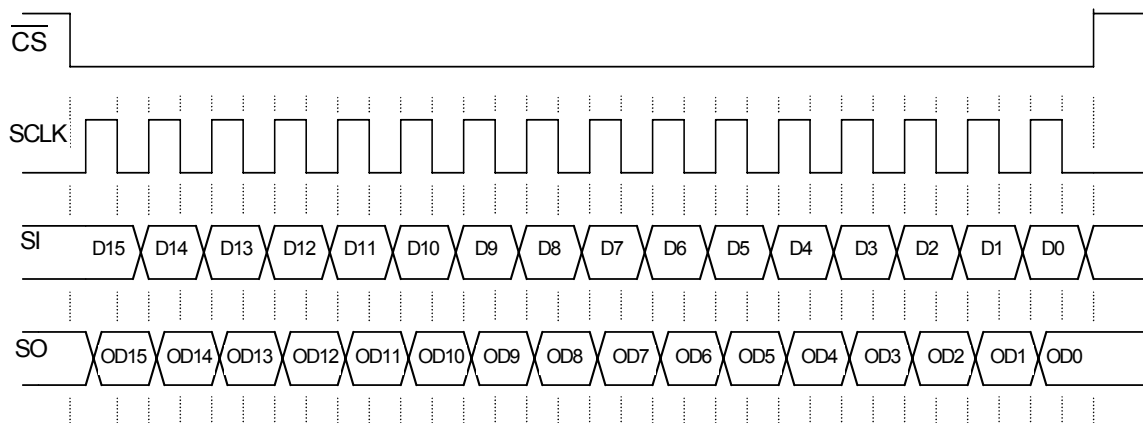
The device allows for control of the 4 outputs through the SPI interface or by use of the parallel inputs, which allows for PWM capability.

## FUNCTIONAL DEVICE OPERATION

### SPI PROTOCOL DESCRIPTION

The SPI interface has a full duplex, three-wire synchronous data transfer with four I/O lines associated with it: Serial Input (SI), Serial Output (SO), Serial Clock (SCLK), and Chip Select ( $\overline{\text{CS}}$ ).

The SI/SO pins of the 33874 follow a first-in first-out (D15 to D0) protocol, with both input and output words transferring the most significant bit (MSB) first. All inputs are compatible with 5.0V CMOS logic levels.



- Notes
1.  $\overline{\text{RST}}$  is a logic [1] state during the above operation.
  2. D15:D0 relate to the most recent ordered entry of data into the device.
  3. OD15:OD0 relate to the first 16 bits of ordered fault and status data out of the device.

Figure 9. Single 16-Bit Word SPI Communication

### OPERATIONAL MODES

The 33874 has four operating modes: Sleep, Normal, Fault, and Fail-safe. [Table 5](#) summarizes details contained in succeeding paragraphs.

Table 5. Fail-Safe Operation and Transitions to Other 33874 Modes

| Mode      | $\overline{\text{FS}}$ | Wake | $\overline{\text{RST}}$ | WDTO | Comments                                                                                                                                                                                                                                                                                                       |
|-----------|------------------------|------|-------------------------|------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Sleep     | x                      | 0    | 0                       | x    | Device is in Sleep mode. All outputs are OFF                                                                                                                                                                                                                                                                   |
| Normal    | 1                      | x    | 1                       | No   | Normal mode. Watchdog is active if enabled.                                                                                                                                                                                                                                                                    |
| Fault     | 0                      | 1    | 1                       | No   | Device is currently in fault mode. The faulted output(s) is (are) OFF.                                                                                                                                                                                                                                         |
|           | 0                      | 1    | 0                       |      |                                                                                                                                                                                                                                                                                                                |
|           | 0                      | 0    | 1                       |      |                                                                                                                                                                                                                                                                                                                |
| Fail-Safe | 1                      | 0    | 1                       | Yes  | Watchdog has timed out and the device is in Fail-safe Mode. The outputs are as configured with the RFS resistor connected to FSI. $\overline{\text{RST}}$ and WAKE must go from logic [1] to logic [0] simultaneously to bring the device out of the Fail-safe mode or momentarily tied the FSI pin to ground. |
|           | 1                      | 1    | 1                       |      |                                                                                                                                                                                                                                                                                                                |
|           | 1                      | 1    | 0                       |      |                                                                                                                                                                                                                                                                                                                |

x = Don't care.

#### SLEEP MODE

The Default mode of the 33874 is the Sleep Mode. This is the state of the device after first applying battery voltage ( $V_{\text{PWR}}$ ) prior to any I/O transitions. This is also the state of the device when the WAKE and  $\overline{\text{RST}}$  are both logic [0]. In the Sleep Mode, the output and all unused internal circuitry, such as the internal 5.0V regulator, are off to minimize current draw. In addition, all SPI-configurable features of the device are as if set to logic [0]. The 33874 will transition to the Normal or Fail-safe operating modes based on the WAKE and  $\overline{\text{RST}}$  inputs as defined in [Table 5](#).

#### NORMAL MODE

The 33874 is in Normal Mode when:

- $V_{\text{PWR}}$  and  $V_{\text{DD}}$  are within the normal voltage range.
- $\overline{\text{RST}}$  pin is logic [1].
- No fault has occurred.

#### FAIL-SAFE MODE

#### FAIL-SAFE MODE AND WATCHDOG

If the FSI input is not grounded, the watchdog timeout detection is active when either the WAKE or  $\overline{\text{RST}}$  input pin transitions from logic [0] to logic [1]. The WAKE input is capable of being pulled up to  $V_{\text{PWR}}$  with a series of limiting

resistance limiting the internal clamp current according to the specification.

The Watchdog timeout is a multiple of an internal oscillator and is specified in the [Table 15](#), page 24. As long as the WD bit (D15) of an incoming SPI message is toggled within the minimum watchdog timeout period (WDTO), based on the programmed value of the WDR, the device will operate normally. If an internal watchdog timeout occurs before the WD bit, the device will revert to a Fail-safe mode until the device is reinitialized.

During the Fail-safe Mode, the outputs will be ON or OFF depending upon the resistor RFS connected to the FSI pin, regardless of the state of the various direct inputs and modes ([Table 6](#)).

**Table 6. Output State During Fail-safe Mode**

| RFS (kΩ)              | High Side State                   |
|-----------------------|-----------------------------------|
| 0 (shorted to ground) | Fail-safe Mode Disabled           |
| 6.0                   | All HS OFF                        |
| 15                    | HS0 ON<br>HS1:HS3 OFF             |
| 30 (open)             | HS0 and HS2 ON<br>HS1 and HS3 OFF |

In the Fail-safe Mode, the SPI register content is retained except for over-current high and low detection levels, timing and latched over-temperature which are reset to their default value (SOCL, SOCH, and OCTL and OT\_latch\_[0:3] bits). Then the watchdog, over-voltage, over-temperature, and over-current circuitry (with default value) are fully operational.

The Fail-safe Mode can be detected by monitoring the WDTO bit D2 of the WD register. This bit is logic [1] when the device is in Fail-safe Mode. The device can be brought out of the Fail-safe Mode by transitioning the WAKE and RST pins from logic [1] to logic [0] or forcing the FSI pin to logic [0].

## PROTECTION AND DIAGNOSTIC FEATURES

### OVER-TEMPERATURE FAULT (LATCHING OR NON-LATCHING)

The 33874 incorporates over-temperature detection and shutdown circuitry for each output structure.

The over-temperature is latched per default and can be unlatched through SPI with OT\_latch\_[0:3] bits.

An over-temperature fault condition results in turning OFF the corresponding output. To remove the fault and be able to turn ON again the outputs, the failure must be removed and:

- in Normal Mode: the corresponding output must be commanded OFF and ON again in case of over-temperature latched (OT\_latch bit = 0).
- in Normal Mode: the corresponding output turns ON automatically if the temperature is below  $T_{SD}-T_{SD(HYS)}$  in case of unlatched over-temperature (OT\_latch bit = 1).

[Table 5](#) summarizes the various methods for resetting the device from the latched Fail-safe Mode.

If the FSI pin is tied to GND, the Watchdog fail-safe operation is disabled.

### LOSS OF $V_{DD}$

If the external 5.0 V supply is not within specification, or even disconnected, all register content is reset. The outputs can still be driven by the direct inputs IN0:IN3. The 33874 uses the battery input to power the output MOSFET-related current sense circuitry and any other internal logic providing fail-safe device operation with no  $V_{DD}$  supplied. In this state, the watchdog, under-voltage, over-voltage, over-temperature (latched) and over-current circuitry are fully operational with default values.

### FAULT MODE

This 33874 indicates the faults below as they occur by driving the  $\overline{FS}$  pin to logic [0]:

- Over-temperature fault
- Over-voltage and under-voltage fault
- Open load fault
- Over-current fault (high and low)

The  $\overline{FS}$  pin will automatically return to logic [1] when the fault condition is removed, except for overcurrent, overtemperature (in case of latching configuration) and in some cases of undervoltage.

The  $\overline{FS}$  pin reports all faults. For latched faults, this pin is reset by a new Switch ON command (via the SPI or direct input IN).

Fault information is retained in the fault register and is available (and reset) via the SO pin during the first valid SPI communication (refer to [Table 17](#), page 26).

- in Fail-safe Mode: the FSI input must be grounded and then set to its nominal voltage to switch ON the outputs.

The over-temperature fault (one for each output) is reported by SPI. If the over-temperature is latched, the SPI reports OTF\_s = [1] and OCLF\_s = [1]. In case of non-latched, OTF\_s = [1] only is reported.

The fault bits will be cleared in the status register after either a valid SPI read command or a power on reset of the device.

### OVERCURRENT FAULT (LATCHING)

The 33874 has eight programmable over-current low detection levels ( $I_{OCL}$ ) and two programmable over-current high detection levels ( $I_{OCH}$ ) for maximum device protection. The two selectable, simultaneously active over-current

detection levels, defined by  $I_{OCH}$  and  $I_{OCL}$ , are illustrated in [Figure 6](#), page 13. The eight different over-current low detect levels ( $I_{OCL0}$ : $I_{OCL7}$ ) are illustrated in [Figure 6](#).

If the load current level ever reaches the selected over-current low detection level and the over-current condition exceeds the programmed over-current time period ( $t_{OCX}$ ), the device will latch the output OFF.

If at any time the current reaches the selected  $I_{OCH}$  level, then the device will immediately latch the fault and turn OFF the output, regardless of the selected  $t_{OCH}$  driver.

For both cases, the device output will stay off indefinitely until the device is commanded OFF and then ON again.

### OVER-VOLTAGE FAULT (NON-LATCHING)

The 33874 shuts down the output during an over-voltage fault (OVF) condition on the VPWR pin. The output remains in the OFF state until the over-voltage condition is removed. When experiencing this fault, the OVF fault bit is set in the bit D1 and cleared after either a valid SPI read or a power reset of the device.

The over-voltage protection can be disabled through SPI (bit OV\_DIS). When disabled, the returned SO bit OD13 still reflects any over-voltage condition (over-voltage warning).

### UNDER-VOLTAGE SHUTDOWN (LATCHING OR NON-LATCHING)

The output(s) will latch off at some battery voltage below 6.0 V. As long as the  $V_{DD}$  level stays within the normal specified range, the internal logic states within the device will be sustained.

In the case where battery voltage drops below the under-voltage threshold ( $V_{PWRUV}$ ) output will turn off,  $\overline{FS}$  will go to logic 0, and the fault register UVF bit will be set to 1.

Two cases need to be considered when the battery level recovers :

- If outputs command are low,  $\overline{FS}$  will go to logic 1 but the UVF bit will remain set to 1 until the next read operation (warning report).
- If the output command is ON, then  $\overline{FS}$  will remain at logic 0. The output must be turned OFF and ON again to re-enable the state of output and release  $\overline{FS}$ . The UVF bit will remain set to 1 until the next read operation.

The under-voltage protection can be disabled through SPI (bit UV\_dis = 1). In this case, the  $\overline{FS}$  does not report any under-voltage fault condition, UVF bit is set to 1, and the output state is not changed as long as the battery voltage does not drop any lower than 2.5 V.

The daisy chain feature is available under VDD in nominal conditions.

Table 7. Device behavior in case of Under-voltage

| Quad High Side Switch (VPWR Battery Voltage)** | State                      | UV Enable IN[0:3] = 0 (Falling VPWR) | UV Enable IN[0:3] = 0 (Rising VPWR) | UV Enable IN_x*** = 1 (Falling VPWR) | UV Enable IN_x*** = 1 (Rising VPWR) | UV Disable IN[0:3] = 0 (Falling or Rising VPWR) | UV Disable IN_x*** = 1 (Falling or Rising VPWR) |
|------------------------------------------------|----------------------------|--------------------------------------|-------------------------------------|--------------------------------------|-------------------------------------|-------------------------------------------------|-------------------------------------------------|
| VPWR > VPWRUV                                  | Output State               | OFF                                  | OFF                                 | ON                                   | OFF                                 | OFF                                             | ON                                              |
|                                                | $\overline{FS}$ State      | 1                                    | 1                                   | 1                                    | 0                                   | 1                                               | 1                                               |
|                                                | SPI Fault Register UVF Bit | 0                                    | 1 until next read                   | 0                                    | 1                                   | 0 (falling)<br>1 until next read (rising)       | 0 (falling)<br>1 until next read (rising)       |
| VPWRUV > VPWR > UVPOR                          | Output State               | OFF                                  | OFF                                 | OFF                                  | OFF                                 | OFF                                             | ON                                              |
|                                                | $\overline{FS}$ State      | 0                                    | 0                                   | 0                                    | 0                                   | 1                                               | 1                                               |
|                                                | SPI Fault Register UVF Bit | 1                                    | 1                                   | 1                                    | 1                                   | 1                                               | 1                                               |
| UVPOR > VPWR > 2.5V*                           | Output State               | OFF                                  | OFF                                 | OFF                                  | OFF                                 | OFF                                             | ON                                              |
|                                                | $\overline{FS}$ State      | 1                                    | 1                                   | 1                                    | 1                                   | 1                                               | 1                                               |
|                                                | SPI Fault Register UVF Bit | 1 until next read                    | 1 until next read                   | 1 until next read                    | 1 until next read                   | 1 until next read                               | 1 until next read                               |
| 2.5V > VPWR > 0V                               | Output State               | OFF                                  | OFF                                 | OFF                                  | OFF                                 | OFF                                             | OFF                                             |
|                                                | $\overline{FS}$ State      | 1                                    | 1                                   | 1                                    | 1                                   | 1                                               | 1                                               |
|                                                | SPI Fault Register UVF Bit | 1 until next read                    | 1 until next read                   | 1 until next read                    | 1 until next read                   | 1 until next read                               | 1 until next read                               |
|                                                | Comments                   | UV fault is not latched              | UV fault is not latched             |                                      | UV fault is latched                 |                                                 |                                                 |

\* = Typical value; not guaranteed

\*\* = While V<sub>DD</sub> remains within specified range.

\*\*\* = IN\_x is equivalent to IN\_x direct input or IN\_spi\_s SPI input.

## OPEN LOAD FAULT (NON-LATCHING)

The 33874 incorporates open load detection circuitry on the output. Output open load fault (OLF) is detected and reported as a fault condition when the output is disabled (OFF). The open load fault is detected and latched into the status register after the internal gate voltage is pulled low enough to turn OFF the output. The OLF fault bit is set in the status register. If the open load fault is removed, the status register will be cleared after reading the register.

The open load protection can be disabled through SPI (bit OL\_DIS). It is recommended to disable open load circuitry in case of a permanent disconnected load.

## REVERSE BATTERY

The output survives the application of reverse voltage as low as -16V. Under these conditions, the output's gate is

enhanced to keep the junction temperature less than 150°C. The ON resistance of the output is fairly similar to that in the Normal mode. No additional passive components are required except on VDD.

## GROUND DISCONNECT PROTECTION

In the event the 33874 ground is disconnected from load ground, the device protects itself and safely turns OFF the output regardless of the state of the output at the time of disconnection. A 10KΩ resistor needs to be added between the wake pin and the rest of the circuitry in order to ensure that the device turns off in case of ground disconnect and to prevent this pin to exceed its maximum ratings.

Current limit resistors in the digital input lines protect the digital supply against excessive current (10kΩ typical).

## LOGIC COMMANDS AND REGISTERS

### SERIAL INPUT COMMUNICATION

SPI communication is accomplished using 16-bit messages. A message is transmitted by the MCU starting with the MSB D15 and ending with the LSB, D0 ([Table 8](#)). Each incoming command message on the SI pin can be interpreted using the following bit assignments: the MSB, D15, is the watchdog bit. In some cases, output selection is done with bits D12:D11. The next three bits, D10:D8, are used to select the command register. The remaining five bits,

D4:D0, are used to configure and control the outputs and their protection features.

Multiple messages can be transmitted in succession to accommodate those applications where daisy-chaining is desirable, or to confirm transmitted data, as long as the messages are all multiples of 16 bits. Any attempt made to latch in a message that is not 16 bits will be ignored.

The 33874 has defined registers, which are used to configure the device and to control the state of the outputs. [Table 9](#), page [22](#), summarizes the SI registers.

**Table 8. SI Message Bit Assignment**

| Bit Sig | SI Msg Bit | Message Bit Description                                                                          |
|---------|------------|--------------------------------------------------------------------------------------------------|
| MSB     | D15        | Watchdog in: toggled to satisfy watchdog requirements.                                           |
|         | D14:D15    | Not used.                                                                                        |
|         | D12:D11    | Register address bits used in some cases for output selection.                                   |
|         | D10:D8     | Register address bits.                                                                           |
|         | D7:D5      | Not used.                                                                                        |
|         | D4:D1      | Used to configure the inputs, outputs, and the device protection features and SO status content. |
| LSB     | D0         | Used to configure the inputs, outputs, and the device protection features and SO status content. |

**Table 9. Serial Input Address and Configuration Bit Map**

| SI Register | SI Data |     |     |                |                |     |    |    |    |    |    |      |                                        |             |           |          |
|-------------|---------|-----|-----|----------------|----------------|-----|----|----|----|----|----|------|----------------------------------------|-------------|-----------|----------|
|             | D15     | D14 | D13 | D12            | D11            | D10 | D9 | D8 | D7 | D6 | D5 | D4   | D3                                     | D2          | D1        | D0       |
| STATR_s     | WDIN    | 0   | 0   | 0              | 0              | 0   | 0  | 0  | 0  | 0  | 0  | SOA4 | SOA3                                   | SOA2        | SOA1      | SOA0     |
| OCR0        | WDIN    | 0   | 0   | 0              | 0              | 0   | 0  | 1  | 0  | 0  | 0  | 0    | IN3_SPI                                | IN2_SPI     | IN1_SPI   | IN0_SPI  |
| OCR1        | WDIN    | 0   | 0   | 0              | 1              | 0   | 0  | 1  | 0  | 0  | 0  | 0    | CSNS3_EN                               | CSNS2_EN    | CSNS1_EN  | CSNS0_EN |
| SOCHLR_s    | WDIN    | 0   | 0   | A <sub>1</sub> | A <sub>0</sub> | 0   | 1  | 0  | 0  | 0  | 0  | 0    | SOCH_s                                 | SOCL2_s     | SOCL1_s   | SOCL0_s  |
| CDTOLR_s    | WDIN    | 0   | 0   | A <sub>1</sub> | A <sub>0</sub> | 0   | 1  | 1  | 0  | 0  | 0  | 0    | OL_DIS_s                               | OCL_DIS_s   | OCLT1_s   | OCLT0_s  |
| DICR_s      | WDIN    | 0   | 0   | A <sub>1</sub> | A <sub>0</sub> | 1   | 0  | 0  | 0  | 0  | 0  | 0    | FAST_SR_s                              | CSNS_high_s | DIR_DIS_s | A/O_s    |
| UOVR        | WDIN    | 0   | 0   | 0              | 0              | 1   | 0  | 1  | 0  | 0  | 0  | 0    | OT_latch_1                             | OT_latch_0  | UV_DIS    | OV_DIS   |
| WDR         | WDIN    | 0   | 0   | 0              | 1              | 1   | 0  | 1  | 0  | 0  | 0  | 0    | OT_latch_3                             | OT_latch_2  | WD1       | WD0      |
| NAR         | WDIN    | 0   | 0   | 0              | 0              | 1   | 1  | 0  | 0  | 0  | 0  | 0    | No Action (Allow Toggling of D15-WDIN) |             |           |          |
| RESET       | 0       | 0   | 0   | X              | X              | X   | X  | X  | 0  | 0  | 0  | 0    | 0                                      | 0           | 0         | 0        |

x=Don't care.

s=Output selection with the bits A<sub>1</sub>A<sub>0</sub> as defined in [Table 10](#).

D15 is used to toggle watchdog event (WDIN)

### DEVICE REGISTER ADDRESSING

The following section describes the possible register addresses and their impact on device operation.

### ADDRESS 00000—STATUS REGISTER (STATR\_S)

The STATR register is used to read the device status and the various configuration register contents without disrupting the device operation or the register contents. The register bits D[4:0] determine the content of the first sixteen bits of SO data. In addition to the device status, this feature provides the ability to read the content of the OCR0, OCR1, SOCHLR,

CDTOLR, DICR, UOVR, WDR, and NAR registers. (Refer to the section entitled [Serial Output Communication \(Device Status Return Data\)](#) beginning on page [24](#).)

#### ADDRESS 00001—OUTPUT CONTROL REGISTER (OCR0)

The OCR0 register allows the MCU to control the ON/OFF state of four outputs through the SPI. Incoming message bit D3:D0 reflects the desired states of the four high side outputs (INx\_SPI), respectively. A logic [1] enables the corresponding output switch and a logic [0] turns it OFF.

#### ADDRESS 01001—OUTPUT CONTROL REGISTER (OCR1)

Incoming message bits D3:D0 reflect the desired output that will be mirrored on the Current Sense (CSNS) pin. A logic [1] on message bits D3:D0 enables the CSNS pin for outputs HS3:HS0, respectively. In the event the current sense is enabled for multiple outputs, the current will be summed. In the event that bits D3:D0 are all logic [0], the output CSNS will be tri-stated. This is useful when several CSNS pins of several devices share the same A/D converter.

#### ADDRESS A<sub>1</sub>A<sub>0</sub>010—SELECT OVER-CURRENT HIGH AND LOW REGISTER (SOCHLR\_S)

The SOCHLR\_s register allows the MCU to configure the output over-current low and high detection levels, respectively. Each output “s” is independently selected for configuration based on the state of the D12:D11 bits ([Table 10](#)).

**Table 10. Output Selection**

| A <sub>1</sub> (D12) | A <sub>0</sub> (D11) | HS_s |
|----------------------|----------------------|------|
| 0                    | 0                    | HS0  |
| 0                    | 1                    | HS1  |
| 1                    | 0                    | HS2  |
| 1                    | 1                    | HS3  |

Each output can be configured to different levels. In addition to protecting the device, this slow blow fuse emulation feature can be used to optimize the load requirements matching system characteristics. Bits D2:D0 set the over-current low detection level to one of eight possible levels, as shown in [Table 11](#), page [23](#). Bit D3 sets the over-current high detection level to one of two levels, as outlined in [Table 12](#), page [23](#).

**Table 11. Over-current Low Detection Levels**

| SOCL2_s* (D2) | SOCL1_s* (D1) | SOCL0_s* (D0) | Over-current Low Detection (Amperes) |
|---------------|---------------|---------------|--------------------------------------|
|               |               |               | HS0 to HS3                           |
| 0             | 0             | 0             | 10                                   |
| 0             | 0             | 1             | 8.9                                  |
| 0             | 1             | 0             | 7.9                                  |
| 0             | 1             | 1             | 7.0                                  |
| 1             | 0             | 0             | 5.8                                  |
| 1             | 0             | 1             | 4.8                                  |
| 1             | 1             | 0             | 3.9                                  |
| 1             | 1             | 1             | 2.8                                  |

\* “\_s” refers to the output, which is selected through bits D12:D11; refer to [Table 10](#), page [23](#).

**Table 12. Over-current High Detection Levels**

| SOCH_s* (D3) | Over-current High Detection (Amperes) |
|--------------|---------------------------------------|
|              | HS0 to HS3                            |
| 0            | 55                                    |
| 1            | 40                                    |

\* “\_s” refers to the output, which is selected through bits D12:D11; refer to [Table 10](#), page [23](#).

#### ADDRESS A<sub>1</sub>A<sub>0</sub>011—CURRENT DETECTION TIME AND OPEN LOAD REGISTER (CDTOLR)

The CDTOLR register is used by the MCU to determine the amount of time the device will allow an over-current low condition before an output latches OFF. Each output is independently selected for configuration based on A<sub>1</sub>A<sub>0</sub>, which are the state of the D12:D11 bits (refer to [Table 10](#), page [23](#)).

Bits D1:D0 (OCLT1\_s:OCLT0\_s) allow the MCU to select one of three over-current fault blanking times defined in [Table 13](#). Note that these timeouts apply only to the over-current low detection levels. If the selected over-current high level is reached, the device will latch off within 20μs.

**Table 13. Over-current Low Detection Blanking Time**

| OCLT[1:0]_s* | Timing     |
|--------------|------------|
| 00           | 155ms      |
| 01           | Do not use |
| 10           | 75ms       |
| 11           | 150μs      |

\* “\_s” refers to the output, which is selected through bits D12:D11; refer to [Table 10](#), page [23](#).

A logic [1] on bit D2 (OCL\_DIS\_s) disables the over-current low detection feature. When disabled, there is no timeout for the selected output and the over-current low detection feature is disabled.

A logic [1] on bit D3 (OL\_DIS\_s) disables the open load (OL) detection feature for the output corresponding to the state of bits D12:D11.

### ADDRESS A<sub>1</sub>A<sub>0</sub>100—DIRECT INPUT CONTROL REGISTER (DICR)

The DICR register is used by the MCU to enable, disable, or configure the direct IN pin control of each output. Each output is independently selected for configuration based on the state bits D12:D11 (refer to [Table 10](#), page 23).

For the selected output, a logic [0] on bit D1 (DIR\_DIS\_s) will enable the output for direct control. A logic [1] on bit D1 will disable the output from direct control.

While addressing this register, if the Input was enabled for direct control, a logic [1] for the D0 (A/O\_s) bit will result in a Boolean AND of the IN pin with its corresponding IN\_SPI D[4:0] message bit when addressing OCR0. Similarly, a logic [0] on the D0 pin results in a Boolean OR of the IN pin to the corresponding message bits when addressing the OCR0. This register is especially useful if several loads are required to be independently PWM controlled. For example, the IN pins of several devices can be configured to operate all of the outputs with one PWM output from the MCU. If each output is then configured to be Boolean ANDed to its respective IN pin, each output can be individually turned OFF by SPI while controlling all of the outputs, commanded on with the single PWM output.

A logic [1] on bit D2 (CSNS\_high\_s) is used to select the high ratio on the CSNS pin for the selected output. The default value [0] is used to select the low ratio ([Table 14](#)).

**Table 14. Current Sense Ratio**

| CSNS_high_s* (D2) | Current Sense Ratio |
|-------------------|---------------------|
|                   | HS0 to HS3          |
| 0                 | 1/7200              |
| 1                 | 1/21400             |

\* “\_s” refers to the output, which is selected through bits D12:D11; refer to [Table 10](#), page 23.

A logic [1] on bit D3 (FAST\_SR\_s) is used to select the high speed slew rate for the selected output, the default value [0] corresponds to the low speed slew rate.

### ADDRESS 00101—UNDER-VOLTAGE/OVER-VOLTAGE AND HS[0,1] OVER-TEMPERATURE REGISTER (UOVR)

The UOVR register disables the under-voltage (D1) and/or over-voltage (D0) protection. When these two bits are [0], the under and over-voltages are active (default value).

The UOVR register allows the over-temperature detection latching on the HS0 and HS1. To latch the over-temperature, the bits (OT\_latch\_1 and OT\_latch\_0) must be set to [0] which is the default value. To disable the latching, both bits must be set to [1].

### ADDRESS 01101—WATCHDOG AND HS[2,3] OVER-TEMPERATURE REGISTER (WDR)

The WDR register is used by the MCU to configure the watchdog timeout. The watchdog timeout is configured using bits D1 and D0. When D1 and D0 bits are programmed for the desired watchdog timeout period ([Table 15](#)), the WDSPI bit should be toggled as well, ensuring the new timeout period is programmed at the beginning of a new count sequence.

The WDR register allows the over-temperature detection latching on the HS2 and HS3. To latch the over-temperature, the bits (OT\_latch\_3 and OT\_latch\_2) must be set to [0] which is the default value. To disable the latching, both bits must be set to [1].

**Table 15. Watchdog Timeout**

| WD[1:0] (D1, D0) | Timing (ms) |
|------------------|-------------|
| 00               | 558         |
| 01               | 279         |
| 10               | 2250        |
| 11               | 1125        |

### ADDRESS 00110—NO ACTION REGISTER (NAR)

The NAR register can be used to no-operation fill SPI data packets in a daisy-chain SPI configuration. This would allow devices to be unaffected by commands being clocked over a daisy-chained SPI configuration. By toggling the WD bit (D15) the watchdog circuitry would continue to be reset while no programming or data read back functions are being requested from the device.

### SERIAL OUTPUT COMMUNICATION (DEVICE STATUS RETURN DATA)

When the  $\overline{CS}$  pin is pulled low, the output register is loaded. Meanwhile, the data is clocked out MSB- (OD15-) first as the new message data is clocked into the SI pin. The first sixteen bits of data clocking out of the SO, and following a  $\overline{CS}$  transition, is dependent upon the previously written SPI word.

Any bits clocked out of the Serial Output (SO) pin after the first 16 bits will be representative of the initial message bits clocked into the SI pin since the  $\overline{CS}$  pin first transitioned to a logic [0]. This feature is useful for daisy-chaining devices as well as message verification.

A valid message length is determined following a  $\overline{CS}$  transition of [0] to [1]. If there is a valid message length, the data is latched into the appropriate registers. A valid message length is a multiple of 16 bits. At this time, the SO pin is tri-stated and the fault status register is now able to accept new fault status information.

SO data will represent information ranging from fault status to register contents, user selected by writing to the STATR bits OD4, OD3, OD2, OD1, and OD0. The value of the previous bits SOA4 and SOA3 will determine which output the SO information applies to for the registers which are output specific; viz., Fault, SOCHLR, CDTOLR, and DICR registers.

Note that the SO data will continue to reflect the information for each output (depending on the previous OD4, OD3 state) that was selected during the most recent STATR write until changed with an updated STATR write.

The output status register correctly reflects the status of the STATR-selected register data at the time that the  $\overline{CS}$  is pulled to a logic [0] during SPI communication, and/or for the period of time since the last valid SPI communication, with the following exceptions:

- The previous SPI communication was determined to be invalid. In this case, the status will be reported as though the invalid SPI communication never occurred.
- Battery transients below 6.0V resulting in an under-voltage shutdown of the outputs may result in incorrect data loaded into the status register. The SO data transmitted to the MCU during the first SPI communication following an under-voltage  $V_{PWR}$  condition should be ignored.
- The  $\overline{RST}$  pin transition from a logic [0] to [1] while the WAKE pin is at logic [0] may result in incorrect data loaded into the Status register. The SO data transmitted to the MCU during the first SPI communication following this condition should be ignored.

## SERIAL OUTPUT BIT ASSIGNMENT

The 16 bits of serial output data depend on the previous serial input message, as explained in the following paragraphs. [Table 16](#), page [26](#), summarizes SO returned data for bits OD15:OD0.

- Bit OD15 is the MSB; it reflects the state of the watchdog bit from the previously clocked-in message.
- Bit OD14 remains logic [0] except when an under-voltage condition occurred.
- Bit OD13 remains logic [0] except when an over-voltage condition occurred.
- Bits OD12:OD8 reflect the state of the bits SOA4:SOA0 from the previously clocked in message.
- Bits OD7:OD4 give the fault status flag of the outputs HS3:HS0, respectively.
- The contents of bits OD3:OD0 depend on bits D4:D0 from the most recent STATR command SOA4:SOA0 as explained in the paragraphs following [Table 16](#).

**Table 16. Serial Output Bit Map Description**

|           | Previous STATR |                |       |       |       | SO Returned Data |       |       |       |       |       |      |      |     |     |     |     |              |              |           |          |
|-----------|----------------|----------------|-------|-------|-------|------------------|-------|-------|-------|-------|-------|------|------|-----|-----|-----|-----|--------------|--------------|-----------|----------|
|           | SO A4          | SO A3          | SO A2 | SO A1 | SO A0 | OD 15            | OD 14 | OD 13 | OD 12 | OD 11 | OD 10 | OD9  | OD8  | OD7 | OD6 | OD5 | OD4 | OD3          | OD2          | OD1       | OD0      |
| START_s   | A <sub>1</sub> | A <sub>0</sub> | 0     | 0     | 0     | WDIN             | UVF   | OVF   | SOA4  | SOA3  | SOA2  | SOA1 | SOA0 | ST3 | ST2 | ST1 | ST0 | OTF_s        | OCHF_s       | OCLF_s    | OLF_s    |
| OCR0      | 0              | 0              | 0     | 0     | 1     | WDIN             | UVF   | OVF   | SOA4  | SOA3  | SOA2  | SOA1 | SOA0 | ST3 | ST2 | ST1 | ST0 | IN3_SPI      | IN2_SPI      | IN1_SPI   | IN0_SPI  |
| OCR1      | 0              | 1              | 0     | 0     | 1     | WDIN             | UVF   | OVF   | SOA4  | SOA3  | SOA2  | SOA1 | SOA0 | ST3 | ST2 | ST1 | ST0 | CSNS3_EN     | CSNS2_EN     | CSNS1_EN  | CSNS0_EN |
| SOCHL_R_s | A <sub>1</sub> | A <sub>0</sub> | 0     | 1     | 0     | WDIN             | UVF   | OVF   | SOA4  | SOA3  | SOA2  | SOA1 | SOA0 | ST3 | ST2 | ST1 | ST0 | SOCH_s       | SOCL2_s      | SOCL1_s   | SOCL0_s  |
| CDTOL_R_s | A <sub>1</sub> | A <sub>0</sub> | 0     | 1     | 1     | WDIN             | UVF   | OVF   | SOA4  | SOA3  | SOA2  | SOA1 | SOA0 | ST3 | ST2 | ST1 | ST0 | OL_DIS_s     | OCL_DIS_s    | OCLT1_s   | OCLT0_s  |
| DICR_s    | A <sub>1</sub> | A <sub>0</sub> | 1     | 0     | 0     | WDIN             | UVF   | OVF   | SOA4  | SOA3  | SOA2  | SOA1 | SOA0 | ST3 | ST2 | ST1 | ST0 | Fast_SR_s    | CSNS_high_s  | DIR_DIS_s | A/O_s    |
| UOVR      | 0              | 0              | 1     | 0     | 1     | WDIN             | UVF   | OVF   | SOA4  | SOA3  | SOA2  | SOA1 | SOA0 | ST3 | ST2 | ST1 | ST0 | OT_latch_1   | OT_latch_0   | UV_DIS    | OV_DIS   |
| WDR       | 0              | 1              | 1     | 0     | 1     | WDIN             | UVF   | OVF   | SOA4  | SOA3  | SOA2  | SOA1 | SOA0 | ST3 | ST2 | ST1 | ST0 | 0            | WDTO         | WD1       | WD0      |
| PINR0     | 0              | 0              | 1     | 1     | 0     | WDIN             | UVF   | OVF   | SOA4  | SOA3  | SOA2  | SOA1 | SOA0 | ST3 | ST2 | ST1 | ST0 | HS2_failsafe | HS0_failsafe | WD_en     | WAKE     |
| PINR1     | 0              | 1              | 1     | 1     | 0     | WDIN             | UVF   | OVF   | SOA4  | SOA3  | SOA2  | SOA1 | SOA0 | ST3 | ST2 | ST1 | ST0 | IN3          | IN2          | IN1       | IN0      |
| PINR2     | 0              | 1              | 1     | 1     | 1     | WDIN             | UVF   | OVF   | SOA4  | SOA3  | SOA2  | SOA1 | SOA0 | ST3 | ST2 | ST1 | ST0 | OT_latch_3   | OT_latch_2   | X         | X        |
| RESET     | N/A            | N/A            | N/A   | N/A   | N/A   | 0                | 0     | 0     | 0     | 0     | 0     | 0    | 0    | 0   | 0   | 0   | 0   | 0            | 0            | 0         | 0        |

s = Output selection with the bits A<sub>1</sub>A<sub>0</sub> as defined in [Table 10](#), page [23](#).

ID[1,0]: product identification

#### PREVIOUS ADDRESS SOA4:SOA0=A<sub>1</sub>A<sub>0</sub>000

Bits OD3:OD0 reflect the current state of the Fault register (FLTR) corresponding to the output previously selected with the bits A<sub>1</sub>A<sub>0</sub> ([Table 17](#)).

**Table 17. Output-Specific Fault Register**

| OD3   | OD2    | OD1    | OD0   |
|-------|--------|--------|-------|
| OTF_s | OCHF_s | OCLF_s | OLF_s |

s = Selection of the output.

**Note** The  $\overline{FS}$  pin reports all faults. For latched faults, this pin is reset by a new Switch OFF command (via SPI or direct input IN).

#### PREVIOUS ADDRESS SOA4:SOA0=00001

Data in bits OD3:OD0 contains IN3\_SPI:IN0\_SPI programmed bits for outputs HS3:HS0, respectively.

#### PREVIOUS ADDRESS SOA4:SOA0=01001

Data in bits OD3:OD0 contains the programmed CSNS3\_EN:CSNS0\_EN bits for outputs HS3:HS0, respectively.

#### PREVIOUS ADDRESS SOA4:SOA0=A<sub>1</sub>A<sub>0</sub>010

Data returned in bits OD3:OD0 are programmed current values for the over-current high detection level (refer to [Table 12](#), page [23](#)) and the over-current low detection level (refer to [Table 11](#), page [23](#)), corresponding to the output previously selected with A<sub>1</sub>A<sub>0</sub>.

#### PREVIOUS ADDRESS SOA4:SOA0=A<sub>1</sub>A<sub>0</sub>011

The returned data contains the programmed values in the CDTOLR register for the output selected with A<sub>1</sub>A<sub>0</sub>.

#### PREVIOUS ADDRESS SOA4:SOA0=A<sub>1</sub>A<sub>0</sub>100

The returned data contains the programmed values in the DICR register for the output selected with A<sub>1</sub>A<sub>0</sub>.

#### PREVIOUS ADDRESS SOA4:SOA0=00101

The returned data contains the programmed values in the UOVR register.

#### PREVIOUS ADDRESS SOA4:SOA0=01101

The returned data contains the programmed values in the WDR register. Bit OD2 (WDTO) reflects the status of the

watchdog circuitry. If WDTO bit is logic [1], the watchdog has timed out and the device is in Fail-safe mode. IF WDTO is logic [0], the device is in Normal Mode (assuming the device is powered and not in the Sleep Mode), with the watchdog either enabled or disabled.

**PREVIOUS ADDRESS SOA4:SOA0=00110**

The returned data OD3 and OD2 contain the state of the outputs HS2 and HS0, respectively, in case of Fail-safe state. This information is stated with the external resistance placed

at the FSI pin. OD1 indicates if the watchdog is enabled or not. OD0 returns the state of the WAKE pin.

**PREVIOUS ADDRESS SOA4:SOA0=01110**

The returned data OD3:OD0 reflects the state of the direct pins IN3:IN0, respectively.

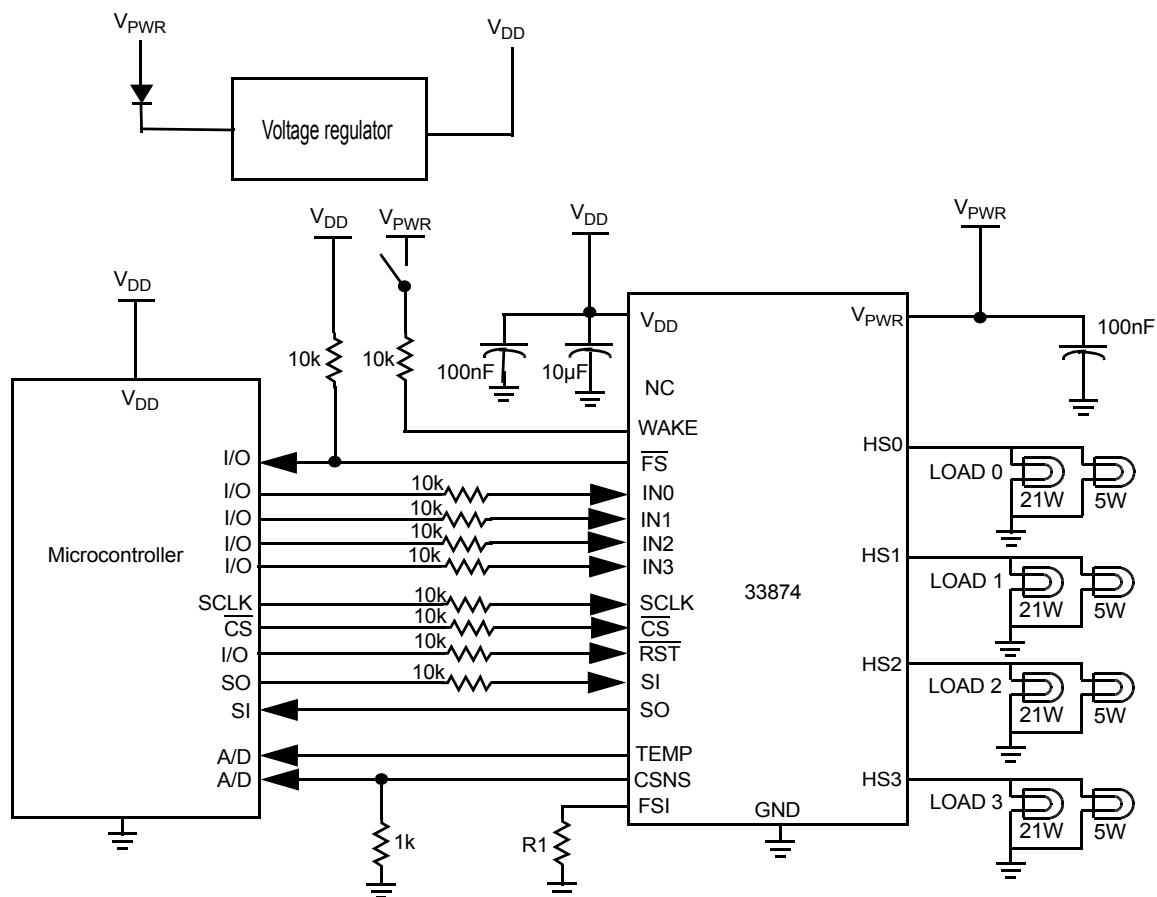
**PREVIOUS ADDRESS SOA4:SOA0=01111**

The returned data OD3-OD2 reports the over-temperature bits configuration of the outputs [3, 2] set through the WDR SPI register.

## TYPICAL APPLICATION

### INTRODUCTION

The 33874 can be configured in several applications. The figure below shows the 33874 in a typical lighting application.



Automotive lamps do not tolerate high voltages very well. Tests of a few lamps indicate that failures can occur when 18V is applied for a few seconds. Consequently, PWM switching reduces the effective RMS voltage in order to drive bulbs safely.

For example, to maintain the power dissipation associated with a 13V battery at 100% duty cycle, the duty cycle would be adjusted to  $(13/18)^2$ , or 52%, when the battery is at 18V.

The loads must be chosen in order to guarantee the device normal operating condition as junction temperature from -40 to 150 °C. In case of permanent short-circuit conditions, the duration and number of activation cycles must be limited with a dedicated MCU fault management using the fault reporting through SPI.

## STANDALONE MODE

This section consists of evaluating the MC33874 standalone capability.

### CONFIGURATION WITHOUT MCU

The standalone mode is intended for customers who desire to plug the device and then immediately “play” with it, without having to connect it to a microcontroller. It also provides an easy way to evaluate the main electrical features.

Without the Microcontroller to select programmable parameters and get full diagnosis via the SPI, the MC33874 runs with all parameters set to default.

The input SPI pins and VDD must be connected to ground. Fail-safe Mode and watchdog timeout must be disabled by connecting the FSI to GND.

All protection functions are available without SPI communication. Nevertheless, any configuration is possible without an MCU to communicate by SPI. Some functions still enable, but diagnosis is reduced. Available functions and default parameters are detailed next.

### FUNCTIONING WITHOUT MCU

Without an MCU, SPI communication is not possible. Fail-safe Mode and watchdog timeout are not useful functions without an MCU, but still enable. Wake/Sleep Mode is used to minimize current consumption during Sleep Mode. IN pins control the corresponding outputs and FS output is active (at 0V) when a default occurs.

The tables 1 and 2 illustrate the available functions without SPI and default parameters.

**Table 1. Available Functions**

| Function                                                                      | With SPI                                                                       | Without SPI                                        |
|-------------------------------------------------------------------------------|--------------------------------------------------------------------------------|----------------------------------------------------|
| Wake/Sleep Mode                                                               | Available                                                                      | Available                                          |
| Output ON/OFF control                                                         | Via SPI or IN pin                                                              | Only with IN pin                                   |
| Over-temperature protection                                                   | Available, can be unlatched                                                    | Available                                          |
| Over-voltage protection                                                       | Available, can be disabled                                                     | Available, always enable                           |
| Under-voltage protection                                                      | Available, can be disabled                                                     | Available, always enable                           |
| Over-current protection                                                       | Available, configurable (with 8 low levels and 2 high levels), can be disabled | Available, always enable with default values       |
| Open load, battery disconnect, reverse battery, ground disconnect protections | Available                                                                      | Available                                          |
| Fault diagnosis                                                               | Full diagnosis with report by SPI and fault status pin (/FS)                   | Limited fault diagnosis with Fault status pin only |
| Current sense                                                                 | Available, 2 configurable ratios                                               | Not available                                      |
| Watchdog timeout                                                              | Available, 4 configurable timings                                              | Available, default value                           |
| Configurable slew rate                                                        | 2 slew rate modes                                                              | Default slew rate mode                             |
| Analog temperature feedback                                                   | Available                                                                      | Available                                          |

**Table 2. Default SPI-configurable parameters**

| Configurable parameter            | Default typical value |
|-----------------------------------|-----------------------|
| Over-voltage protection           | Enable                |
| Under-voltage protection          | Enable                |
| Over-current protection           | Enable                |
| Over-current low level            | OCL00                 |
| Over-current high level           | OCH10                 |
| Over-current detect blanking time | t <sub>OCL00</sub>    |
| Current sense                     | Disable               |
| Watchdog time timeout             | T <sub>WDT00</sub>    |
| Slew rate mode                    | Slow mode             |

Table 2 illustrates default parameters after resetting or applying supply voltage to the MC33874. Levels and timings are typical values.

## DIAGNOSIS WITHOUT MCU

When any fault appears (over-current, open load...), a full diagnosis can be reported via the SPI. Without an MCU, the

fault status pin allows reduced diagnosis, as illustrated in table 3.

**Table 3. Diagnosis without SPI**

|                                                                                              | IN[x] level | HS[x] level | $\overline{\text{FS}}$ level | Latched |
|----------------------------------------------------------------------------------------------|-------------|-------------|------------------------------|---------|
| Normal operation                                                                             | H           | H           | H                            | N/A     |
|                                                                                              | L           | L           | H                            |         |
| Over-temperature                                                                             | L           | L           | L                            | YES     |
|                                                                                              | H           | L           | L                            |         |
| Under-voltage                                                                                | L           | L           | L                            | YES     |
|                                                                                              | H           | L           | L                            |         |
| Over-voltage                                                                                 | L           | L           | H                            | NO      |
|                                                                                              | H           | L           | L                            |         |
| Over-current                                                                                 | L           | L           | H                            | YES     |
|                                                                                              | H           | L           | L                            |         |
| Short-circuit to VPWR                                                                        | L           | H           | L                            | NO      |
|                                                                                              | H           | H           | H                            |         |
| Open load                                                                                    | L           | Z           | L                            | NO      |
|                                                                                              | H           | H           | H                            |         |
| H : High Level, L : Low Level, Z : High-impedance, potential depends on the external circuit |             |             |                              |         |

We can note that it is not possible to distinguish over temperature, over-current, under-voltage, and over-voltage. Nevertheless, Open load and short-circuit to  $V_{PWR}$  fault can be singled out. All protections are reported to Fault status pin ( $\overline{\text{FS}}$ ). Open load and short-circuit to  $V_{PWR}$  are reported only if the Output is OFF. If the fault is latched, the output must be turned OFF then ON to disable the fault.

## CONCLUSION

Although the MC33874 is not fully functional without a microcontroller to control and program it, standalone functioning is safe because all protections are available. Diagnosis is limited, but the fault status pin will report any malfunction.

This is a good way to evaluate the main electrical MC33874 features. Some simplified applications can also use the MC33874 switch without an MCU to drive a high power load with full protection.

## PACKAGING

### SOLDERING INFORMATION

The 33874 is packaged in a surface mount power package intended to be soldered directly on the printed circuit board.

The 33874 was qualified in accordance with JEDEC standards JESD22-A113-B, J-STD-020A with MSL3/245°C

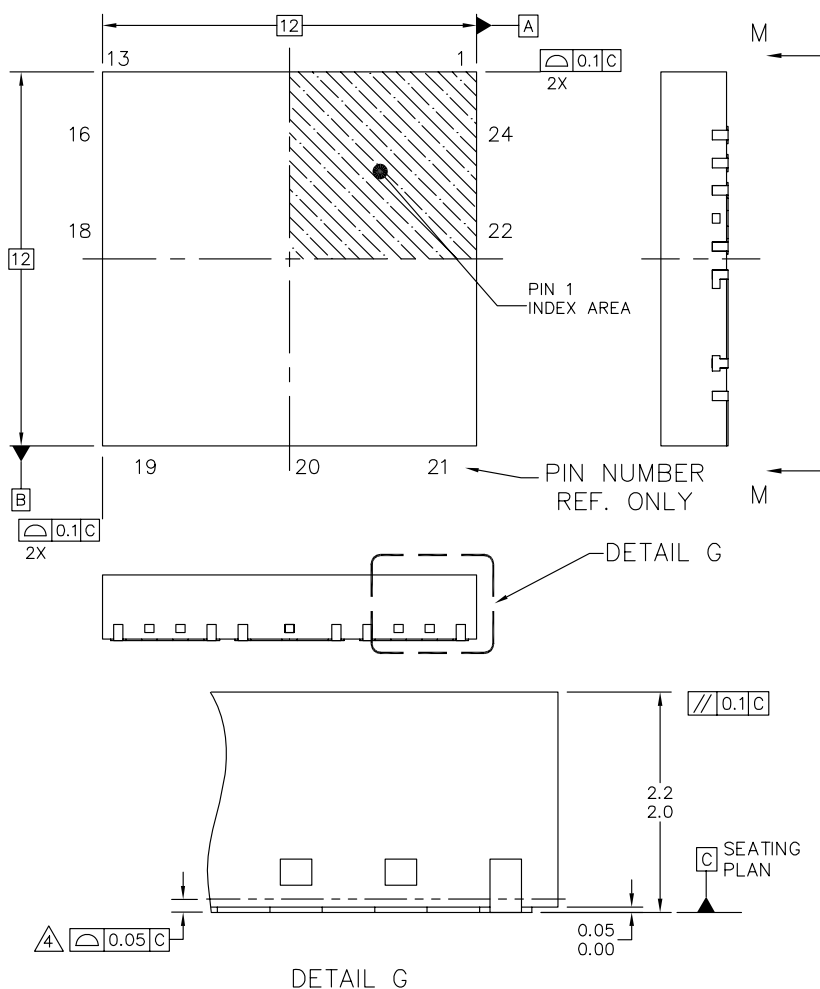
Sn-Pb soldering profile and JESD22-B102D as for solderability test, with reflow conditions as follows:

Reflow Soldering: 215°C+/-5°C

Wave Soldering: 245°C +/-5°C

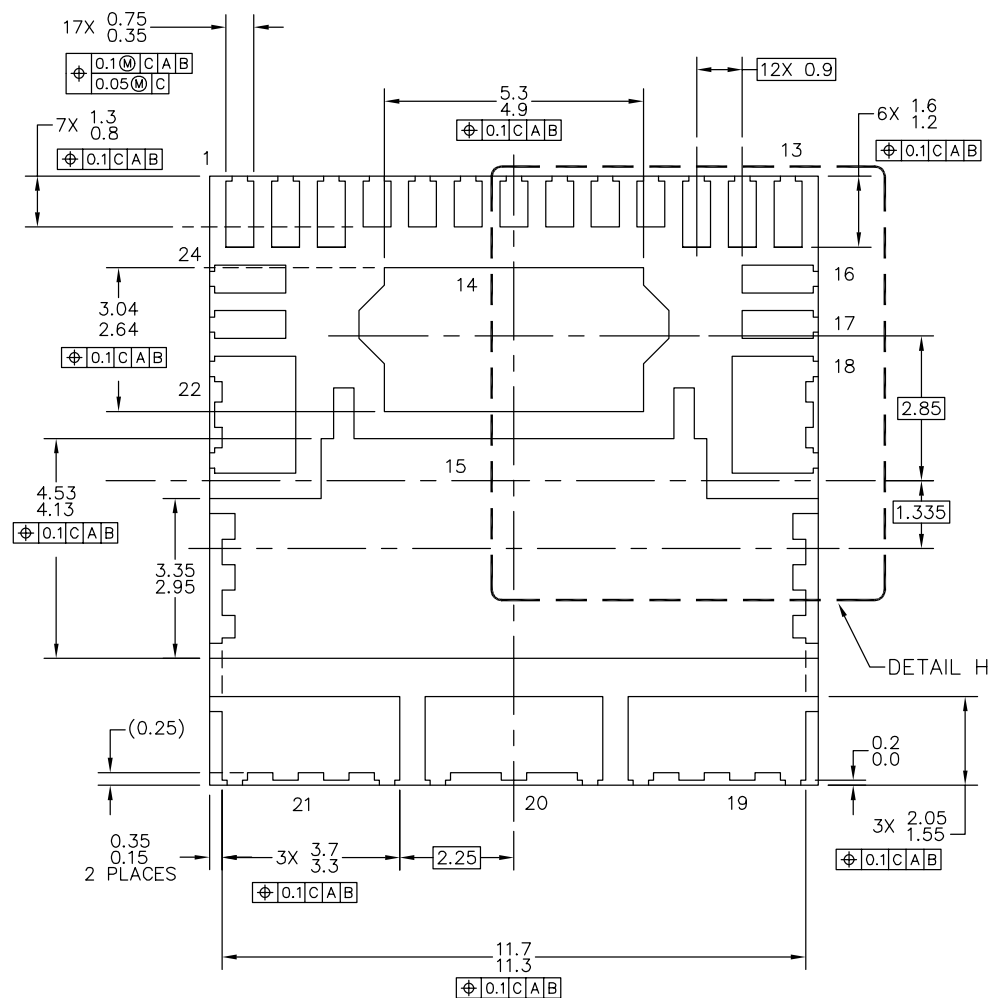
### PACKAGE DIMENSIONS

For the most current package revision, visit [www.freescale.com](http://www.freescale.com) and perform a keyword search using the 98ART10510D listed below.



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**PNA SUFFIX (PB-FREE)**  
24-PIN PQFN  
NONLEADED PACKAGE  
98ART10510D  
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**PNA SUFFIX (PB-FREE)**  
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NONLEADED PACKAGE  
98ART10510D  
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**PNA SUFFIX (PB-FREE)**  
24-PIN PQFN  
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## ADDITIONAL DOCUMENTATION

### THERMAL ADDENDUM (REV 2.0)

#### Introduction

This thermal addendum is provided as a supplement to the 33874 technical datasheet. The addendum provides thermal performance information that may be critical in the design and development of system applications. All electrical, application, and packaging information is provided in the datasheet.

#### Packaging and Thermal Considerations

This package is a dual die package. There are two heat sources in the package independently heating with  $P_1$  and  $P_2$ . This results in two junction temperatures,  $T_{J1}$  and  $T_{J2}$ , and a thermal resistance matrix with  $R_{\theta JA mn}$ .

For  $m, n = 1$ ,  $R_{\theta JA11}$  is the thermal resistance from Junction 1 to the reference temperature while only heat source 1 is heating with  $P_1$ .

For  $m = 1, n = 2$ ,  $R_{\theta JA12}$  is the thermal resistance from Junction 1 to the reference temperature while heat source 2 is heating with  $P_2$ . This applies to  $R_{\theta J21}$  and  $R_{\theta J22}$ , respectively.

$$\begin{Bmatrix} T_{J1} \\ T_{J2} \end{Bmatrix} = \begin{bmatrix} R_{\theta JA11} & R_{\theta JA12} \\ R_{\theta JA21} & R_{\theta JA22} \end{bmatrix} \cdot \begin{Bmatrix} P_1 \\ P_2 \end{Bmatrix}$$

The stated values are solely for a thermal performance comparison of one package to another in a standardized environment. This methodology is not meant to and will not predict the performance of a package in an application-specific environment. Stated values were obtained by measurement and simulation according to the standards listed below.

Table 18. Thermal Performance Comparison

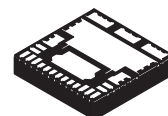
| Thermal Resistance          | 1 = Power Chip, 2 = Logic Chip [ $^{\circ}\text{C}/\text{W}$ ] |                                  |                |
|-----------------------------|----------------------------------------------------------------|----------------------------------|----------------|
|                             | $m = 1, n = 1$                                                 | $m = 1, n = 2$<br>$m = 2, n = 1$ | $m = 2, n = 2$ |
| $R_{\theta JA mn}$ (1), (2) | 20                                                             | 16                               | 39             |
| $R_{\theta JB mn}$ (2), (3) | 6                                                              | 2.0                              | 26             |
| $R_{\theta JA mn}$ (1), (4) | 53                                                             | 40                               | 73             |
| $R_{\theta JC mn}$ (5)      | <0.5                                                           | 0.0                              | 1.0            |

Notes:

- Per JEDEC JESD51-2 at natural convection, still air condition.
- 2s2p thermal test board per JEDEC JESD51-7 and JESD51-5.
- Per JEDEC JESD51-8, with the board temperature on the center trace near the power outputs.
- Single layer thermal test board per JEDEC JESD51-3 and JESD51-5.
- Thermal resistance between the die junction and the exposed pad, "infinite" heat sink attached to exposed pad.

33874

HIGH SIDE SWITCH



PNA SUFFIX  
98ART10510D  
24-PIN PQFN (12 x 12)

**Note** For package dimensions, refer to the 33874 data sheet.

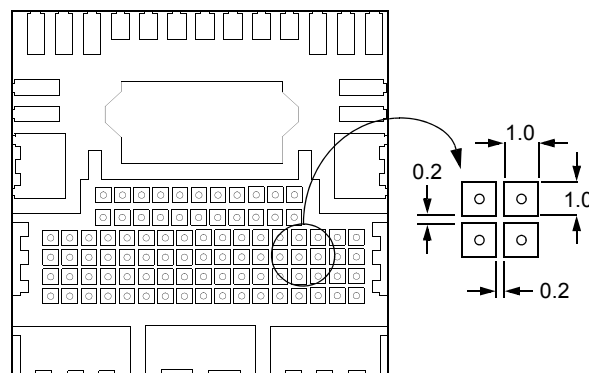


Figure 10. Testboard According to JEDEC

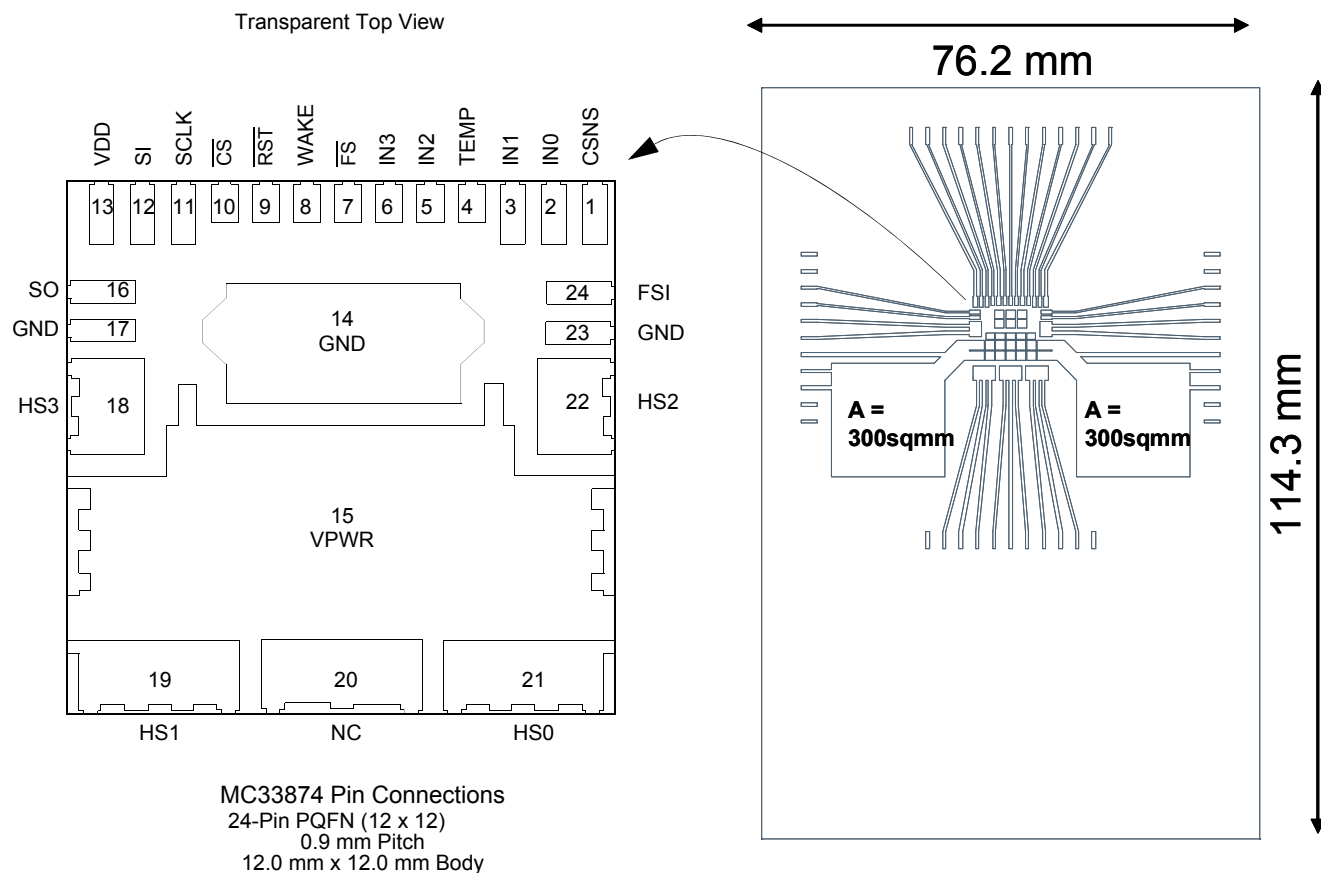


Figure 11. Thermal Test Board

#### Device on Thermal Test Board

|                     |                                                                                           |
|---------------------|-------------------------------------------------------------------------------------------|
| Material:           | Single layer printed circuit board<br>FR4, 1.6mm thickness<br>Cu traces, 0.07mm thickness |
| Outline:            | 80mm x 100mm board area,<br>including edge connector for thermal<br>testing               |
| Area <b>A</b> :     | Cu heat-spreading areas on board<br>surface                                               |
| Ambient Conditions: | Natural convection, still air                                                             |

Table 19. Thermal Resistance Performance

| Thermal<br>Resistance | Area A<br>(mm <sup>2</sup> ) | 1 = Power Chip, 2 = Logic Chip (°C/W) |                                                          |                               |
|-----------------------|------------------------------|---------------------------------------|----------------------------------------------------------|-------------------------------|
|                       |                              | <i>m</i> = 1,<br><i>n</i> = 1         | <i>m</i> = 1, <i>n</i> = 2<br><i>m</i> = 2, <i>n</i> = 1 | <i>m</i> = 2,<br><i>n</i> = 2 |
| $R_{\theta JA mn}$    | 0                            | 53                                    | 38                                                       | 61                            |
|                       | 300                          | 44                                    | 32                                                       | 56                            |
|                       | 600                          | 42                                    | 30                                                       | 55                            |

$R_{\theta JA}$  is the thermal resistance between die junction and ambient air.

This device is a dual die package. Index *m* indicates the die that is heated. Index *n* refers to the number of the die where the junction temperature is sensed.

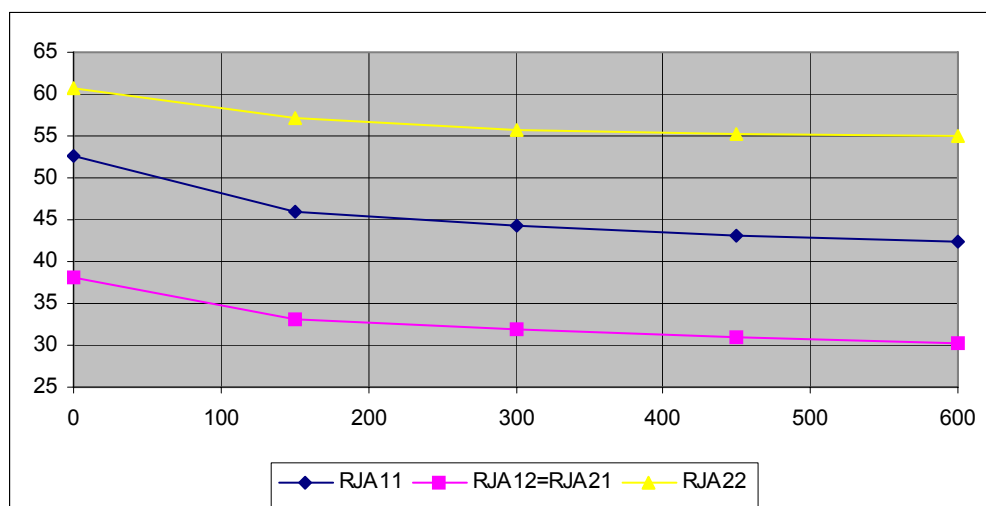


Figure 12. Steady State Thermal Resistance 1W step response;  
device on 1s thermal test board with heat spreading areas sq 600mm.

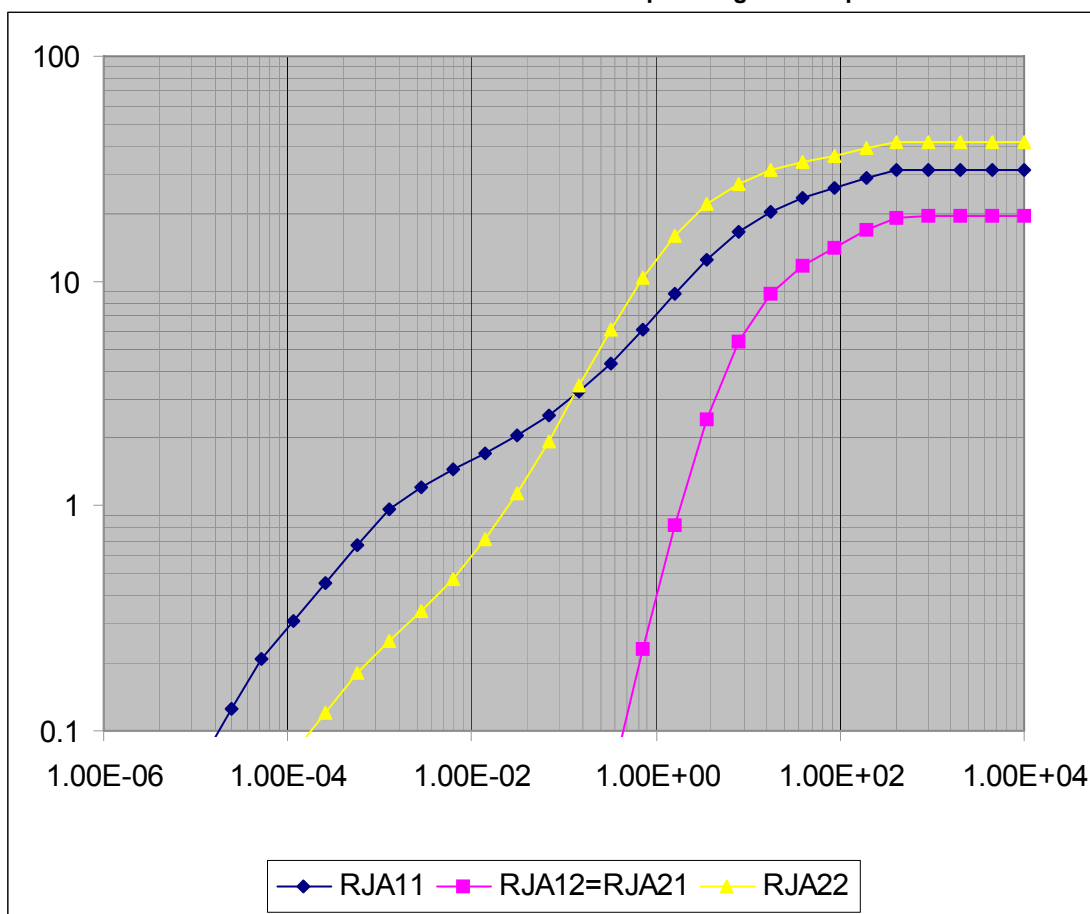


Figure 13. Transient Thermal Resistance

## REVISION HISTORY

| Revision | Date    | Description of Changes                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
|----------|---------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 3.0      | 03/2006 | <ul style="list-style-type: none"> <li>Implemented Revision History page</li> <li>Converted to Freescale format</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| 4.0      | 04/2006 | <ul style="list-style-type: none"> <li>Added ROHS logo</li> <li>Added "It is recommended to disable open load circuitry in case of a permanent disconnected load." to the <a href="#">Open Load Fault (Non-Latching)</a> paragraph</li> <li>Changed 1k to 10k in the second paragraph of <a href="#">Ground Disconnect Protection</a></li> <li>Added the section <a href="#">StandAlone mode</a> to <a href="#">Typical Application</a></li> <li>Updated <a href="#">Package Dimensions</a> to Issue C</li> <li>Added <a href="#">Thermal Addendum (Rev 2.0)</a> to Data Sheet</li> </ul> |
| 5.0      | 6/2002  | <ul style="list-style-type: none"> <li>Corrected part number ordering information</li> <li>Modified Output Turn ON Delay Times on page <a href="#">10</a></li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                      |
| 6.0      | 9/2006  | <ul style="list-style-type: none"> <li>Changed status from Preliminary to Advance.</li> <li>Made changes the resistive loads on the Typical Applications diagram and added a paragraph describing the behavior of automotive lamps.</li> <li>Added new thermal curves to the <a href="#">Thermal Addendum (Rev 2.0)</a> on page 34</li> <li>Made updates to <a href="#">Thermal Resistance Performance</a> on page 35</li> </ul>                                                                                                                                                          |
| 7.0      | 9/2006  | <ul style="list-style-type: none"> <li>Made changes to <a href="#">Thermal Addendum (Rev 2.0)</a> relating to <a href="#">Figure 11</a>, <a href="#">Table 19</a>, <a href="#">Thermal Resistance Performance</a>, <a href="#">Figure 12</a>, and <a href="#">Figure 13</a></li> </ul>                                                                                                                                                                                                                                                                                                    |
| 8.0      | 4/2007  | <ul style="list-style-type: none"> <li>Added Direct Input Switching Frequency to Dynamic Electrical Characteristics Table</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| 9.0      | 1/2008  | <ul style="list-style-type: none"> <li>Updated Freescale form and style</li> <li>Added section for <a href="#">Functional Internal Block Description</a></li> <li>Clarified Legend in "Figure 13, Transient Thermal Resistance, on Page 36</li> <li>Corrected Figure 3, Pin Numbers and Table 1 Pin Definitions for pins 2, 3, 5, &amp; 6 Formal Name from Serial Inputs to Parallel Inputs.</li> <li>Changed Package drawing from 98ARL10596D to 98ART10510D.</li> </ul>                                                                                                                 |

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