
LIN Transceiver with Voltage Regulator

Features:

- The MCP2050 is compliant with:
 - LIN Bus Specifications Version 1.3, 2.1 and with SAE J2602-2
- Support Baud Rates Up to 20 kBaud
- 43V Load Dump Protected
- Maximum Continuous Input Voltage of 30V
- Wide LIN Compliant Supply Voltage, 6.0-18.0V
- Extended Temperature Range: -40 to +125°C
- Interface to PIC® EUSART and Standard USARTs
- Wake-Up on LIN Bus Activity or Local Wake Input
- LIN Bus Pin
 - Internal pull-up termination resistor and diode for slave node
 - Protected against VBAT shorts
 - Protected against loss of ground
 - High current drive
- TXD and LIN Bus Dominant Time-Out Function
- Two Low-Power Modes
 - Transmitter Off mode: 90 µA (typical)
 - Power Down mode: 4.5 µA (typical)
- Output Indicating Internal Reset State (POR or Sleep Wake)
- MCP2050 On-Chip Voltage Regulator
 - Output voltage of 5.0V or 3.3V with 70 mA capability and tolerances of ±3% over operating temperature range
 - Internal short-circuit current limit
 - Only external filter and load capacitors needed
- Programmable Windowed Watchdog Timer (WWDT)
 - External resistor programmable from 7 ms to 140 ms
 - Disabled by connecting the WWDTSELECT pin to VREG or let the pin float
- Ratiometric Output of VBAT Voltage Scaled to VREG
- Automatic Thermal Shutdown
- High Electromagnetic Immunity (EMI), Low Electromagnetic Emission (EME)
- Robust ESD Performance: ±15 kV for LBUS and VBB pin (IEC61000-4-2)
- Transient Protection for LBUS and VBB Pins in Automotive Environment (ISO7637)

- Meets Stringent Automotive Design Requirements Including “OEM Hardware Requirements for LIN, CAN and FlexRay Interfaces in Automotive Applications”, Version 1.3, May 2012
- Multiple Package Options Including Small 5x5 QFN

Description:

The MCP2050 provides a bidirectional, half-duplex communication physical interface to meet the LIN bus specification Revision 2.1 and SAE J2602. The device incorporates a voltage regulator with 5V or 3.3V 70 mA regulated power supply output. The on-chip WWDT allows users to adjust the size of the reset window by using an external resistor. The ratiometric VBAT pin scales down VBAT to the range of VREG so it can be monitored by an A/D converter.

The device has been designed to meet the stringent quiescent current requirements of the automotive industry and will survive +43V load dump transients, and double battery jumps.

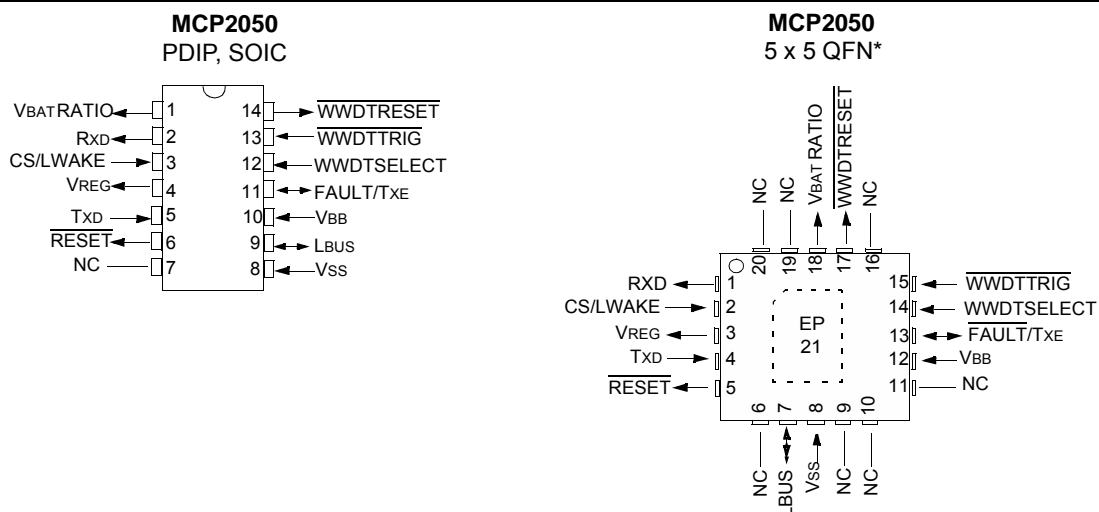
MCP2050 family members:

- MCP2050-500, 14-pin, LIN driver with 5.0V regulator
- MCP2050-330, 14-pin, LIN driver with 3.3V regulator
- MCP2050-500, 20-pin QFN, LIN driver with 5.0V regulator
- MCP2050-330, 20-pin QFN, LIN driver with 3.3V regulator

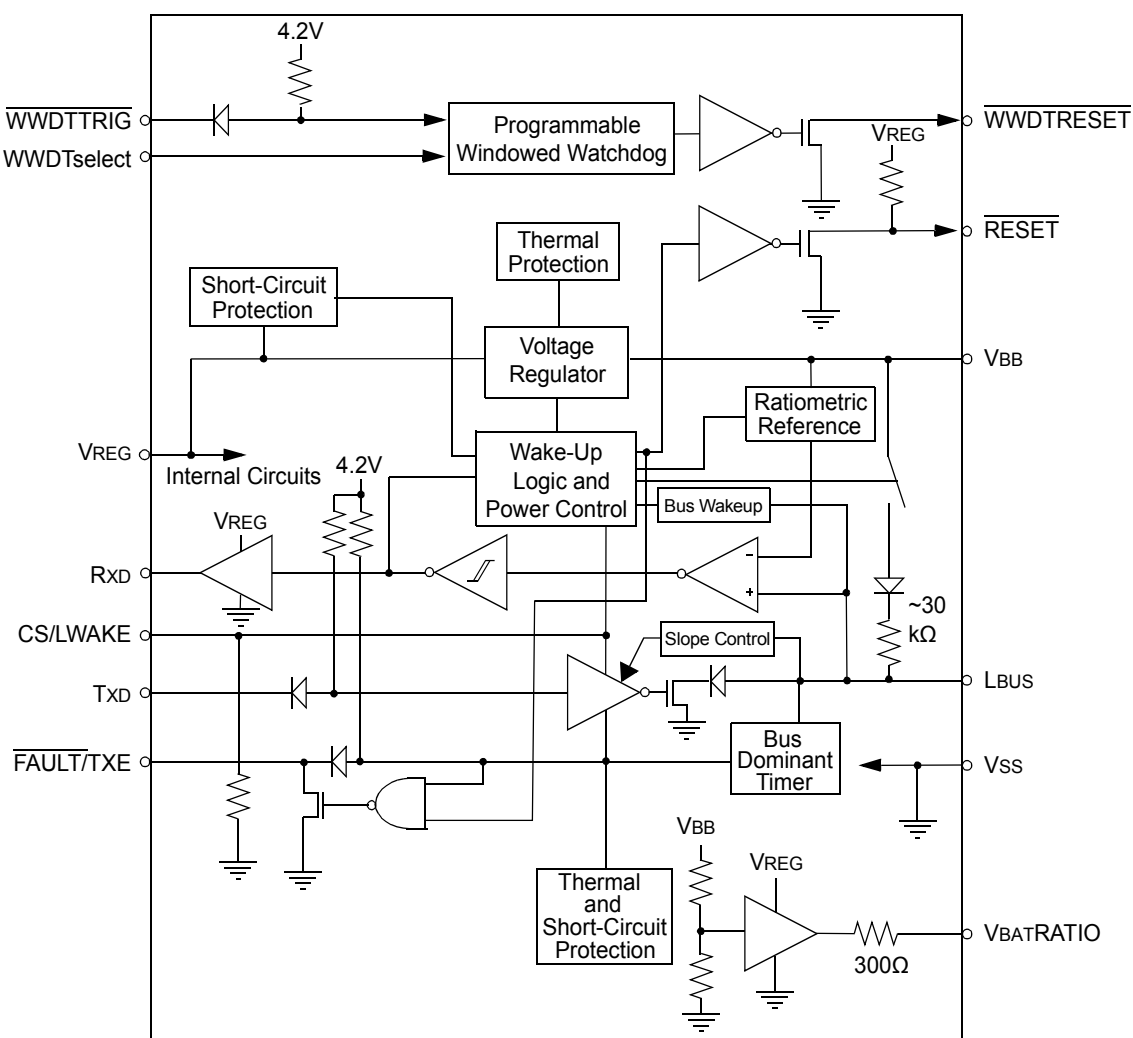


MCP2050

Package Types



Block Diagram



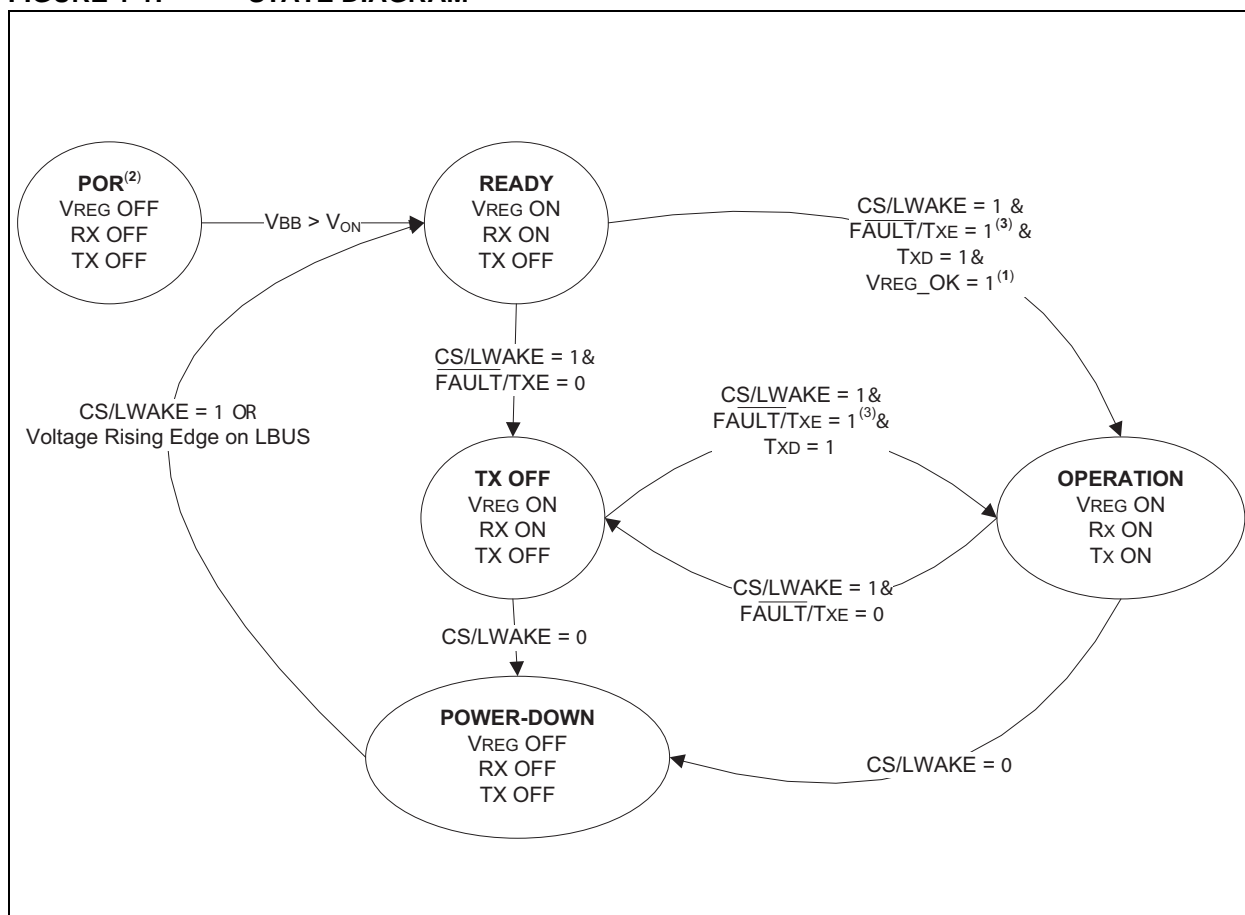
1.0 FUNCTION DESCRIPTION

The MCP2050 provides a physical interface between a microcontroller and a LIN half-duplex bus. It is intended for automotive and industrial applications with serial bus baud rates up to 20 kbaud. This device will translate the CMOS/TTL logic levels to LIN logic levels, and vice versa. The device offers optimum EMI and ESD performance; it can withstand high voltage on the LIN bus. The device supports two low-power modes to meet automotive industry power consumption requirements. The MCP2050 also provides a +5V or 3.3V 70 mA regulated power output.

1.1 Modes of Operation

The MCP2050 works in five modes: Power-On Reset mode, Power-Down mode, Ready mode, Operation mode, and Transmitter Off mode. For an overview of all operational modes, please refer to [Table 1-1](#). For the operational mode transition, please refer to [Figure 1-1](#).

FIGURE 1-1: STATE DIAGRAM



Note 1: VREG_OK: Regulator Output Voltage > 0.8V_{REG_NOM}.

2: If the voltage on pin VBB falls below V_{OFF}, the device will enter Power-On Reset mode from all other modes, which is not shown in the figure.

3: $\overline{FAULT}/TXE = 1$ represents input and no fault conditions. $\overline{FAULT}/TXE = 0$ represents input low or a fault condition. Refer to [Table 1-3](#).

1.1.1 POWER-ON-RESET MODE

Upon application of VBB, or whenever the voltage on VBB is below the threshold of regulator turn-off voltage VOFF (typically 4.50V), the device enters Power-On Reset mode (POR). During this mode, the device maintains the digital section in a reset mode and waits until the voltage on pin VBB rises above the threshold of regulator turn-on voltage VON (typically 5.75V) to enter into Ready mode. In Power-On-Reset mode, the LIN physical layer and voltage regulator are disabled, and RESET output is forced to low.

1.1.2 READY MODE

The device enters Ready mode from POR mode after the voltage on VBB rises above the threshold of regulator turn-on voltage VON or from Power-Down mode when a remote or local wake-up event happens.

Upon entering Ready mode, the voltage regulator and receiver section of the transceiver are powered up. The transmitter remains in off state. The device is ready to receive data but not to transmit. In order to minimize the power consumption, the regulator operates in a reduced-power mode. It has a lower GBW product and thus is slower. However, the 70 mA drive capability is unchanged.

The device stays in Ready mode until the output of the voltage regulator has stabilized and the CS/LWAKE pin is high ('1').

1.1.3 OPERATION MODE

If VREG is OK ($V_{REG} > 0.8 V_{REG_NOM}$), CS/LWAKE pin, FAULT/TxE pin and TxD pin are high, the part enters the Operation mode from either Ready or Transmitter Off mode.

In this mode, all internal modules are operational. The internal pull-up resistor between LBus and VBB is connected only in this mode.

The device goes into the Power-Down mode at the falling edge on CS/LWAKE; or to the Transmitter Off mode at the falling on FAULT/TxE while CS/LWAKE stays high.

1.1.4 TRANSMITTER OFF MODE

In Transmitter Off mode, the receiver is enabled but the LBus transmitter is off. It is a lower-power mode.

In order to minimize the power consumption, the window watchdog timer is disabled and the regulator operates in a reduced-power mode. It has a lower GBW product and thus is slower. However, the 70 mA drive capability is unchanged.

The transmitter may be re-enabled whenever the FAULT/TxE signal returns high, by removing the internal fault condition and the CPU returning the FAULT/TxE high. The transmitter will not be enabled even if the FAULT/TxE pin is brought high externally, when the internal fault is still present. However, externally forcing the FAULT/TxE high, while the internal fault is still present, should be avoided since this will induce high current and power dissipation in the FAULT/TxE pin.

The transmitter is also turned off whenever the voltage regulator is unstable or recovering from a fault. This prevents unwanted disruption of the bus during times of uncertain operation.

1.1.5 POWER-DOWN MODE

In Power-Down mode, the transceiver and the voltage regulator are both off. Only the Bus Wake-up section and the CS/LWAKE pin wake-up circuits are in operation. This is the lowest-power mode.

If any bus activity (e.g. a BREAK character) occurs during Power-Down mode, the device will immediately enter Ready mode and enable the voltage regulator. Then, once the regulator output has stabilized (approximately 0.3 ms to 1.2 ms) it goes to Operation mode. Refer to [Section 1.1.6 "Remote Wake-up"](#) for more details.

The part will also enter Ready mode from Power-Down mode, followed by Operation mode, if the CS/LWAKE pin becomes active high ('1').

1.1.6 REMOTE WAKE-UP

The remote wake-up sub module observes the LBus in order to detect bus activity. In Power-Down mode, normal LIN recessive/dominant threshold is disabled, and the LIN bus Wake-Up Voltage Threshold $V_{WK(LBUS)}$ is used to detect bus activities. Bus activity is detected when the voltage on the LBus falls below the LIN bus Wake-Up Voltage Threshold $V_{WK(LBUS)}$ (approximately 3.4V) for at least tBDB (a typical duration of 80 μ s) followed by a rising edge. Such a condition causes the device to leave Power-Down mode

TABLE 1-1: OVERVIEW OF OPERATIONAL MODES

| State | Transmitter | Receiver | Internal Wake Module | Voltage Regulator | Watch Dog Timer | Operation | Comments |
|-----------------|-------------|----------|-----------------------|-------------------|-----------------|--|---------------------------------|
| PoR | Off | Off | Off | Off | Off | Proceed to Ready mode after $V_{BB} > V_{ON}$. | — |
| Ready | Off | On | Off | On | On | If CS/LWAKE high, then proceed to Operation or Transmitter Off mode. | Bus Off state |
| Operation | On | On | Off | On | On | If CS/LWAKE low level, then proceed to Power-Down. If FAULT/TXE low level, then Transmitter-Off mode. | Normal Operation mode |
| Power-Down | Off | Off | On Activity Detect | Off | Off | On LIN bus rising edge or CS/LWAKE high level, proceed to READY mode. | Lowest-Power mode |
| Transmitter Off | Off | On | Off | On | Off | If CS/LWAKE low level, then proceed to Power down. If FAULT/TXE high, then Operation mode. | Bus Off state, Lower-Power mode |

1.2 Windowed Watchdog Reset

The Watchdog Timer monitors for activity on the Windowed Watchdog Timer Trigger input pin WWDTRIG. The WWDTRIG pin is expected to be strobed within a given time frame. When this time frame has expired without an edge transition on the WWDTRIG pin, the WWDTRSET pin is driven active (low) to reset the system. This feature is enabled by connecting a resistor between the WWDTSELECT pin and Vss. Monitoring is then done by requiring the host processor to force a falling edge transition on the WWDTRIG pin within a predetermined time frame (Twd).

The start time of the trigger window is fixed at 50% of the total watchdog period, after the last trigger. The length of the window is determined by the value of the resistor on pin WWDTSELECT. The Watchdog Timer is disabled if WWDTSELECT is floating.

1.2.1 WWDT DURING INITIAL POWER-UP

The WWDTRSET is driven high after a power-on reset. The Watchdog Timer begins counting at this point, awaiting an edge on WWDTRIG pin. Note that there is no window enabled, yet. If no falling edge is detected on the WWDTRIG pin before the timer expires, the WWDTRSET is pulse low and the timer is restarted. When a trigger edge on the WWDTRIG pin is seen, the window is enabled and the timer is reset.

FIGURE 1-2: WWDTRSET DURING INITIAL POWER-UP

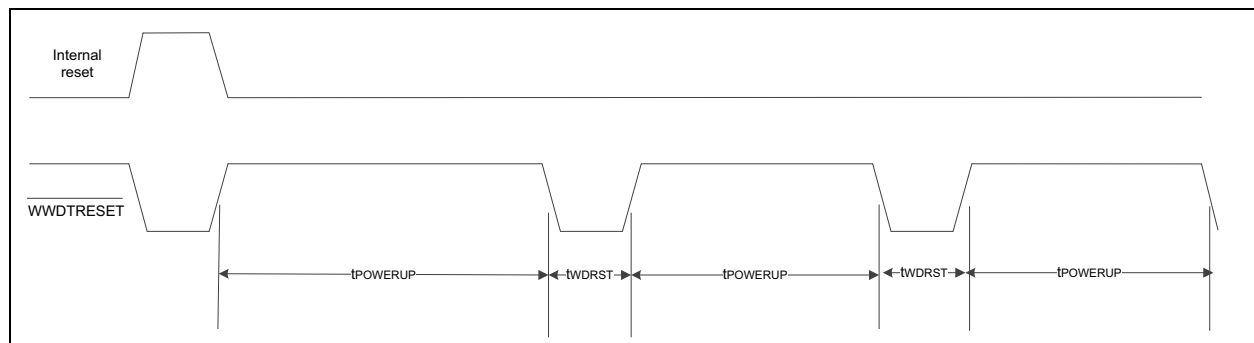


Figure 1-2 shows the behavior of the WWDTRSET pin after a system reset with no trig at all. If no trig is given during the power-up window, WWDTRSET is reset low for the time t_{WDRST} .

The power-up window length $t_{POWERUP}$ duration is determined by the value of the resistor connected between pin WWDTSELECT and pin Vss, while the reset pulse duration is about 150 μs .

Duration for $t_{POWERUP}$ and t_{WDRST} are:

- $t_{POWERUP} = 0.8 \text{ ms} \times (R_{WWDTSELECT} + 1)$ typical
- $t_{WDRST} = 150 \mu s$ typical
- $R_{WWDTSELECT}$ is in $k\Omega$.

Once a trig is asserted, the power-up sequence “stops” and the normal behavior begins.

1.2.2 WINDOWED WATCHDOG BEHAVIOR

After windowed watchdog begins its normal behavior, three different cases can appear.

- A pulse (falling edge) on the $\overline{\text{WWDTTTRIG}}$ pin is detected within the trigger window; the watchdog timer will be reset, and a new watchdog period will begin; $\overline{\text{WWDTRESET}}$ pin remains high (Figure 1-3.)
- A pulse (falling edge) on the $\overline{\text{WWDTTTRIG}}$ pin is detected before the trigger window (too early trigger); $\overline{\text{WWDTRESET}}$ is asserted (low) immediately after the falling edge is detected for approximately t_{WDRST} ; the counter is reset and the next watchdog period begins at the rising edge of the voltage on $\overline{\text{WWDTRESET}}$ pin (Figure 1-12).
- No pulse on the $\overline{\text{WWDTTTRIG}}$ pin is detected during the whole watchdog window (no trigger); $\overline{\text{WWDTRESET}}$ is asserted (low) for approximately t_{WDRST} when the timer has expired; the counter is reset and the next watchdog period begins at the rising edge of the voltage on $\overline{\text{WWDTRESET}}$ pin (Figure 1-5).

The trigger window is between 50% to 100% of the watchdog window length, t_{WLENGTH} . The window length is determined by the external resistor between $\overline{\text{WWDTSELECT}}$ pin and V_{ss} .

EQUATION 1-1:

$$t_{\text{WLENGTH}} = (0.175 \text{ ms} \times \text{RWWDTSELECT}) + 1.2 \text{ typical}$$

$t_{\text{WDRST}} = 150 \text{ } \mu\text{s}$ typical

RWWDTSELECT is in $\text{k}\Omega$; its value ranges from 33 $\text{k}\Omega$ to 680 $\text{k}\Omega$ and window length ranges from 7 ms to 120 ms typical.

If the $\overline{\text{WWDTSELECT}}$ pin is floating, the watchdog is disabled and the $\overline{\text{WWDTRESET}}$ remains high.

FIGURE 1-3: CORRECT TRIGGER

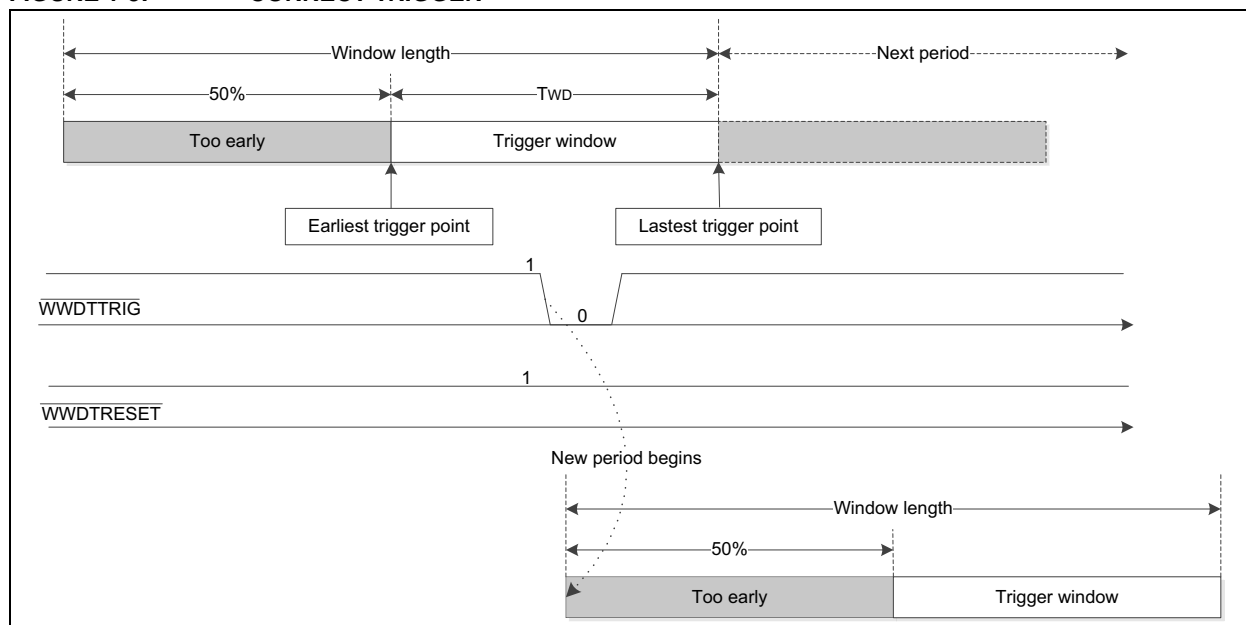


FIGURE 1-4: TOO EARLY TRIGGER

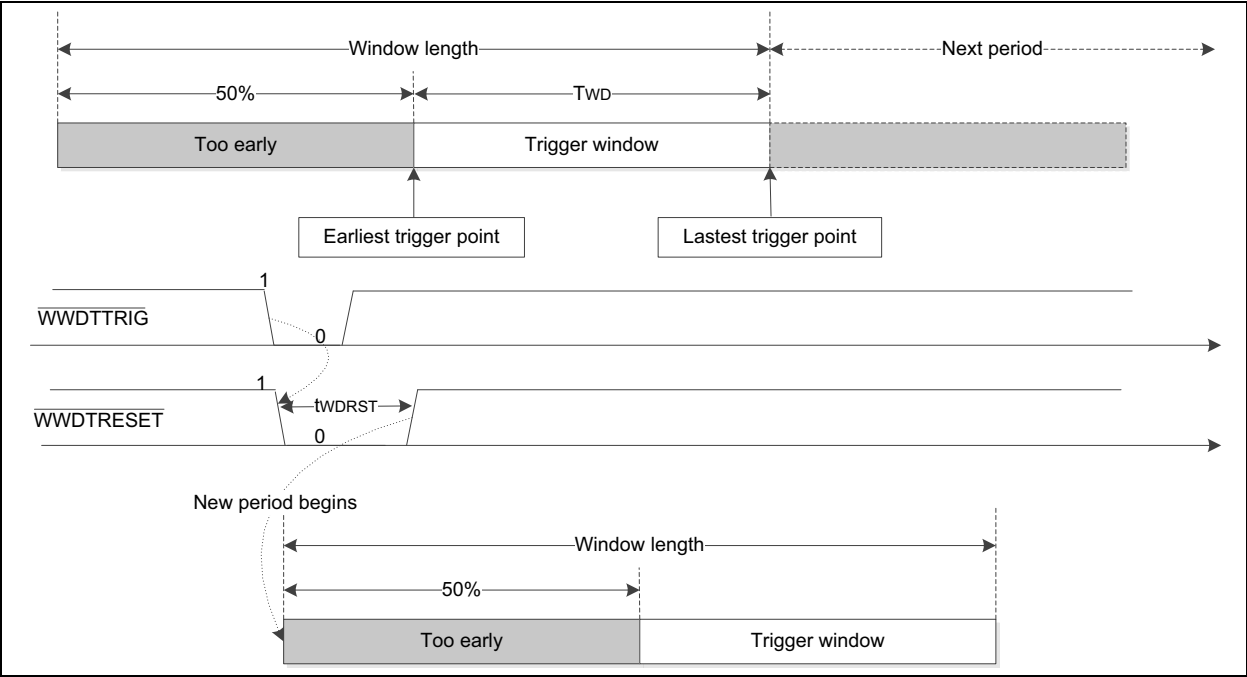
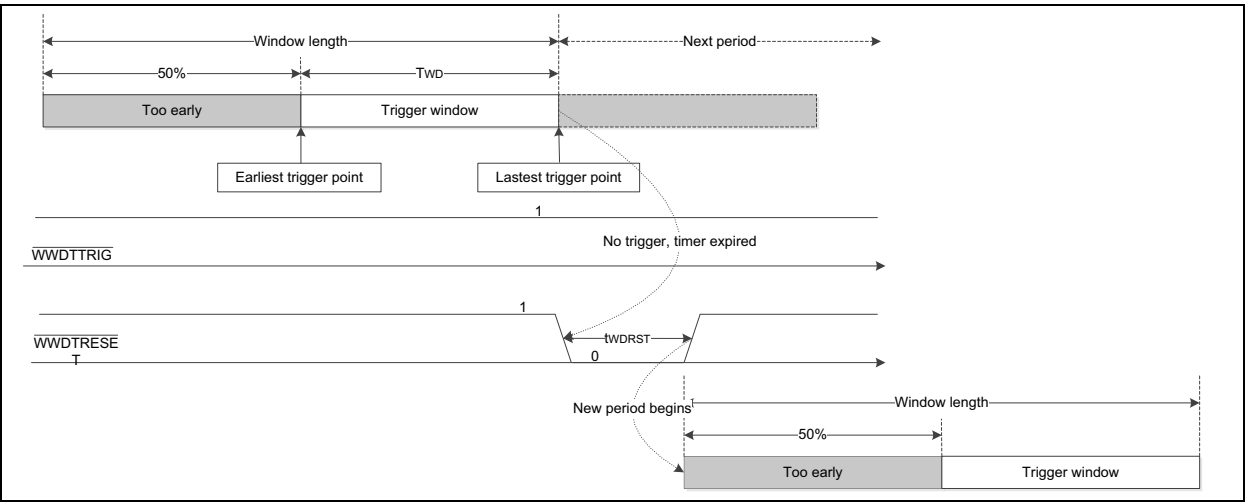


FIGURE 1-5: NO TRIGGER



MCP2050

1.3 Pin Descriptions

Please refer to [Table 1-2](#) for the pinout overview.

TABLE 1-2: PINOUT DESCRIPTIONS

| PIN Name | Devices | | PIN Type | Function |
|------------------------|----------------------|------------------------|--------------------------|--|
| | 14-Pin PDIP, SOIC | 5 x 5 QFN | | Normal Operation |
| VBATRATIO | 1 | 18 | Analog Output | $VBATRATIO = VBAT/24 \times VREG$ |
| RxD | 2 | 1 | Output | Receive Data Output |
| CS/LWAKE | 3 | 2 | TTL Input, HV-tolerant | Chip Select and Local Wake-up Input |
| VREG | 4 | 3 | Output | Voltage Regulator Output |
| TxD | 5 | 4 | Input, HV-tolerant | Transmit Data Input |
| \overline{RESET} | 6 | 5 | Output | Reset Output |
| NC | 7 | 6,9,10,11, 16,19,20 | Not Connected | — |
| VSS | 8 | 8 | Power | Ground |
| LBUS | 9 | 7 | I/O, HV | LIN Bus |
| VBB | 10 | 12 | Power | Battery |
| \overline{FAULT}/TXE | 11 | 13 | I/O, HV-tolerant | Fault Detect Output/Transmitter Enable Input |
| WWDTSELECT | 12 | 14 | Input | A Resistor between this pin and Ground determines the Watchdog Window length |
| $\overline{WWDTTTRIG}$ | 13 | 15 | Input | Windowed Watchdog Trigger Input |
| $\overline{WWDTRESET}$ | 14 | 17 | Output, HV-tolerant | Windowed Watchdog Reset Output |
| EP | — | 21 | Exposed Thermal Pad (EP) | Exposed Thermal Pad can be left unconnected, or connected to the ground. |

1.3.1 VBATRATIO

This is an analog output pin that reflects the voltage at the VBAT pin. It is scaled by VREG such that:

$$VBATRATIO = VBAT/24 \times VREG$$

$$0 \leq VBATRATIO \leq VREG$$

The resistive divider and the output driver are switched off during Power-Down mode in order to reduce power consumption.

1.3.2 RxD

Receive Data Output pin. The RxD pin is a standard CMOS output pin and it follows the state of the LBUS pin.

1.3.3 CS/LWAKE

Chip Select and Local Wake-Up Input pin (TTL level, high voltage tolerant). This pin controls the device state transition. Refer to [Figure 1-1](#).

If CS/LWAKE = 1, the device can work in Operation mode ($\overline{FAULT}/TXE = 1$) or Transmitter Off mode ($\overline{FAULT}/TXE = 0$).

If CS/LWAKE = 0, the device can work in Power-Down mode or Ready mode.

An internal pull-down resistor will keep the CS/LWAKE pin low to ensure that no disruptive data will be present on the bus while the microcontroller is executing a Power-on Reset and I/O initialization sequence. When CS/LWAKE is '1', a weak pull-down (~600 kΩ) is used to reduce current. When CS/LWAKE is '0' a stronger pull-down (~300 kΩ) is used to maintain the logic level.

This pin may also be used as a local wake-up input (see [Figure 1-12](#)). The microcontroller will set the I/O pin to control the CS/LWAKE. An external switch, or other source, can then wake-up both the transceiver and the microcontroller.

Note: CS/LWAKE should NOT be tied directly to pin VREG as this could force the MCP2050 into Operation Mode before the microcontroller is initialized.

1.3.4 VREG

Positive Supply Voltage Regulator Output pin. An on-chip LDO gives +5.0 or +3.3V 70 mA regulated voltage on this pin.

1.3.5 TXD

Transmit Data Input pin (TTL level, HV compliant, adaptive pull-up). The transmitter reads the data stream on TXD pin and sends it to LIN bus. The LBUS pin is low (dominant) when TXD is low, and high (recessive) when TXD is high.

The Transmit Data Input pin has an internal adaptive pull-up to an internally-generated 4.2V (approximate). When TXD is '0', a weak pull-up (~900 kΩ) is used to reduce current. When TXD is '1' a stronger pull-up (~300 kΩ) is used to maintain the logic level. A series reverse-blocking diode allows applying TXD input voltages greater than the internally generated 4.2V and renders TXD pin HV compliant up to 30V (see the Block Diagram on page 2).

1.3.6 RESET

Reset Output pin. This pin is open drain with ~90 kΩ pull-up to VREG. It indicates the internal voltage has reached a valid, stable level. As long as the internal voltage is valid (above 0.8VREG), this pin will remain high ('1'); otherwise the RESET pin switches to low ('0').

1.3.7 VSS

Ground pin.

1.3.8 LBUS

LBUS is a bidirectional LIN bus Interface pin and is controlled by the signal TXD. It has an open collector output with a current limitation. To reduce electromagnetic emission, the slopes during signal changes are controlled, and the LBUS pin has corner-rounding control for both falling and rising edges.

The internal LIN receiver observes the activities on LIN bus, and generates the output signal RXD that follows the state of the LBUS. A first degree 160 kHz, low-pass input filter optimizes electromagnetic immunity.

1.3.9 VBB

Battery Positive Supply Voltage pin. An external diode is connected in series to prevent the device from being reversely powered (refer [Figure 1-12](#)).

1.3.10 FAULT/TXE

Fault Detect Output/Transmitter Enable Input pin. The output section is HV tolerant open drain (up to 30V). The input section is identical with TXD section (TTL level, HV compliant, adaptive pull-up). The internal pull-up resistor may be too weak for some applications. An external 10kΩ pull-up resistor is recommended to ensure a logic high level. Its state is defined as shown in [Table 1-3](#). The device is placed in Transmitter Off mode whenever this pin is low ('0'), either from an internal fault condition or by external drive.

If CS/LWAKE is high ('1'), the FAULT/TXE signals a mismatch between the TXD input and the LBUS level. This can be used to detect a bus contention. Since the bus exhibits a propagation delay, the sampling of the internal compare is debounced to eliminate false faults.

After the device wakes up, the FAULT/TXE indicates what wakes the device if CS/LWAKE remains low ('0') (refer [Table 1-3](#)).

The FAULT/TXE pin sampled at a rate faster than every 10 μs.

1.3.11 WWDTSELECT

This is an analog input pin that sets the open window time to accept a trigger reset. A resistor between this pin and VSS sets this time. The equation to determine the value of the resistor can be found in [Section 1.2.2 "Windowed Watchdog Behavior"](#).

1.3.12 WWDTTTRIG

This is an input pin to reset the Windowed Watchdog Timer. A high-to-low transition during the open window time will reset the timer and prevent the WWDT from timing out. The pin has an internal adaptive pull-up to an internally-generated 4.2V (approximate.).

When WWDTTTRIG is '0', a weak pull-up (~800 kΩ) is connected to reduce current.

When WWDTTTRIG is '1', the pull-up is stronger to maintain the logic level.

1.3.13 WWDTRESET

WWDTRESET is an open-drain output pin. This pin is asserted low when the internal Windowed Watchdog Timer has expired or an attempt was made to clear the timer before the window has opened.

1.3.14 EP

It is recommended to connect this pad to VSS to enhance electromagnetic immunity and thermal resistance.

MCP2050

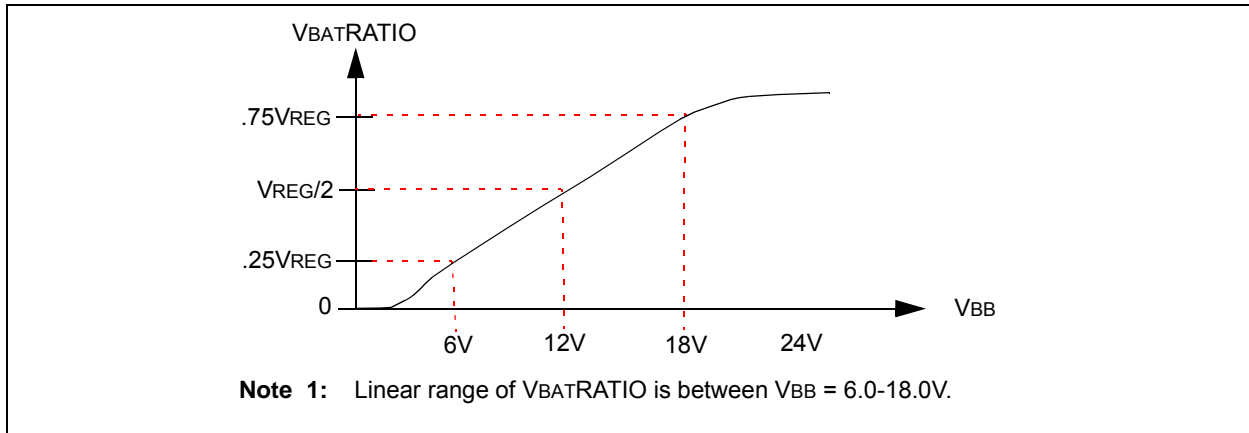
TABLE 1-3: FAULT/TXE TRUTH TABLE

| TxD In | RxD Out | LIN BUS I/O | Thermal Override | FAULT/TxE | | Definition |
|------------------------|---------|-------------|------------------|----------------|---------------|--|
| | | | | External Input | Driven Output | |
| CS = 1 | | | | | | |
| L | H | VBB | OFF | H | L | FAULT , TXD driven low, LBUS shorted to VBB (Note 1), or LBUS/TxD permanent dominant detected, and transmit time-out shutdown. |
| H | H | VBB | OFF | H | H | OK |
| L | L | GND | OFF | H | H | OK |
| H | L | GND | OFF | H | H | OK , data is being received from LBUS |
| x | x | VBB | ON | H | L | FAULT , transceiver in thermal shutdown |
| x | x | VBB | x | L | x | NO FAULT , the CPU is commanding the transceiver to turn off the transmitter driver |
| CS = 0 after a wake-up | | | | | | |
| x | x | x | x | x | L | Wake-up from LIN bus activity |
| x | x | x | x | x | H | Wake-up from POR |

Legend: x = don't care

Note 1: The FAULT/TXE is valid after approximately 25 μ s after TXD falling edge. This is to eliminate false fault reporting during bus propagation delays.

FIGURE 1-6: VBATRATIO OUTPUT RANGE



1.4 Fail-Safe Features

1.4.1 GENERAL FAIL-SAFE FEATURES

- An internal pull-down resistor on the CS/LWAKE pin disables the transmitter if the pin is floating.
- An internal pull-up resistor on the TXD pin places TXD in high, thus the LBUS is recessive if the TXD pin is floating.
- High-Impedance and low leakage current on LBUS during loss of power or ground.
- The current limit on LBUS protects the transceiver from being damaged if the pin is shorted to VBB.

1.4.2 THERMAL PROTECTION

The thermal protection circuit monitors the die temperature and is able to shut down the LIN transmitter and voltage regulator.

There are three causes for a thermal overload. A thermal shut down can be triggered by any one, or a combination of, the following thermal overload conditions.

- Voltage regulator overload
- LIN bus output overload
- Increase in die temperature due to increase in environment temperature

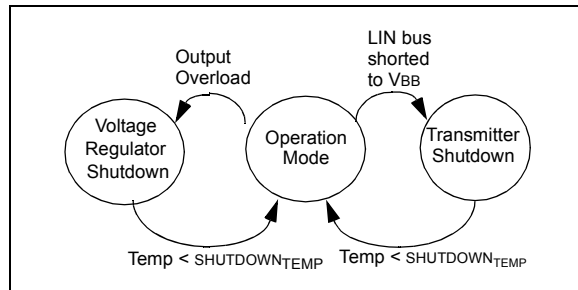
The recovery time from the thermal shutdown is equal to adequate cooling time.

Driving the TXD and checking the RXD pin makes it possible to determine whether there is a bus contention (TXD = high, RXD = low) or a thermal overload condition (TXD = low, RXD = high).

1.4.3 TXD/LBUS TIME-OUT TIMER

LIN bus can be driven to a dominant level either from TXD pin or externally. An internal timer deactivates the LBUS transmitter if a dominant status (low) on LIN bus lasts longer than Bus Dominant Time-Out Time $t_{TO(LIN)}$ (approximately 20 ms); at the same time, RXD output is put in recessive (high), \overline{FAULT}/TXE is also driven to low and the internal LIN pull-up resistor is disconnected. The timer is reset on any recessive LBUS status or POR mode. The recessive status on LBUS can be caused either by the bus being externally pulled up or by TXD pin being returned high.

FIGURE 1-7: THERMAL SHUTDOWN STATE DIAGRAMS



1.5 Internal Voltage Regulator

The MCP2050 has a positive regulator capable of supplying +5.0V or +3.3V at up to 70 mA of load current with tolerances of $\pm 3\%$ over the entire operating temperature range of -40°C to $+125^{\circ}\text{C}$. The regulator uses an LDO design, is short-circuit-protected and will turn the regulator output off if its output falls below the Shutdown Voltage Threshold V_{SD} .

With a load current of 70 mA, the minimum input-to-output voltage differential required for the output to remain in regulation is typically +0.5V (+1V maximum over the full operating temperature range). Quiescent current is less than 100 μA with a full 70 mA load current when the input-to-output voltage differential is greater than +3.00V.

Regarding the correlation between V_{BB} , V_{REG} and I_{DD} , refer to Figure 1-9 and Figure 1-10. When the input voltage (V_{BB}) drops below the differential needed to provide stable regulation, the voltage regulator output V_{REG} will track the input down to approximately V_{OFF} . The regulator will turn off the output at this point. This will allow PIC[®] microcontrollers, with internal POR circuits, to generate a clean arming of the Power-on Reset trip point. The MCP2050 will then monitor V_{BB} and turn on the regulator when V_{BB} is above the threshold of regulator turn-on voltage V_{ON} .

Under specific ambient temperature and battery voltage range, the voltage regulator can output as high as 150 mA current.

For current load capability of the voltage regulator, refer to Figure 1-9 and Figure 1-10.

In Power-Down mode, the V_{BB} monitor is turned off.

Note: The regulator overload current limit is approximately 250 mA. The regulator output voltage V_{REG} is monitored. If output voltage V_{REG} is lower than V_{SD} , the voltage regulator will turn off. After a recovery time of about 3 ms, the V_{REG} will be checked again. If there is no short circuit, ($V_{REG} > V_{SD}$) then the voltage regulator remains on.

The regulator requires an external output bypass capacitor for stability. See Figure 2-1 for correct capacity and ESR for stable operation.

Note: A ceramic capacitor of at least 10 μF , or a tantalum capacitor of at least 2.2 μF is recommended for stability.

Warning: In worst-case scenarios, the ceramic capacitor may derate by 50%, based on tolerance, voltage and temperature. Therefore, in order to ensure stability, ceramic capacitors smaller than 10 μF may require a small series resistance to meet the ESR requirements, as shown in Table 1-4.

TABLE 1-4: RECOMMENDED SERIES RESISTANCE FOR CERAMIC CAPACITORS

| Resistance | Capacitor |
|---------------|-------------------|
| 1 Ω | 1 μF |
| 0.47 Ω | 2.2 μF |
| 0.22 Ω | 4.7 μF |
| 0.1 Ω | 6.8 μF |

FIGURE 1-8: VOLTAGE REGULATOR BLOCK DIAGRAM

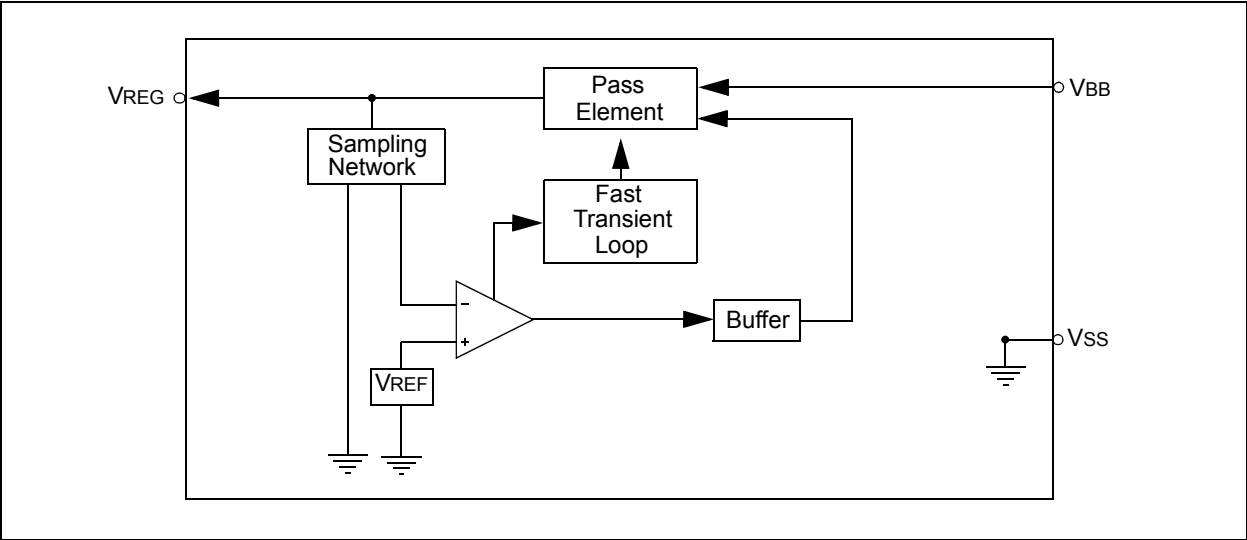
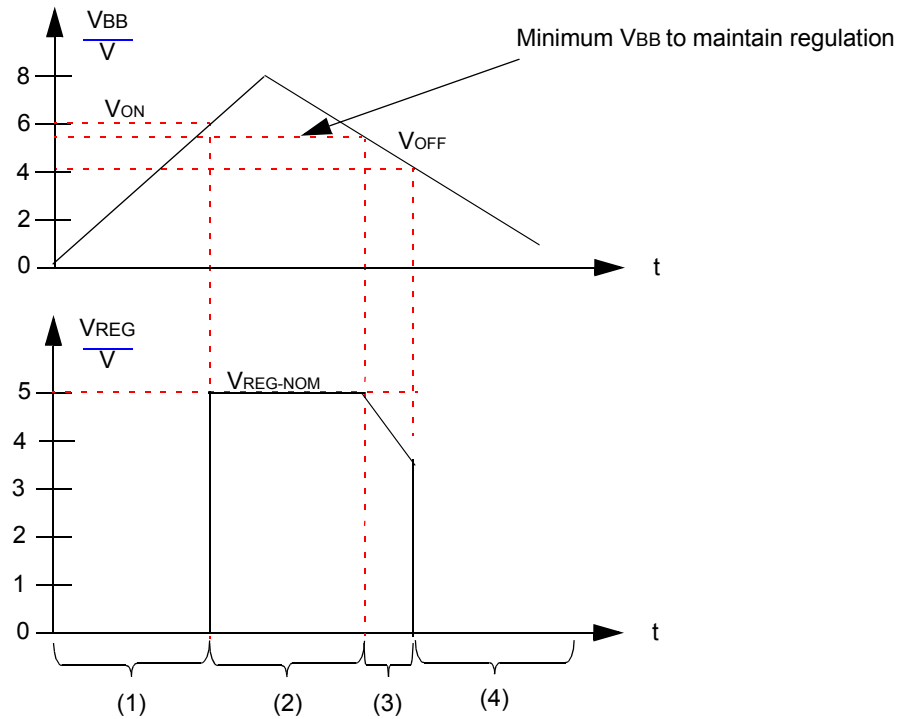
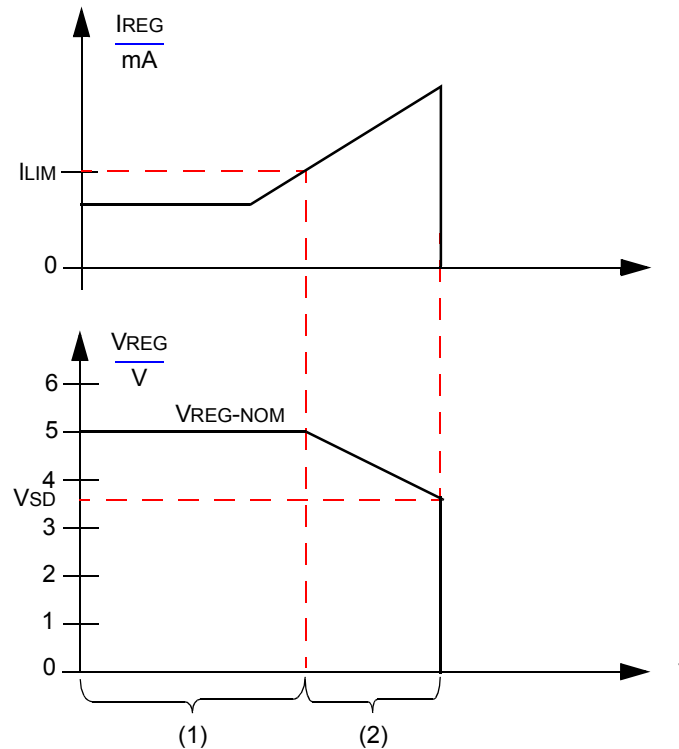


FIGURE 1-9: VOLTAGE REGULATOR OUTPUT ON POWER-ON RESET

- Note**
- 1: Start-Up, $V_{BB} < V_{ON}$, regulator off.
 - 2: $V_{BB} > V_{ON}$, regulator on.
 - 3: $V_{BB} \leq$ minimum V_{BB} to maintain regulation.
 - 4: $V_{BB} < V_{OFF}$, regulator will turn off.

FIGURE 1-10: VOLTAGE REGULATOR OUTPUT ON OVER CURRENT SITUATION



Note 1: I_{REG} less than I_{LIM} , regulator on.

2: After I_{REG} exceeds I_{LIM} , the voltage regulator output will be reduced until V_{SD} is reached.

1.6 Optional External Protection

1.6.1 REVERSE BATTERY PROTECTION

An external reverse-battery-blocking diode should be used to provide polarity protection (see [Figure 1-12](#)).

1.6.2 TRANSIENT VOLTAGE PROTECTION (LOAD DUMP)

An external 43V transient suppressor (TVS) diode, between V_{BB} and ground, with a transient protection resistor (RTP) in series with the battery supply and the V_{BB} pin protects the device from power transients and ESD events greater than 43V (see [Figure 1-12](#)). The maximum value for the RTP protection resistor depends on two parameters: the minimum voltage the part will start at, and the impacts of this RTP resistor on the V_{BB} value, thus on the Bus recessive level and slopes.

This leads to a set of three equations to fulfill.

[Equation 1-2](#) provides a max RTP value according to the minimum battery voltage the user wants the part to start at.

[Equation 1-3](#) provides a max RTP value according to the maximum error on the recessive level thus V_{BB} since the part uses V_{BB} as the reference value for the recessive level.

[Equation 1-4](#) provides a max RTP value according to the maximum relative variation the user can accept on the slope when I_{REG} varies.

Since both [Equation 1-2](#) and [Equation 1-3](#) must be fulfilled, the maximum allowed value for RTP is thus the smaller of the two values found when solving [Equation 1-2](#) and [Equation 1-3](#).

Usually [Equation 1-2](#) gives the higher constraint (smaller value) for RTP as shown in the following example where V_{BATmin} is 8V.

However, the user needs to check that the value found with [Equation 1-2](#) also fulfills [Equation 1-3](#) and [Equation 1-4](#).

While this protection is optional, it should be considered as good engineering practice.

EQUATION 1-2:

$$R_{TP} \leq \frac{V_{BATmin} - 5.5V}{250mA}$$

$$5.5V = V_{OFF} + 1.0V$$

250 mA is the peak current at power-on when $V_{BB} = 5.5V$

Assume $V_{BATMIN} = 8V$. Equation 1-2 shows 10Ω.

EQUATION 1-3:

$$R_{TP} \leq \frac{\Delta V_{RECESSIVE}}{I_{REGMAX}}$$

Where:

$\Delta V_{RECESSIVE}$ = Maximum variation tolerated on the recessive level

Assume $\Delta V_{RECESSIVE} = 1V$ and $I_{REGMAX} = 50\text{ mA}$. Equation 1-3 shows 20Ω.

EQUATION 1-4:

$$R_{TP} \leq \frac{\Delta Slope \times (V_{BATMIN} - 1V)}{I_{REGMAX}}$$

Where:

$\Delta Slope$ = Maximum variation tolerated on the slope level

I_{REGMAX} = Maximum current the current will provide to the load

$V_{BATMIN} > V_{OFF} + 1.0V$

Assume $\Delta Slope = 15\%$, $V_{BATMIN} = 8V$ and $I_{REGMAX} = 50\text{ mA}$. Equation 1-3 shows 20Ω.

1.6.3 CBAT CAPACITOR

Selecting $CBAT = 10 \times CREG$ is recommended. However, this leads to a high-value capacitor. Lower values for $CBAT$ capacitor can be used with respect to some rules. In any case, the voltage at the V_{BB} pin should remain above V_{OFF} when the device is turned on.

The current peak at start-up (due to the fast charge of the $CREG$ and $CBAT$ capacitors) may induce a significant drop on the V_{BB} pin. This drop is proportional to the impedance of the V_{BAT} connection (see Figure 1-12).

The V_{BAT} connection is mainly inductive and resistive. Therefore, it can be modeled as a resistor (R_{TOT}) in series with an inductor (L). R_{TOT} and L can be measured.

The following formula gives an indication of the minimum value of $CBAT$ using R_{TOT} and L :

EQUATION 1-5:

$$\frac{C_{BAT}}{C_{REG}} = \sqrt{\frac{100L^2 + R_{TOT}^2}{1 + L^2 + \frac{R_{TOT}^2}{100}}}$$

Where:

L = Inductor (measured in mH)

$R_{TOT} = R_{LINE} + R_{TP}$ (measured in Ω)

Equation 1-5 allows lower $CBAT/CREG$ values than the 10x ratio we recommend.

Assume that we have a good quality V_{BAT} connection with $R_{TOT} = 0.1\Omega$ and $L = 0.1\text{ mH}$.

Solving the equation gives $CBAT/CREG = 1$.

If we increase R_{TOT} up to 1Ω, the result becomes $CBAT/CREG = 1.4$. However, if the connection is highly resistive or highly inductive (poor connection), the $CBAT/CREG$ ratio greatly increases.

TABLE 1-5: CBAT/CREG RATIO BY VBAT CONNECTION TYPE

| Connection Type | R_{TOT} | L | $CBAT/CREG$ Ratio |
|------------------|-----------|--------|-------------------|
| Good | 0.1Ω | 0.1 mH | 1 |
| Typical | 1Ω | 0.1 mH | 1.4 |
| Highly inductive | 0.1Ω | 1 mH | 7 |
| Highly resistive | 10Ω | 0.1 mH | 7 |

Figure 1-11 shows the minimum recommended $CBAT/CREG$ ratio as a function of the impedance of the V_{BAT} connection.

FIGURE 1-11: MINIMUM RECOMMENDED CBAT/CREG RATIO

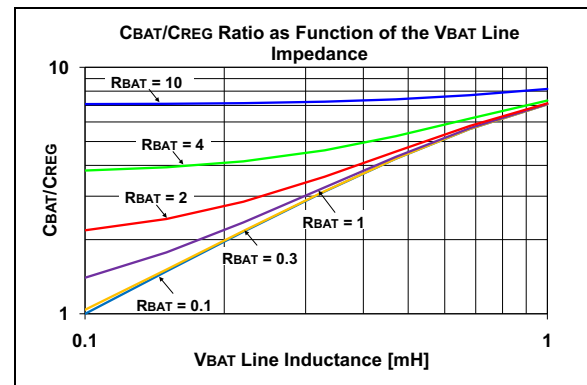
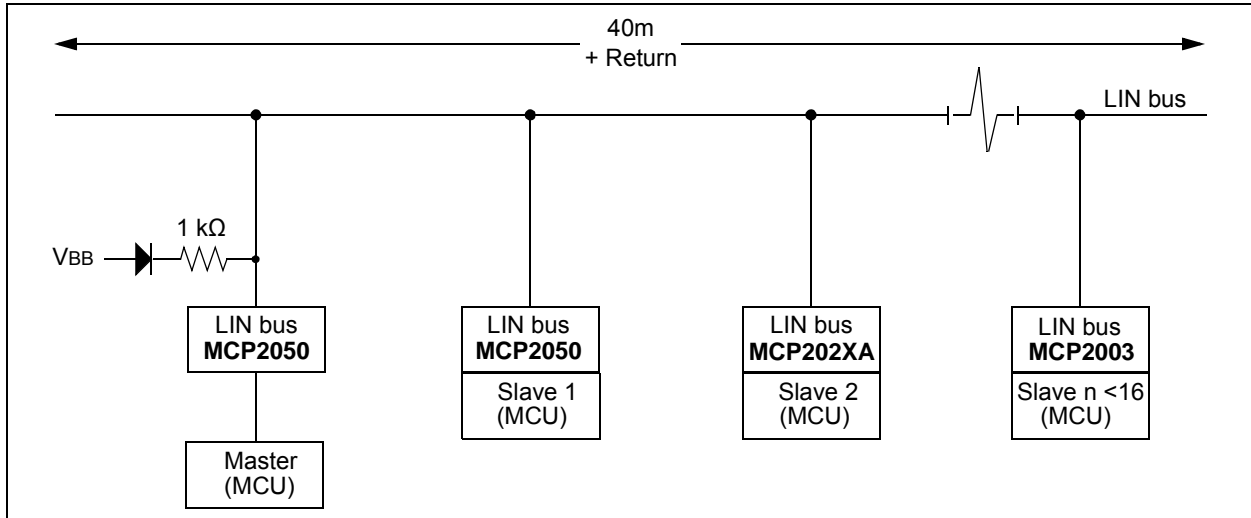


FIGURE 1-13: TYPICAL LIN NETWORK CONFIGURATION



1.8 ICSP™ Considerations

The following should be considered when the MCP2050 is connected to pins supporting in-circuit programming:

- Power used for programming the microcontroller can be supplied from the programmer, or from the MCP2050.
- The voltage on the VREG pin should not exceed the maximum value of VREG as shown in [Section 2.3, DC Specifications](#).

MCP2050

2.0 ELECTRICAL CHARACTERISTICS

2.1 Absolute Maximum Ratings†

| | |
|---|---------------------------------|
| V _{IN} DC Voltage on RXD, and $\overline{\text{RESET}}$ | -0.3V to V _{REG} + 0.3 |
| V _{IN} DC Voltage on TXD, CS/LWAKE, $\overline{\text{FAULT}}$ /TXE | -0.3 to + 40V |
| V _{BB} Battery Voltage, continuous, non-operating (Note 1) | -0.3 to + 40V |
| V _{BB} Battery Voltage, non-operating (LIN bus recessive, no regulator load, t < 60s) (Note 2) | -0.3 to + 43V |
| V _{BB} Battery Voltage, transient ISO 7637 Test 1 | -100V |
| V _{BB} Battery Voltage, transient ISO 7637 Test 2a | +75V |
| V _{BB} Battery Voltage, transient ISO 7637 Test 3a | -150V |
| V _{BB} Battery Voltage, transient ISO 7637 Test 3b | +100V |
| V _{LBUS} Bus Voltage, continuous | -18 to + 30V |
| V _{LBUS} Bus Voltage, transient (Note 3) | -27 to + 43V |
| I _{LBUS} Bus Short-Circuit Current Limit | 200 mA |
| ESD protection on LIN, V _{BB} (IEC 61000-4-2) (Note 4) | ±15 KV |
| ESD protection on LIN, V _{BB} (Human Body Model) (Note 5) | ±8 KV |
| ESD protection on all other pins (Human Body Model) (Note 5) | ±4 KV |
| ESD protection on all pins (Charge Device Model) (Note 6) | ±1500V |
| ESD protection on all pins (Machine Model) (Note 7) | ±200V |
| Maximum Junction Temperature | 150°C |
| Storage Temperature | -65 to + 150°C |

† **NOTICE:** Stresses above those listed under “Maximum Ratings” may cause permanent damage to the device. This is a stress rating only and functional operation of the device at those or any other conditions above those indicated in the operational listings of this specification is not implied. Exposure to maximum rating conditions for extended periods may affect device reliability.

Note 1: LIN 2.x compliant specification.

2: SAE J2602-2 compliant specification.

3: ISO 7637/1 load dump compliant (t < 500 ms).

4: According to IEC 61000-4-2, 330 ohm, 150 pF and Transceiver EMC Test Specifications [2] to [4]

5: According to AEC-Q100-002/JESD22-A114

6: According to AEC-Q100-011B

7: According to AEC-Q100-003/JESD22-A115

2.2 Nomenclature used in this document

Some terms and names used in this data sheet deviate from those referred to in the LIN specifications. Equivalent values are shown below.

| LIN 2.1 Name | Term used in the following tables | Definition |
|--------------|-----------------------------------|------------------------------|
| VBAT | <i>not used</i> | ECU operating voltage |
| VSUP | V _{BB} | Supply voltage at device pin |
| VBUS_LIM | ISC | Current Limit of Driver |
| VBUSREC | V _{IH} (LBUS) | Recessive state |
| VBUSDOM | V _{IL} (LBUS) | Dominant state |

2.3 DC Specifications

| DC Specifications | | Electrical Characteristics: Unless otherwise indicated, all limits are specified for: V _{BB} = 6.0V to 18.0V, T _A = -40°C to +125°C C _{REG} = 10 µF | | | | |
|---|----------|---|------|------|-------|---|
| Parameter | Sym. | Min. | Typ. | Max. | Units | Conditions |
| Power | | | | | | |
| V _{BB} Quiescent Operating Current | IBBQ | — | — | 200 | µA | I _{OUT} = 0 mA, L _{BUS} recessive, V _{REG} = 5.0V |
| | | — | — | 200 | µA | I _{OUT} = 0 mA, L _{BUS} recessive, V _{REG} = 3.3V |
| V _{BB} Quiescent Operating Current with Watchdog Enabled | IBBQWDT | — | — | 250 | µA | I _{OUT} = 0 mA, L _{BUS} recessive, V _{REG} = 5.0V |
| | | | | 250 | | I _{OUT} = 0 mA, L _{BUS} recessive, V _{REG} = 3.3V |
| V _{BB} READY Current | IBBRD | — | — | 100 | µA | I _{OUT} = 0 mA, L _{BUS} recessive, V _{REG} = 5.0V |
| | | — | — | 100 | µA | I _{OUT} = 0 mA, L _{BUS} recessive, V _{REG} = 3.3V |
| V _{BB} Ready Current WWDT Enabled | IBBRDWDT | — | — | 150 | µA | With voltage regulator on, transmitter off, receiver on, FAULT/T _{XE} = V _{IL} , CS = V _{IH} , V _{REG} = 5.0V |
| | | | | 150 | | With voltage regulator on, transmitter off, receiver on, FAULT/T _{XE} = V _{IL} , CS = V _{IH} , V _{REG} = 3.3V |
| V _{BB} Transmitter-Off Current with Watchdog Disabled | IBBTO | — | — | 100 | µA | With voltage regulator on, transmitter off, receiver on, FAULT/T _{XE} = V _{IL} , CS = V _{IH} , V _{REG} = 5.0V |
| | | — | — | 100 | µA | With voltage regulator on, transmitter off, receiver on, FAULT/T _{XE} = V _{IL} , CS = V _{IH} , V _{REG} = 3.3V |
| V _{BB} Power-Down Current | IBBPD | — | 4.5 | 8 | µA | With voltage regulator powered-off, receiver on and transmitter off, FAULT/T _{XE} = V _{IH} , T _{XD} = V _{IH} , CS = V _{IL}) |
| V _{BB} Current with V _{SS} Floating | IBBNOGND | -1 | — | 1 | mA | V _{BB} = 12V, GND to V _{BB} , V _{LIN} = 0-18V |

- Note 1:** Internal current limited. 2.0 ms maximum recovery time (R_{LBUS} = 0Ω, T_x = 0, V_{LBUS} = V_{BB}).
- 2:** Characterized, not 100% tested.
- 3:** In Power-Down mode, normal LIN recessive/dominant threshold is disabled; V_{WK}(L_{BUS}) is used to detect bus activities.

MCP2050

2.3 DC Specifications (Continued)

| DC Specifications | | Electrical Characteristics: Unless otherwise indicated, all limits are specified for: $V_{BB} = 6.0V$ to $18.0V$, $T_A = -40^{\circ}C$ to $+125^{\circ}C$ $C_{REG} = 10 \mu F$ | | | | |
|--|-------------|--|------|-----------------|---------|--|
| Parameter | Sym. | Min. | Typ. | Max. | Units | Conditions |
| Microcontroller Interface | | | | | | |
| High-Level Input Voltage (T_{XD} , $FAULT/T_{XE}$, $WWDTTTRIG$) | V_{IH} | 2.0 | — | $V_{REG} + 0.3$ | V | |
| Low-Level Input Voltage (T_{XD} , $FAULT/T_{XE}$, $WWDTTTRIG$) | V_{IL} | -0.3 | — | 0.8 | V | |
| High-Level Input Current (T_{XD} , $FAULT/T_{XE}$, $WWDTTTRIG$) | I_{IH} | -2.5 | — | 0.4 | μA | Input voltage = 4.0V. ~800 k Ω internal adaptive pull-up |
| Low-Level Input Current (T_{XD} , $FAULT/T_{XE}$, $WWDTTTRIG$) | I_{IL} | -10 | — | — | μA | Input voltage = 0.5V. ~800 k Ω internal adaptive pull-up |
| High-Level Input Voltage ($CS/LWAKE$) | V_{IH} | 2.0 | — | V_{BB} | V | Through a current-limiting resistor |
| Low-Level Input Voltage ($CS/LWAKE$) | V_{IL} | -0.3 | — | 0.8 | V | |
| High-Level Input Current ($CS/LWAKE$) | I_{IH} | — | — | 8.0 | μA | Input voltage = $0.8V_{REG}$ ~1.3 M Ω internal pull-down to V_{SS} |
| Low-Level Input Current ($CS/LWAKE$) | I_{IL} | — | — | 5.0 | μA | Input voltage = $0.2V_{REG}$ ~1.3 M Ω internal pull-down to V_{SS} |
| Low-Level Output Voltage (R_{XD}) | V_{OLRXD} | — | — | $0.2V_{REG}$ | V | $I_{OL} = 2 \text{ mA}$ |
| High-Level Output Voltage (R_{XD}) | V_{OHRXD} | $0.8V_{REG}$ | — | — | V | $I_{OH} = 2 \text{ mA}$ |
| Low-Level Output Voltage ($FAULT/T_{XE}$) | V_{OLOD} | — | — | 1.0 | V | $I_{OL} = 4 \text{ mA}$ |
| Low-Level Output Voltage ($RESET$) | V_{OLRST} | — | — | 1.0 | V | $I_{OL} = 4 \text{ mA}$ |

Note 1: Internal current limited. 2.0 ms maximum recovery time ($R_{LBUS} = 0\Omega$, $T_x = 0$, $V_{LBUS} = V_{BB}$).

2: Characterized, not 100% tested.

3: In Power-Down mode, normal LIN recessive/dominant threshold is disabled; $V_{WK}(LBUS)$ is used to detect bus activities.

2.3 DC Specifications (Continued)

| DC Specifications | Electrical Characteristics: | | | | | |
|--|--|-----------------------|------------------------|-----------------------|-------|--|
| | Unless otherwise indicated, all limits are specified for: V _{BB} = 6.0V to 18.0V, T _A = -40°C to +125°C C _{REG} = 10 µF | | | | | |
| Parameter | Sym. | Min. | Typ. | Max. | Units | Conditions |
| Bus Interface | | | | | | |
| High-Level Input Voltage | V _{IH} (LBUS) | 0.6 V _{BB} | — | — | V | Recessive state |
| Low-Level Input Voltage | V _{IL} (LBUS) | -8 | — | 0.4 V _{BB} | V | Dominant state |
| Input Hysteresis | V _{HYS} | — | — | 0.175 V _{BB} | V | V _{IH} (LBUS) – V _{IL} (LBUS) |
| Low-Level Output Current | I _{OL} (LBUS) | 40 | — | 200 | mA | Output voltage = 0.1 V _{BB} , V _{BB} = 12V |
| Pull-Up Current on Input | I _{PU} (LBUS) | -180 | — | -72 | µA | ~30 kΩ internal pull-up @ V _{IH} (LBUS) = 0.7 V _{BB} , V _{BB} =12V |
| Short-Circuit Current Limit | I _{SC} | 50 | — | 200 | mA | (Note 1) |
| High-Level Output Voltage | V _{OH} (LBUS) | 0.8 V _{BB} | — | V _{BB} | V | |
| Driver Dominant Voltage | V _{LOSUP} | — | — | 1.1 | V | V _{BB} = 7.3V, R _{LOAD} = 1000Ω |
| Driver Dominant Voltage | V _{HISUP} | — | — | 1.2 | V | V _{BB} = 18V, R _{LOAD} = 1000Ω |
| Input Leakage Current (at the receiver during dominant bus level) | I _{BUS_PAS_} DOM | -1 | — | — | mA | Driver off, V _{BUS} = 0V, V _{BB} = 12V |
| Input Leakage Current (at the receiver during recessive bus level) | I _{BUS_PAS_} REC | -20 | — | 20 | µA | Driver off, 8V < V _{BB} < 18V 8V < V _{BUS} < 18V V _{BUS} ≥ V _{BB} |
| Leakage Current (disconnected from ground) | I _{BUS_NO_G} ND | -10 | — | +10 | µA | GND _{DEVICE} = V _{BB} , 0V < V _{BUS} < 18V, V _{BB} = 12V |
| Leakage Current (disconnected from V _{BB}) | I _{BUS_NO_P} WR | -10 | — | +10 | µA | V _{BB} = GND, 0 < V _{BUS} < 18V |
| Receiver Center Voltage | V _{BUS_CNT} | 0.475 V _{BB} | 0.5 V _{BB} | 0.525 V _{BB} | V | V _{BUS_CNT} = (V _{IL} (LBUS) + V _{IH} (LBUS))/2 |
| Slave Termination | R _{SLAVE} | 20 | 30 | 47 | kΩ | (Note 2) |
| Capacitance of slave node | C _{SLAVE} | | | 50 | pF | (Note 2) |
| Wake-Up Voltage Threshold on LIN Bus | V _{WK} (LBUS) | — | — | 3.4 | V | Wake up from Power- Down mode (Note 3) |

Note 1: Internal current limited. 2.0 ms maximum recovery time (R_{LBUS} = 0Ω, T_x = 0, V_{LBUS} = V_{BB}).

2: Characterized, not 100% tested.

3: In Power-Down mode, normal LIN recessive/dominant threshold is disabled; V_{WK}(LBUS) is used to detect bus activities.

MCP2050

2.3 DC Specifications (Continued)

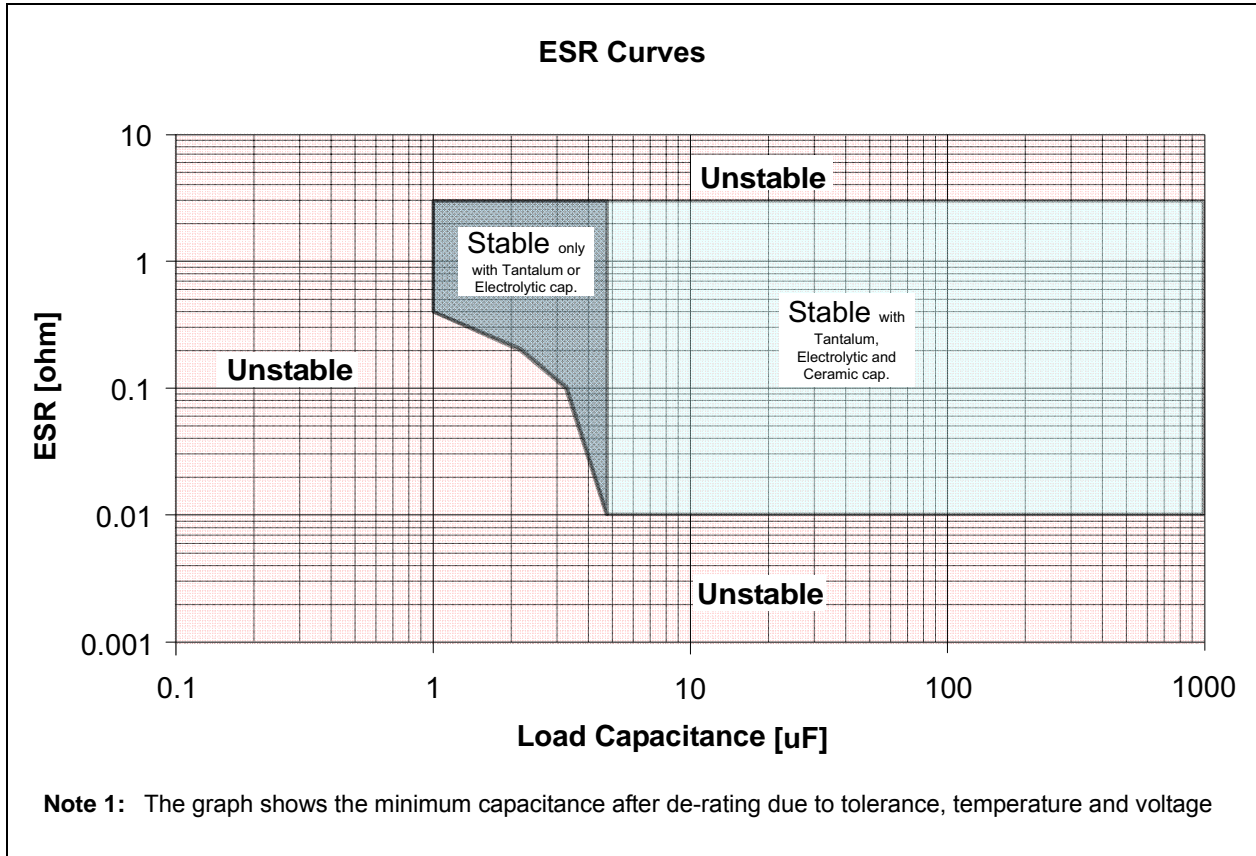
| DC Specifications | | Electrical Characteristics: Unless otherwise indicated, all limits are specified for: $V_{BB} = 6.0V$ to $18.0V$, $T_A = -40^{\circ}C$ to $+125^{\circ}C$ $C_{REG} = 10 \mu F$ | | | | |
|----------------------------------|-------------------|--|------|------|---------------------------|---|
| Parameter | Sym. | Min. | Typ. | Max. | Units | Conditions |
| Voltage Regulator – 5.0V | | | | | | |
| Output Voltage Range | V_{REG} | 4.85 | 5.00 | 5.15 | V | $0 \text{ mA} < I_{OUT} < 70 \text{ mA}$ |
| Line Regulation | ΔV_{OUT1} | — | 10 | 50 | mV | $I_{OUT} = 1 \text{ mA}$, $6.0V < V_{BB} < 18V$ |
| Load Regulation | ΔV_{OUT2} | — | 10 | 50 | mV | $5 \text{ mA} < I_{OUT} < 70 \text{ mA}$ $6.0V < V_{BB} < 12V$ |
| Power Supply Ripple Reject | PSRR | — | — | 50 | dB | $1 V_{PP}$ @10-20 kHz $I_{LOAD} = 20 \text{ mA}$ |
| Output Noise Voltage | eN | — | — | 100 | μV_{RMS} | 10 Hz – 40 MHz $C_{FILTER} = 10 \mu f$, $C_{BP} = 0.1 \mu f$, $I_{LOAD} = 20 \text{ mA}$ |
| Shutdown Voltage Threshold | V_{SD} | 3.5 | — | 4.0 | V | See Figure 1-10 (Note 2) |
| Input Voltage to Turn Off Output | V_{OFF} | 3.9 | — | 4.5 | V | |
| Input Voltage to Turn On Output | V_{ON} | 5.25 | — | 6.0 | V | |
| Voltage Regulator – 3.3V | | | | | | |
| Output Voltage | V_{REG} | 3.20 | 3.30 | 3.40 | V | $0 \text{ mA} < I_{OUT} < 70 \text{ mA}$ |
| Line Regulation | ΔV_{OUT1} | — | 10 | 50 | mV | $I_{OUT} = 1 \text{ mA}$, $6.0V < V_{BB} < 18V$ |
| Load Regulation | ΔV_{OUT2} | — | 10 | 50 | mV | $5 \text{ mA} < I_{OUT} < 70 \text{ mA}$, $6.0V < V_{BB} < 12V$ |
| Power Supply Ripple Reject | PSRR | — | — | 50 | dB | $1 V_{PP}$ @10-20 kHz, $I_{LOAD} = 20 \text{ mA}$ |
| Output Noise Voltage | eN | — | — | 100 | $\mu V_{RMS} / \sqrt{Hz}$ | 10 Hz – 40 MHz $C_{FILTER} = 10 \mu f$, $C_{BP} = 0.1 \mu f$, $I_{LOAD} = 20 \text{ mA}$ |
| Shutdown Voltage | V_{SD} | 2.5 | — | 2.7 | V | See Figure 1-10 (Note 2) |

Note 1: Internal current limited. 2.0 ms maximum recovery time ($R_{LBUS} = 0\Omega$, $T_x = 0$, $V_{LBUS} = V_{BB}$).

2: Characterized, not 100% tested.

3: In Power-Down mode, normal LIN recessive/dominant threshold is disabled; $V_{WK}(LBUS)$ is used to detect bus activities.

FIGURE 2-1: ESR CURVES FOR LOAD CAPACITOR SELECTION



MCP2050

2.4 AC Specifications

| AC CHARACTERISTICS | | Electrical Characteristics: Unless otherwise indicated, all limits are specified for $V_{BB} = 6.0V$ to $18.0V$; $T_A = -40^{\circ}C$ to $+125^{\circ}C$ | | | | |
|---|----------------|---|------|-------|---------|--|
| Parameter | Sym. | Min. | Typ. | Max. | Units | Test Conditions |
| Bus Interface - Constant Slope Time Parameters (DC specifications are for a V_{BB} range of 6.0 to 18.0V) | | | | | | |
| Slope Rising and Falling Edges | t_{SLOPE} | 3.5 | — | 22.5 | μs | $7.3V \leq V_{BB} \leq 18V$ |
| Propagation Delay of Transmitter | $t_{TRANSPD}$ | — | — | 5.0 | μs | $t_{TRANSPD} = \max(t_{TRANSPDR} \text{ or } t_{TRANSPDF})$ |
| Propagation Delay of Receiver | t_{RECPD} | — | — | 6.0 | μs | $t_{RECPD} = \max(t_{RECPDR} \text{ or } t_{RECPDF})$ |
| Symmetry of Propagation Delay of Receiver Rising Edge w.r.t. Falling Edge | t_{RECSYM} | -2.0 | — | 2.0 | μs | $t_{recsym} = \max(t_{RECPDF} - t_{RECPDR})$ RRXD 2.4 k Ω to V_{CC} , CRXD 20pF |
| Symmetry of Propagation Delay of Transmitter Rising Edge w.r.t. Falling Edge | $t_{TRANSSYM}$ | -2.0 | — | 2.0 | μs | $t_{transsym} = \max(t_{TRANSPDF} - t_{TRANSPDR})$ |
| Bus Dominant Time-Out Time | $t_{TO(LIN)}$ | — | 25 | — | mS | |
| Time to Sample of FAULT/TXE for Bus Conflict Reporting | t_{FAULT} | — | — | 32.5 | μs | $t_{FAULT} = \max(t_{TRANSPD} + t_{SLOPE} + t_{RECPD})$ |
| Duty Cycle 1 @ 20.0 kbit/sec | | 0.396 | — | — | %tBIT | CBUS;RBUS conditions: 1 nF; 1 k Ω 6.8 nF; 660 Ω 10 nF; 500 Ω $TH_{REC}(MAX) = 0.744 \times V_{BB}$, $TH_{DOM}(MAX) = 0.581 \times V_{BB}$, $V_{BB} = 7.0V - 18V$; tBIT = 50 μs . $D1 = t_{BUS_REC}(MIN) / 2 \times t_{BIT}$ |
| Duty Cycle 2 @ 20.0 kbit/sec | | — | — | 0.581 | %tBIT | CBUS;RBUS conditions: 1 nF; 1 k Ω 6.8 nF; 660 Ω 10 nF; 500 Ω $TH_{REC}(MAX) = 0.284 \times V_{BB}$, $TH_{DOM}(MAX) = 0.422 \times V_{BB}$, $V_{BB} = 7.6V - 18V$; tBIT = 50 μs . $D2 = t_{BUS_REC}(MAX) / 2 \times t_{BIT}$ |
| Duty Cycle 3 @ 10.4 kbit/sec | | 0.417 | — | — | %tBIT | CBUS;RBUS conditions: 1 nF; 1 k Ω 6.8 nF; 660 Ω 10 nF; 500 Ω $TH_{REC}(MAX) = 0.778 \times V_{BB}$, $TH_{DOM}(MAX) = 0.616 \times V_{BB}$, $V_{BB} = 7.0V - 18V$; tBIT = 96 μs . $D3 = t_{BUS_REC}(MIN) / 2 \times t_{BIT}$ |
| Duty Cycle 4 @ 10.4 kbit/sec | | — | — | 0.590 | %tBIT | CBUS;RBUS conditions: 1 nF; 1 k Ω 6.8 nF; 660 Ω 10 nF; 500 Ω $TH_{REC}(MAX) = 0.251 \times V_{BB}$, $TH_{DOM}(MAX) = 0.389 \times V_{BB}$, $V_{BB} = 7.6V - 18V$; tBIT = 96 μs . $D4 = t_{BUS_REC}(MAX) / 2 \times t_{BIT}$ |

2.4 AC Specifications (Continued)

| AC CHARACTERISTICS | | Electrical Characteristics: Unless otherwise indicated, all limits are specified for $V_{BB} = 6.0V$ to $18.0V$; $T_A = -40^{\circ}C$ to $+125^{\circ}C$ | | | | |
|---|----------------|---|------|------|---------|--|
| Parameter | Sym. | Min. | Typ. | Max. | Units | Test Conditions |
| Voltage Regulator | | | | | | |
| Bus Activity Debounce time | t_{BDB} | 30 | 80 | 250 | μs | |
| Bus Activity to Voltage Regulator Enabled | $t_{BACTIVE}$ | 35 | — | 200 | μs | |
| Voltage Regulator Enabled to Ready | t_{VEVR} | 300 | — | 1200 | μs | (Note 1) |
| Chip Select to Ready Mode | t_{CSR} | — | — | 230 | μs | |
| Chip Select to Power-Down | t_{CSPD} | — | — | 300 | μs | (Note 2) |
| Short-Circuit to Shutdown | $t_{SHUTDOWN}$ | 20 | — | 100 | μs | |
| RESET Timing | | | | | | |
| VREG OK detect to \overline{RESET} inactive | t_{RPU} | — | — | 60.0 | μs | |
| VREG not OK detect to \overline{RESET} active | t_{RPD} | — | — | 60.0 | μs | |
| WWDT | | | | | | |
| Reset Pulse Length | t_{WDRST} | — | 150 | — | μs | -40/+100% |
| Power-Up Watchdog Window Length | $t_{POWERUP}$ | — | 27.2 | — | ms | $\pm 15\%$ RWWDTSELECT = 33 k Ω (Note 2, Note 3) |
| Watchdog Window Length | $t_{WLENGTH}$ | 5.95 | 7 | 8.05 | ms | $\pm 15\%$ RWWDTSELECT = 33 k Ω (Note 4, Note 5) |
| | | 102 | 120 | 138 | ms | $\pm 15\%$ RWWDTSELECT = 680 k Ω (Note 4, Note 5) |

Note 1: Time depends on external capacitance and load. Test condition: $C_{REG} = 4.7\mu F$, no resistor load.

2: Characterized, not 100% tested.

3: $t_{POWERUP} = 0.8 \text{ ms} \times (\text{RWWDTSELECT} + 1)$; R in k Ω .

4: $t_{WLENGTH} = (0.175 \text{ ms} \times \text{RWWDTSELECT}) + 1.2 \pm 15\%$; R in k Ω .

5: Characterized; tested for RWWDTSELECT = 33 k Ω and 680 k Ω

2.5 Thermal Specifications

| Parameter | Symbol | Typ | Max | Units | Test Conditions |
|------------------------------------|---------------------|------|-----|---------------|-----------------|
| Recovery Temperature | $\theta_{RECOVERY}$ | +140 | — | $^{\circ}C$ | |
| Shutdown Temperature | $\theta_{SHUTDOWN}$ | +150 | — | $^{\circ}C$ | |
| Short Circuit Recovery Time | t_{THERM} | 1.5 | 5.0 | ms | |
| Thermal Package Resistances | | | | | |
| Thermal Resistance, 14L-PDIP | θ_{JA} | 70 | — | $^{\circ}C/W$ | |
| Thermal Resistance, 14L-SOIC | θ_{JA} | 90.8 | — | $^{\circ}C/W$ | |
| Thermal Resistance, 20L-QFN | θ_{JA} | 44.6 | — | $^{\circ}C/W$ | |

Note 1: The maximum power dissipation is a function of T_{JMAX} , θ_{JA} and ambient temperature T_A . The maximum allowable power dissipation at an ambient temperature is $P_D = (T_{JMAX} - T_A) \theta_{JA}$. If this dissipation is exceeded, the die temperature will rise above $150^{\circ}C$ and the MCP2050 will go into thermal shutdown.

MCP2050

2.6 Typical Performance Curves

Note: The graphs and tables provided following this note are a statistical summary based on a limited number of samples and are provided for informational purposes only. The performance characteristics listed herein are not tested or guaranteed. In some graphs or tables, the data presented may be outside the specified operating range (e.g., outside specified power supply range) and therefore outside the warranted range.

Note: Unless otherwise indicated, $V_{BB} = 6.0V$ to $18.0V$; $T_A = -40^{\circ}C$ to $+125^{\circ}C$

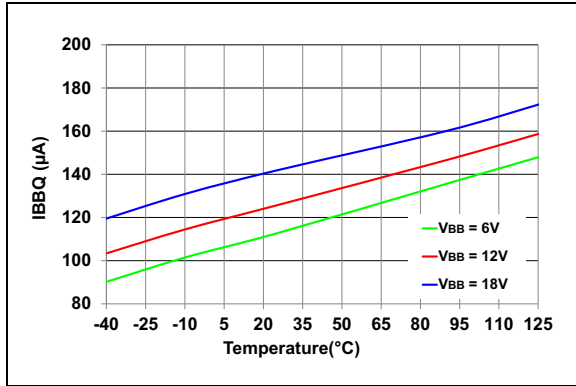


FIGURE 2-2: Typical $IBBQ$ vs. Temperature – 5.0V.

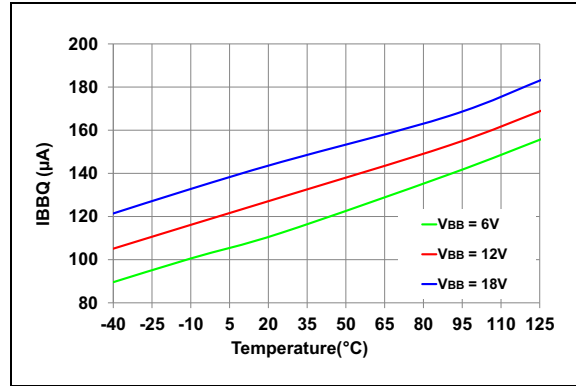


FIGURE 2-5: Typical $IBBQ$ vs. Temperature – 3.3V.

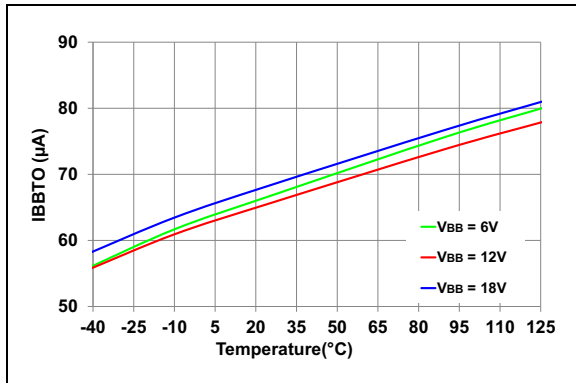


FIGURE 2-3: Typical $IBBTO$ vs. Temperature – 5.0V.

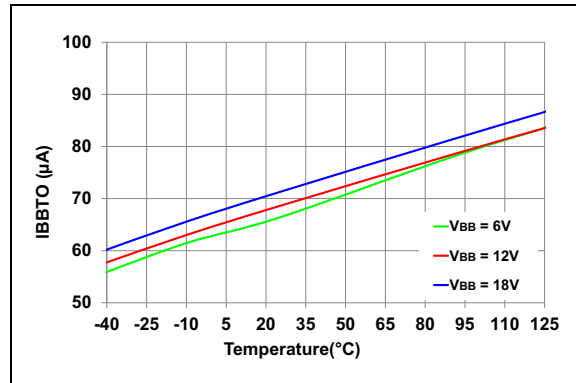


FIGURE 2-6: Typical $IBBTO$ vs. Temperature – 3.3V.

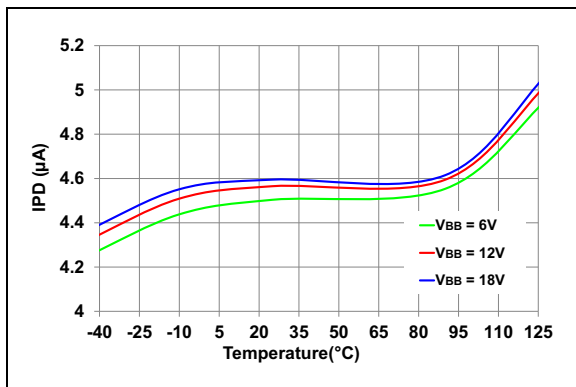


FIGURE 2-4: Typical IPD vs. Temperature – 5.0V.

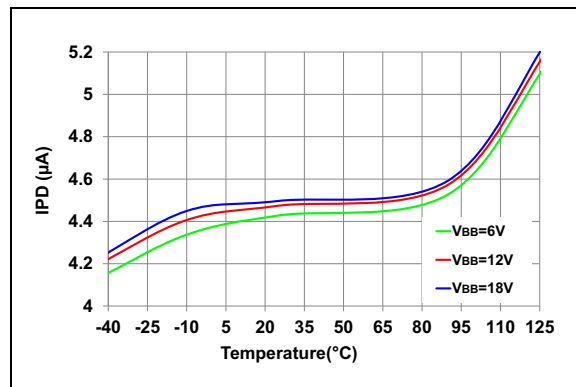


FIGURE 2-7: Typical IPD vs. Temperature – 3.3V.

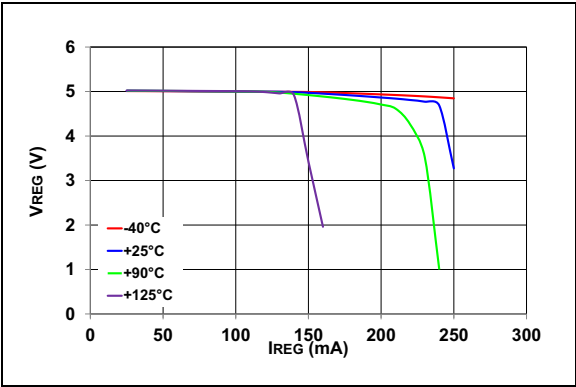


FIGURE 2-8: 5.0 VREG vs. IREG at VBB = 12V.

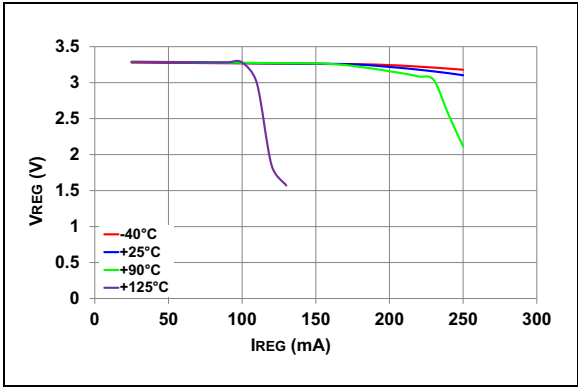


FIGURE 2-9: 3.3V VREG vs. IREG at VBB = 12V.

2.7 Timing Diagrams and Specifications

FIGURE 2-10: BUS TIMING DIAGRAM

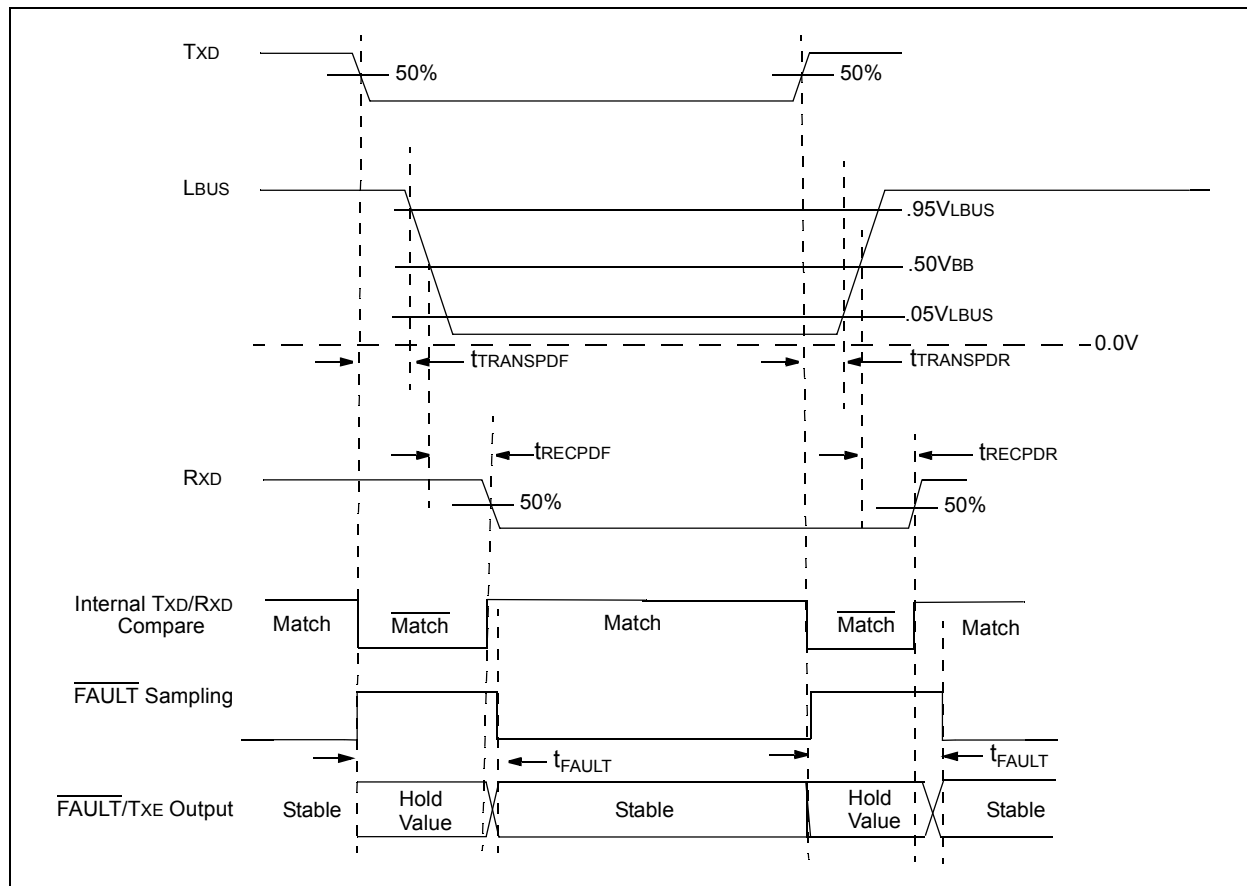


FIGURE 2-11: REGULATOR BUS WAKE TIMING DIAGRAM

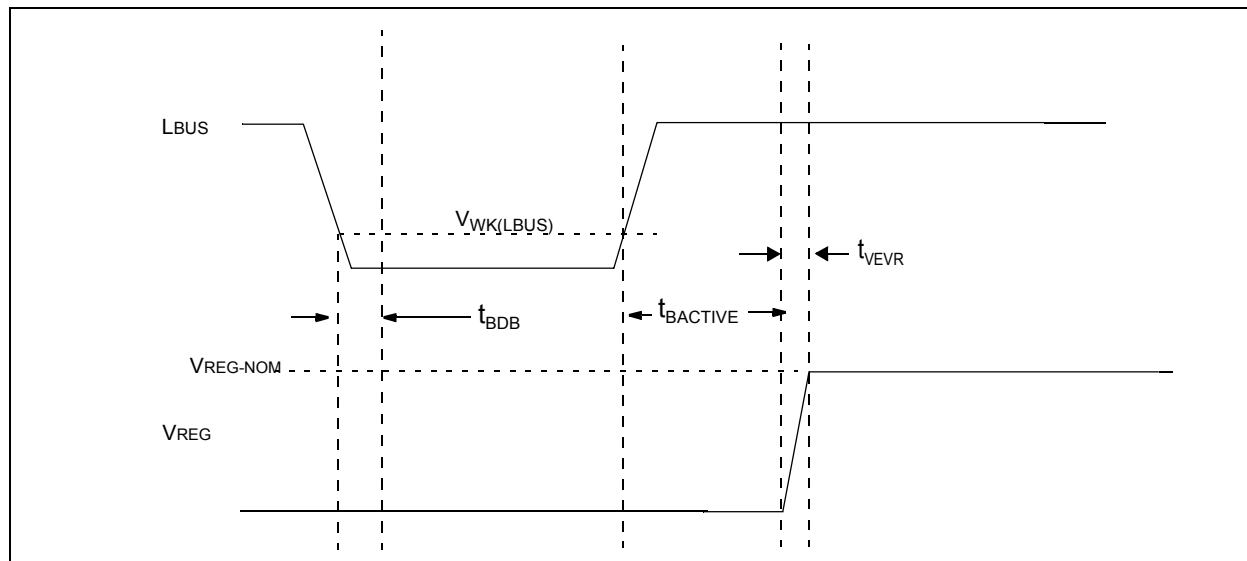
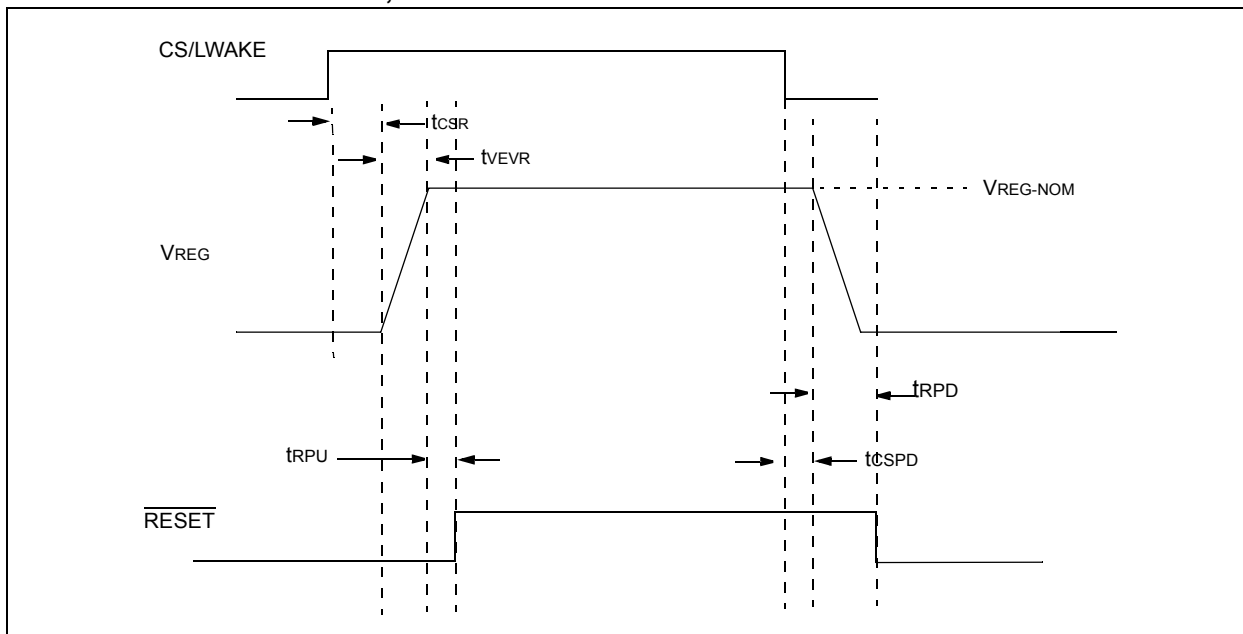


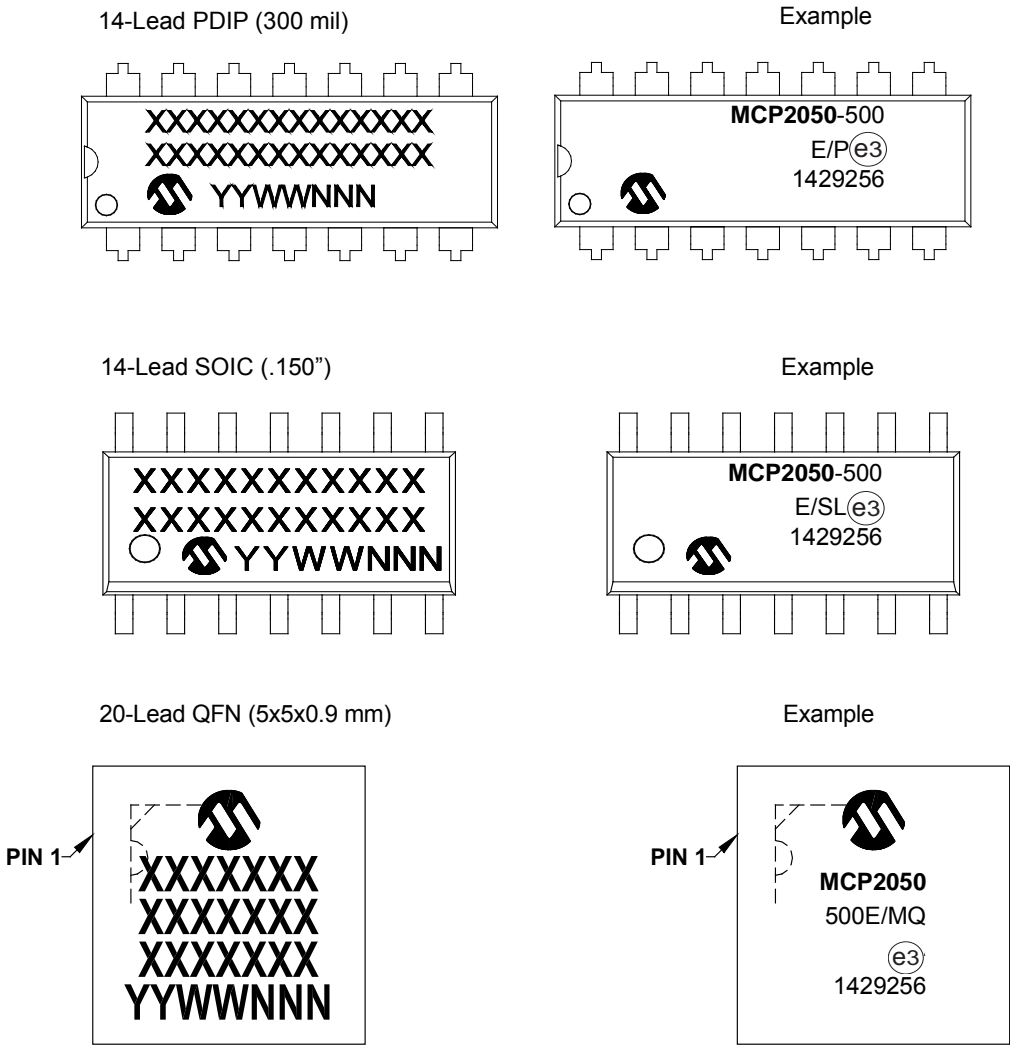
FIGURE 2-12: CS/LWAKE, REGULATOR AND RESET TIMING DIAGRAM



MCP2050

3.0 PACKAGING INFORMATION

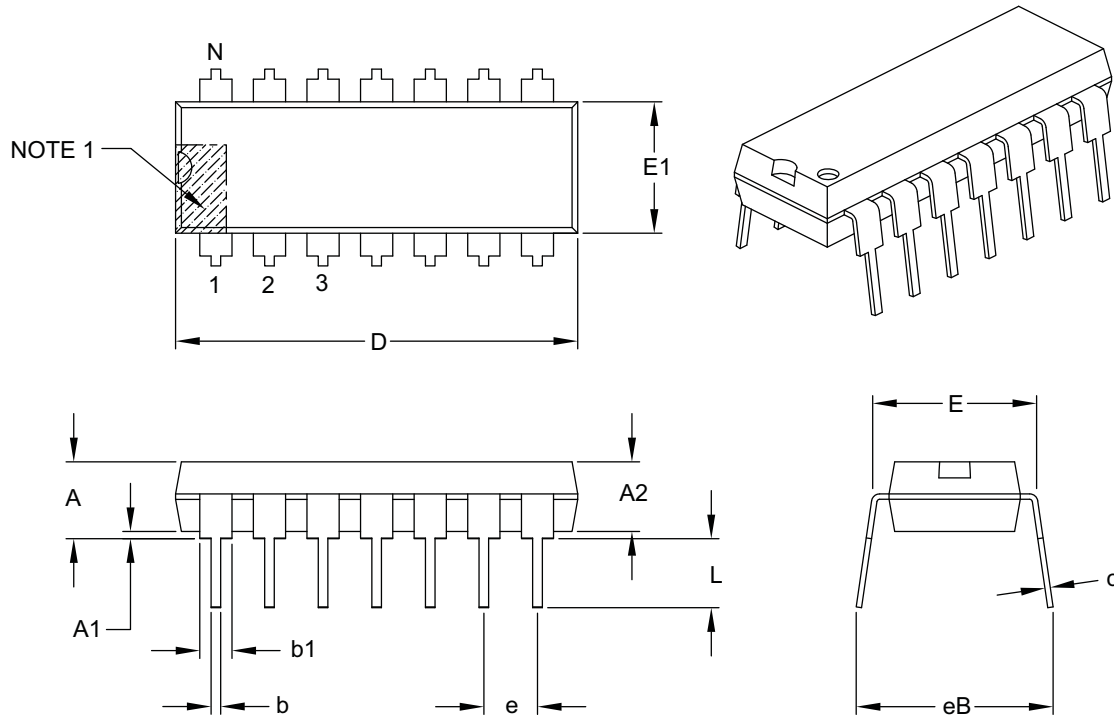
3.1 Package Marking Information



| | | |
|----------------|---|--|
| Legend: | XX...X | Customer-specific information |
| | Y | Year code (last digit of calendar year) |
| | YY | Year code (last 2 digits of calendar year) |
| | WW | Week code (week of January 1 is week '01') |
| | NNN | Alphanumeric traceability code |
| | (e3) | Pb-free JEDEC® designator for Matte Tin (Sn) |
| | * | This package is Pb-free. The Pb-free JEDEC designator (e3) can be found on the outer packaging for this package. |
| Note: | In the event the full Microchip part number cannot be marked on one line, it will be carried over to the next line, thus limiting the number of available characters for customer-specific information. | |

14-Lead Plastic Dual In-Line (P) – 300 mil Body [PDIP]

Note: For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packages>



| Dimension Limits | Units | INCHES | | |
|----------------------------|-------|----------|------|------|
| | | MIN | NOM | MAX |
| Number of Pins | N | 14 | | |
| Pitch | e | .100 BSC | | |
| Top to Seating Plane | A | – | – | .210 |
| Molded Package Thickness | A2 | .115 | .130 | .195 |
| Base to Seating Plane | A1 | .015 | – | – |
| Shoulder to Shoulder Width | E | .290 | .310 | .325 |
| Molded Package Width | E1 | .240 | .250 | .280 |
| Overall Length | D | .735 | .750 | .775 |
| Tip to Seating Plane | L | .115 | .130 | .150 |
| Lead Thickness | c | .008 | .010 | .015 |
| Upper Lead Width | b1 | .045 | .060 | .070 |
| Lower Lead Width | b | .014 | .018 | .022 |
| Overall Row Spacing § | eB | – | – | .430 |

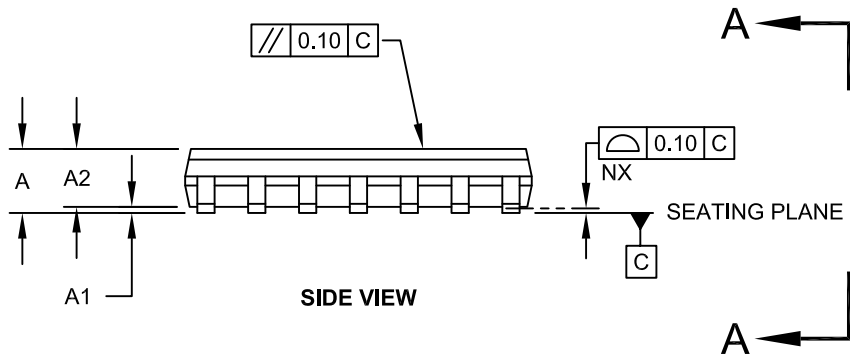
Notes:

- Pin 1 visual index feature may vary, but must be located with the hatched area.
- § Significant Characteristic.
- Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .010" per side.
- Dimensioning and tolerancing per ASME Y14.5M.

BSC: Basic Dimension. Theoretically exact value shown without tolerances.

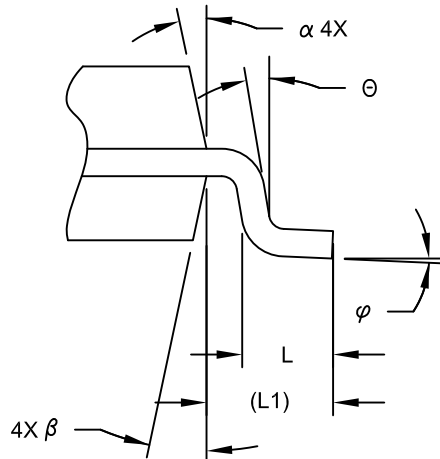
Microchip Technology Drawing C04-005B

Note: For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/package3>

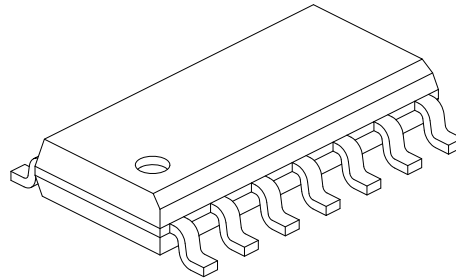


14-Lead Plastic Small Outline (SL) - Narrow, 3.90 mm Body [SOIC]

Note: For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packaging>



VIEW C



| Units | | MILLIMETERS | | |
|--------------------------|----|-------------|-----|------|
| Dimension Limits | | MIN | NOM | MAX |
| Number of Pins | N | 14 | | |
| Pitch | e | 1.27 BSC | | |
| Overall Height | A | - | - | 1.75 |
| Molded Package Thickness | A2 | 1.25 | - | - |
| Standoff § | A1 | 0.10 | - | 0.25 |
| Overall Width | E | 6.00 BSC | | |
| Molded Package Width | E1 | 3.90 BSC | | |
| Overall Length | D | 8.65 BSC | | |
| Chamfer (Optional) | h | 0.25 | - | 0.50 |
| Foot Length | L | 0.40 | - | 1.27 |
| Footprint | L1 | 1.04 REF | | |
| Lead Angle | Θ | 0° | - | - |
| Foot Angle | φ | 0° | - | 8° |
| Lead Thickness | c | 0.10 | - | 0.25 |
| Lead Width | b | 0.31 | - | 0.51 |
| Mold Draft Angle Top | α | 5° | - | 15° |
| Mold Draft Angle Bottom | β | 5° | - | 15° |

Notes:

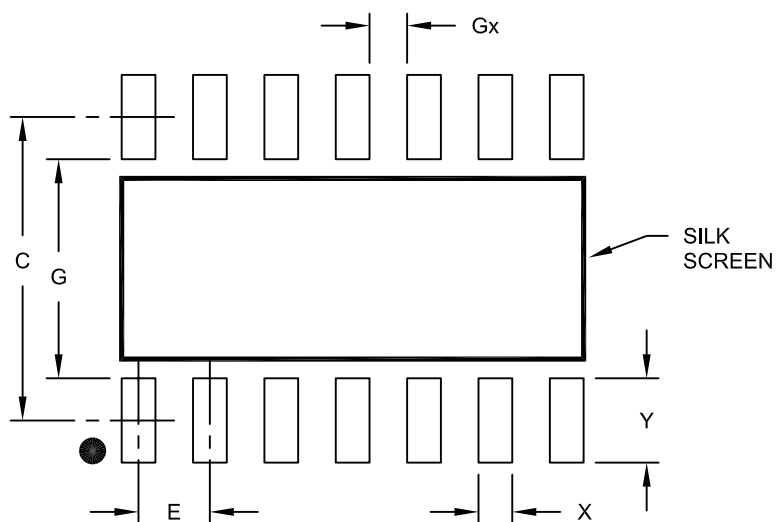
- Pin 1 visual index feature may vary, but must be located within the hatched area.
- § Significant Characteristic
- Dimension D does not include mold flash, protrusions or gate burrs, which shall not exceed 0.15 mm per end. Dimension E1 does not include interlead flash or protrusion, which shall not exceed 0.25 mm per side.
- Dimensioning and tolerancing per ASME Y14.5M
 - BSC: Basic Dimension. Theoretically exact value shown without tolerances.
 - REF: Reference Dimension, usually without tolerance, for information purposes only.
- Datums A & B to be determined at Datum H.

Microchip Technology Drawing No. C04-065C Sheet 2 of 2

MCP2050

14-Lead Plastic Small Outline (SL) - Narrow, 3.90 mm Body [SOIC]

Note: For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packaging>



RECOMMENDED LAND PATTERN

| Units | | MILLIMETERS | | |
|-----------------------|----|-------------|------|------|
| Dimension Limits | | MIN | NOM | MAX |
| Contact Pitch | E | 1.27 BSC | | |
| Contact Pad Spacing | C | | 5.40 | |
| Contact Pad Width | X | | | 0.60 |
| Contact Pad Length | Y | | | 1.50 |
| Distance Between Pads | Gx | 0.67 | | |
| Distance Between Pads | G | 3.90 | | |

Notes:

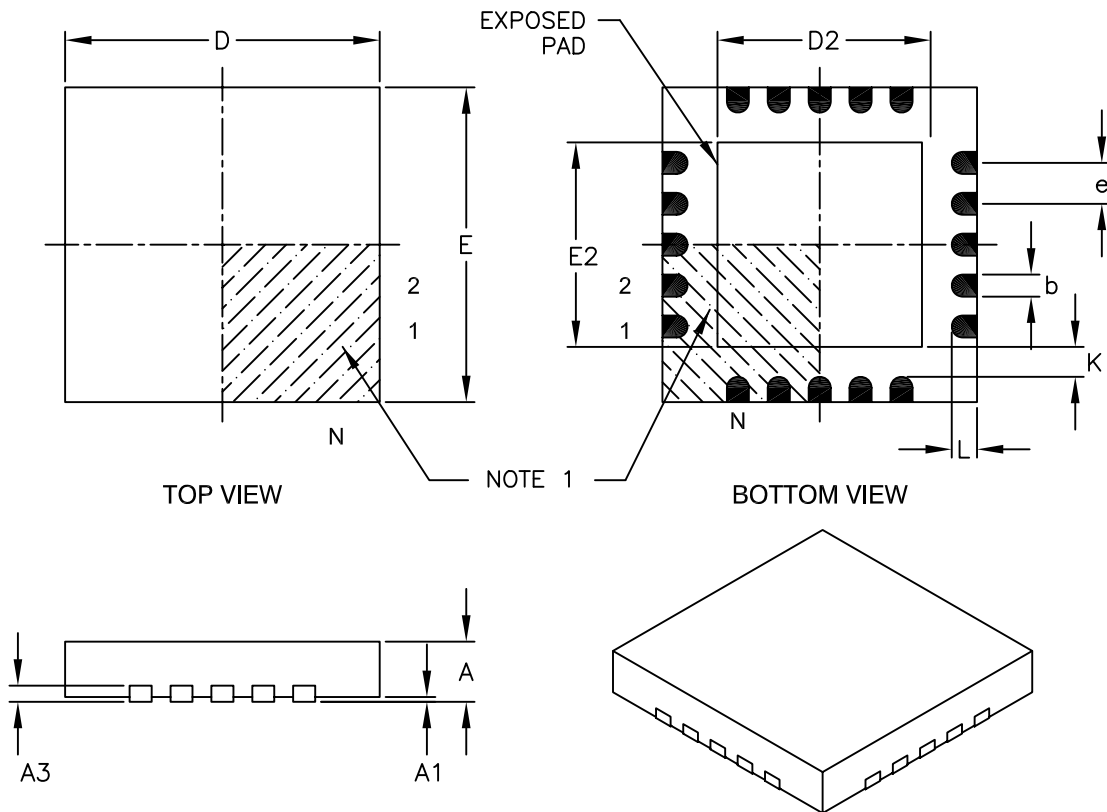
1. Dimensioning and tolerancing per ASME Y14.5M

BSC: Basic Dimension. Theoretically exact value shown without tolerances.

Microchip Technology Drawing No. C04-2065A

20-Lead Plastic Quad Flat, No Lead Package (MQ) – 5x5x0.9 mm Body [QFN]

Note: For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packaging>



| Units | | MILLIMETERS | | |
|------------------------|----|-------------|------|------|
| Dimension Limits | | MIN | NOM | MAX |
| Number of Pins | N | 20 | | |
| Pitch | e | 0.65 BSC | | |
| Overall Height | A | 0.80 | 0.90 | 1.00 |
| Standoff | A1 | 0.00 | 0.02 | 0.05 |
| Contact Thickness | A3 | 0.20 REF | | |
| Overall Width | E | 5.00 BSC | | |
| Exposed Pad Width | E2 | 3.15 | 3.25 | 3.35 |
| Overall Length | D | 5.00 BSC | | |
| Exposed Pad Length | D2 | 3.15 | 3.25 | 3.35 |
| Contact Width | b | 0.25 | 0.30 | 0.35 |
| Contact Length | L | 0.35 | 0.40 | 0.45 |
| Contact-to-Exposed Pad | K | 0.20 | - | - |

Notes:

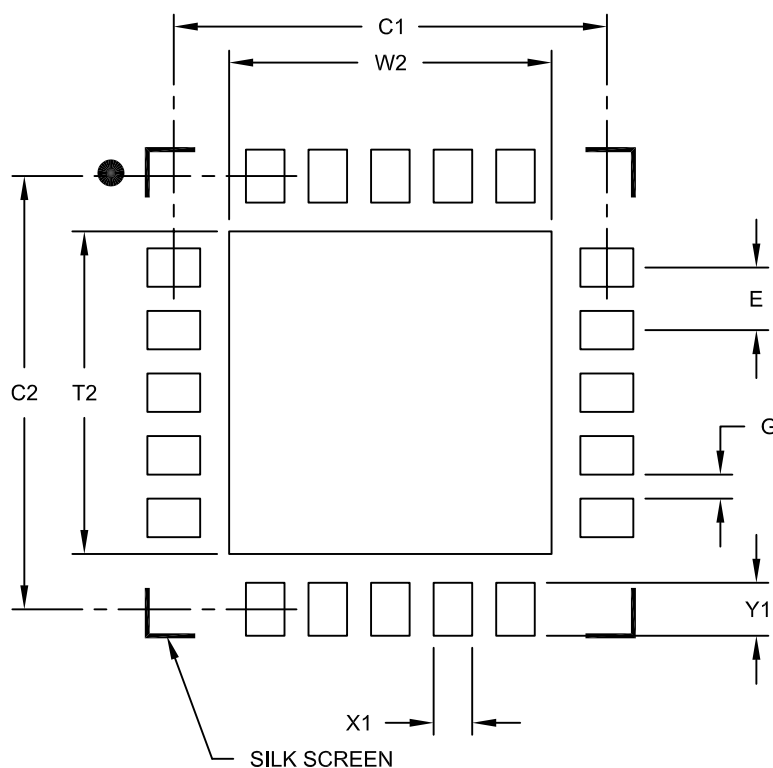
- Pin 1 visual index feature may vary, but must be located within the hatched area.
- Package is saw singulated.
- Dimensioning and tolerancing per ASME Y14.5M.
BSC: Basic Dimension. Theoretically exact value shown without tolerances.
REF: Reference Dimension, usually without tolerance, for information purposes only.

Microchip Technology Drawing C04-139B

MCP2050

20-Lead Plastic Quad Flat, No Lead Package (MQ) - 5x5 mm Body [QFN]
With 0.40mm Contact Length

Note: For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packaging>



RECOMMENDED LAND PATTERN

| Units | | MILLIMETERS | | |
|----------------------------|----|-------------|------|------|
| Dimension Limits | | MIN | NOM | MAX |
| Contact Pitch | E | 0.65 BSC | | |
| Optional Center Pad Width | W2 | | | 3.35 |
| Optional Center Pad Length | T2 | | | 3.35 |
| Contact Pad Spacing | C1 | | 4.50 | |
| Contact Pad Spacing | C2 | | 4.50 | |
| Contact Pad Width (X20) | X1 | | | 0.40 |
| Contact Pad Length (X20) | Y1 | | | 0.55 |
| Distance Between Pads | G | 0.20 | | |

Notes:

1. Dimensioning and tolerancing per ASME Y14.5M

BSC: Basic Dimension. Theoretically exact value shown without tolerances.

Microchip Technology Drawing No. C04-2139A

PRODUCT IDENTIFICATION SYSTEM

To order or obtain information, e.g., on pricing or delivery, refer to the factory or the listed sales office.

| <u>PART NO.</u> | <u>/X/</u> ⁽¹⁾ | <u>-X</u> | <u>/XX</u> |
|--|---------------------------|-------------------|------------|
| Device | Tape and Reel Option | Temperature Range | Package |
| <p>Device: MCP2050: LIN Transceiver with Voltage Regulator MCP2050T: LIN Transceiver with Voltage Regulator (Tape and Reel) (SOIC and QFN)</p> <p>Tape and Reel Option: Blank = Standard packaging (tube or tray) T = Tape and Reel⁽¹⁾</p> <p>Temperature Range: E = -40°C to +125°C</p> <p>Package: MQ = 20-Lead Plastic Quad Flat, No Lead Package – 5x5x0.9 mm Body (QFN) P = 14-Lead Plastic Dual In-Line – 300 mil Body (PDIP) SL = 14-Lead Plastic Small Outline – Narrow, 3.90 mm Body (SOIC)</p> | | | |
| <p>Examples:</p> <p>a) MCP2050-330E/P: 3.3V, Extended Temperature, 14-LD PDIP Package</p> <p>b) MCP2050-330E/MQ: 3.3V, Extended Temperature, 20-LD QFN Package</p> <p>c) MCP2050T-330E/MQ: Tape and Reel, 3.3V, Extended Temperature, 20-LD QFN Package</p> <p>d) MCP2050-330E/SL: 3.3V, Extended Temperature, 14-LD SOIC Package</p> <p>e) MCP2050T-330E/SL: Tape and Reel, 3.3V, Extended Temperature, 14-LD SOIC Package</p> <p>f) MCP2050-500E/P: 5.0V, Extended Temperature, 14-LD PDIP Package</p> <p>g) MCP2050-500E/MQ: 5.0V, Extended Temperature, 20-LD QFN Package</p> <p>h) MCP2050T-500E/MQ: Tape and Reel, 5.0V, Extended Temperature, 20-LD QFN Package</p> <p>i) MCP2050-500E/SL: 5.0V, Extended Temperature, 14-LD SOIC Package</p> <p>j) MCP2050T-500E/SL: Tape and Reel, 5.0V, Extended Temperature, 14-LD SOIC package</p> <p>Note 1: Tape and Reel identifier only appears in the catalog part number description. This identifier is used for ordering purposes and is not printed on the device package. Check with your Microchip Sales Office for package availability with the Tape and Reel option.</p> | | | |

APPENDIX A: REVISION HISTORY

Revision D (September 2014)

The following is the list of modifications:

1. Added Exposed Thermal Pad pin on QFN and in [Section 1.3, Pin Descriptions](#).
2. Updated [Figure 1-7](#).
3. Added note in [Figure 2-1](#).
4. Added AC parameter for WWDT in [Section 2.4, AC Specifications](#).
5. Created new [Section 2.6, Typical Performance Curves](#).
6. Fixed minor typographical errors.

Revision C (August 2012)

The following is the list of modifications:

1. Removed two notes in [Section 2.4 “AC Specifications”](#).

Revision B (April 2012)

The following is the list of modifications:

1. Corrected a label in [Figure 1-12](#).
2. Corrected a label in [Figure 1-13](#).
3. Updated the [Product Identification System](#) page.

Revision A (March 2012)

Original release of this document.

Note the following details of the code protection feature on Microchip devices:

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