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APPLICATION NOTE 6427

CALCULATING THE POWER DISSIPATION OF THE MAX14819 DUAL-CHANNEL IO-LINK MASTER TRANSCEIVER

Abstract: The MAX14819 dual-channel IO-Link master transceiver is a comparatively low-power device integrating multiple functions including dual sensor-supply controllers, IO-Link transceivers, and industrial digital inputs. When developing high-port IO-Link master solutions, it is important to know the power dissipation of the transceivers to manage the heat in the modules. This application note discusses the factors that add to the power dissipation in the MAX14819 in its many operating modes, and includes an Excel spreadsheet power dissipation calculator for quick calculations.

Introduction

The MAX14819 low-power, dual-channel, IO-Link® master transceiver provides a robust interface for IO-Link communication in harsh industrial environments. As the module sizes become smaller and sensor and actuator density on production floors continue to rise, it is important to manage heat in industrial sensors, actuators, and their counterparts to ensure long-term system reliability.

The MAX14819 features two SPI-configurable, IO-Link-compatible CQ transceivers that support standard input and output (SIO) operating as type 1/type 3 digital inputs to allow operation in multiple modes, including SIO mode, digital input (DI) and digital output modes, and IO-Link mode. The IC also includes two L+_ current-limiting sensor supply controllers. Depending on the mode of operation and the configuration of the IC, the power dissipation during normal operation varies.

This application note discusses the factors that add to the power dissipation in the MAX14819 during normal operation and includes an Excel spreadsheet power dissipation calculator Calculating the MAX14819 Power Dissipation for quick calculations.

Total Power Dissipation Overview

To calculate the total power dissipation in the MAX14819, multiple settings and factors need to be considered. Overall, the total power dissipated (PDIS) can include any of the following:

- Quiescent power
- 5V regulator power
- Power dissipated in the CQ_ drivers
- Power dissipated in the CQ_ receivers
- Power dissipated in the DI inputs

Other factors can also add some power dissipation, including LED sink currents; however, these are considered to be minimal and can be ignored in most cases. They are not factored into the Calculating the MAX14819 Power Dissipation spreadsheet.

Quiescent Power: Using the Internal Regulator or an External Regulator

The MAX14819 features an integrated regulator to generate 5V on the V_5 pin. This regulator can be enabled (REG = open/unconnected) or disabled (REG = GND). 5V must be present on the V_5 pin for the device to operate normally. So, if the internal regulator is disabled, an external 5V source must supply the 5V to the V_5 pin. The quiescent power dissipation in the MAX14819 varies significantly depending on whether this regulator is enabled or disabled.

When enabled, and assuming no load on V_5, the quiescent power (P_{Q_EN}) can be calculated as:

$$P_{Q\_EN} = (V_{CC} \text{ x } I_{CC\_EN}) + ([V_{CC} – V_5] \text{ x } I_{V5\_LOAD})$$

Note that the 5V regulator can drive external loads up to 20mA. It is clear from this equation that any external load on the regulator output (V5) increases the power dissipation significantly.

Example: assume a typical IO-Link supply voltage of 24V with no external load applied to V5. Using this configuration, the maximum quiescent power is:

$$P_{Q\_EN} = (24V \times 1.9mA) + ([24V – 5V] \times 0mA)$$

$$P_{Q\_EN} = 43.2mW$$

When the internal regulator is disabled, the quiescent power dissipation (P_{Q_DIS}) includes two factors: the power dissipation due to the supply on the V_{CC} pin and the power dissipation due to the supply on the V_5 pin:

$$P_{Q\_DIS} = P_{CC} + P_{LDO5}$$

$$P_{Q\_DIS} = (V_{CC} \times I_{CC\_DIS}) + (V_5 \text{ x } I_5)$$

From the IC data sheet, the V_{CC} supply current drops from 1.8mA (typ) to 0.4mA (typ) and the V5 quiescent current is around 1.4mA. Assuming the same V_{CC} conditions as used in the calculation above, the P_{Q_DIS} power is:

$$P_{Q\_DIS} = (V_{CC} \times I_{CC\_DIS}) + (V_5 \times I_5)$$

$$P_{Q\_DIS} = (24V \times 0.4mA) + (5V \times 1.4mA) = 9.6mW + 7mW = 16.6mW$$

Power Dissipation Calculations for Different Modes of Operation

SIO DO Mode (CQA/CQB)

A standard digital output is defined by the IEC 61131-2 standard. The MAX14819 CQ_ I/Os can be configured to operate in this mode. When using the CQ_ channels as standard digital outputs (SIO DO), it is important to include the selected CQ_ current limit in the power calculation. In this mode, the power dissipated in the CQ_ drivers (P_{CQ_D}) can be calculated as:

$$P_{CQ\_DO} = (R_{ON} \times I_{CQLOAD}^2)$$

Note that this calculation assumes that only one driver is operating in SIO DO mode. If both drivers are configured for this mode, the power dissipated will need to be multiplied by a factor of 2.

Adding the power dissipated in the drivers to the quiescent power dissipation, the total power dissipated in the MAX14819 in SIO DO mode is calculated as:

$$P_{TOTAL} = P_Q + P_{CQ\_DO}$$

where P_Q is the quiescent power dissipation (see the "Quiescent Power: Using the Internal Regulator or an External Regulator" section above) with the internal regulator enabled (P_{Q_EN}) or disabled (P_{Q_DIS}), depending on the selected configuration. Note that if both drivers are configured for this mode, the power dissipated in the CQ drivers needs to be multiplied by a factor of 2.

Example: using a 24V supply with the internal regulator (no external load) and using both CQA and CQB for SIO DO operation with a 200mA load current, the total power dissipated is:

$$P_{TOTAL} = (V_{CC} \times I_{CC\_EN}) + [2 \times (R_{ON} \times I_{CQLOAD}^2)]$$

$$P_{TOTAL} = (24V \times 1.8mA) + [2 \times (1\Omega \times 200mA)2] = 43.2mW + 80mW$$

$$P_{TOTAL} = 123.2mW$$

SIO DI Mode (CQA/CQB and DIA/DIB)

A standard digital input (SIO DI) is defined by the IEC 61131-2 standard. The MAX14819 supports type 1 and type 3 characteristics on the CQ_ and DI pins When using the CQ_ and/or DI_ channels in SIO DI mode, it is important to include the selected current sink in the power calculation. Power dissipated in the CQ_ or DI_ receiver inputs in this mode, P_{CQ_DI}, is calculated as:

$$P_{CQ\_DI} = (V_{CQ\_OR\_DI} \times I_{SINK})$$

Note that this calculation is for one input only. If multiple inputs are used (for example, both CQ_ channels are configured as SIO DI inputs), this value should be multiplied by the number of enabled inputs.

Adding the power dissipated in the receivers to the quiescent power dissipation, the total power dissipated in the MAX14819 in SIO DI mode is calculated as:

$$P_{TOTAL} = P_Q + P_{CQ\_DI}$$

where P_Q is the quiescent power dissipation (see the "Quiescent Power: Using the Internal Regulator or an External Regulator" section above) with the internal regulator enabled (P_{Q_EN}) or disabled (P_{Q_DIS}), depending on the selected configuration. Note that if both drivers are configured for this mode, the power dissipated in the CQ drivers needs to be multiplied by a factor of 2.

Example: using a 24V supply with the internal regulator (no external load) and configuring both CQA and CQB for SIO DI operation with a 2.5mA (typ) current sink enabled, the total power dissipated is:

$$P_{TOTAL} = (V_{CC} \times I_{CC\_EN}) + [2 \times (V_{CQ} \times I_{SINK})]$$

$$P_{TOTAL} = (24V \times 1.8mA) + [2 \times (24 \times 2.5mA)] = 43.2mW + 120mW$$

$$P_{TOTAL} = 163.2mW$$

IO-Link Mode (CQA/CQB)

When operating the MAX14819 in IO-Link mode, the CQ_ channels act as both receivers (with a current sink for discharging the line) and as line drivers. The CQ current sinks must be taken into account for the percentage of time that the CQ receiver inputs are pulled high. But, because the CQ driver outputs drive a high impedance, the driver's I^2R_{ON} power dissipation is negligible for this calculation. Power dissipation in the CQ I/Os, P_{IO_LINK}, in this mode is calculated as:

$$P_{IO\_LINK} = \%TIME\ HIGH \times (V_{CQ} \times I_{SINK})$$

Note that this calculation is for one I/O only. If both channels are used for IO-Link communication, this value should be multiplied by a factor of 2.

Adding the power dissipated in IO-Link I/Os to the quiescent power dissipation, the total power dissipated in the MAX14819 in IO-Link mode is calculated as:

$$P_{TOTAL} = P_Q + P_{IO\text{-}LINK}$$

where P_Q is the quiescent power dissipation (see the "Quiescent Power: Using the Internal Regulator or an External Regulator" section above) with the internal regulator enabled (P_{Q_EN}) or disabled (P_{Q_DIS}), depending on the selected configuration. Note that if both drivers are configured for IO-Link communication, the power dissipated in the CQ I/Os needs to be multiplied by a factor of 2.

Example: using a 24V supply with the internal regulator (no external load) and configuring both CQA and CQB for IO-Link operation with a 5.8mA (typ) current sink enabled (assuming that the CQ_ receivers are pulled high 20% of the time during communication), the total power dissipated is:

$$P_{TOTAL} = (V_{CC} \times I_{CC\_EN}) + [2 \text{ x } (0.2 \times V_{CQ} \times I_{SINK})]$$

$$P_{TOTAL} = (24V \times 1.8mA) + [2 \times 0.2 \text{ x } (24 \times 5.8mA))] = 43.2mW + 55.7mW$$

$$P_{TOTAL} = 98.9mW$$

Power Dissipated in External Components

The MAX14819 uses external p-channel MOSFETs and sense resistors for the L+A and L+B supply controllers. The L+ lines can be required to supply a significant amount of power, so special attention should be paid when selecting these external components to minimize power dissipation. Power dissipated in the L+ line (P_{L+}) includes the power dissipated in the sense resistor (R_{SENSE}) and power dissipated in the FETs :

$$P_{L+} = [I_{L+LOAD}^2 \times (R_{SENSE} + (2 \times R_{ON\_FET}))]$$

This calculation is for one L+ supply controller. Multiply by two if both controllers are enabled.

Example: assuming a 500mA L+ supply load current, with a current limit set to 1A (R_{SENSE} = 15mΩ), and using the ON Semiconductor NTTFS5116PL p-channel MOSFETs in the line, the external component power dissipation for L+A or L+B is as follows:

$$P_{L+} = [I_{L+LOAD}^2 \times (R_{SENSE} + (2 \times R_{ON\_FET}))]$$

$$P_{L+} = [500mA^2 \times (15m + (2 \times 37m\Omega))] = 22.2mW \text{ per channel}$$

Using the Calculating the MAX14819 Power Dissipation Calculator

The Calculating the MAX14819 Power Dissipation calculator is provided to help streamline power calculations when using the MAX14819. To effectively use the calculator, follow these steps:

- Select the circuit configuration for your MAX14819 circuit: Internal regulator or external regulator. Internal Regulator Enabled (REGEN is Open): Use the spreadsheet labeled INT_REG Internal Regulator Disabled (REGEN = GND), External Regulator Used for V5: Use the spreadsheet labeled EXT_REG.
- Enter the voltage, current, and resistance values for the circuit in the yellow boxes in the INPUT section. Note that two columns are included: TYP and MAX. Enter the maximum values in the MAX column for the worst-case/highest power dissipation values.
- Enter the number of channels used for each configuration in the Channel Mode Selection section. Power dissipation values are automatically calculated in the OUTPUT section when the voltage, current, resistance, and number of channels values have been input.
- To calculate the total power dissipation in a circuit: Check the boxes next to each line in the OUTPUT section that applies to the final circuit. Values in these lines are added to the TOTAL calculation at the bottom of the OUTPUT section.

The calculator also includes a third spreadsheet: PKG. This sheet is intended as a quick reference for package and thermal characteristics for the device. A simple junction temperature calculator is also included. Enter thermal characteristics in the yellow boxes to calculate the junction temperature of the MAX14819.

Related Parts		
MAX14819	Dual IO-Link Master Transceiver with Integrated Framers and L+ Supply Controllers	Free Samples

More Information

For Technical Support: https://www.maximintegrated.com/en/support
For Samples: https://www.maximintegrated.com/en/samples
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