MIC2871 Evaluation Board

1.2A High-Brightness LED Flash Driver with Single-Wire Serial Interface

General Description

The MIC2871 is a high-current, high-efficiency flash LED driver which can operate in either torch mode or flash mode. MIC2871 has a built-in internally-compensated current-mode PWM 2MHz boost converter which allows the use of very small inductor and output capacitor. It is for stepping up the supply voltage to a high enough value at the OUT pin to drive the LED current. If the supply voltage is high enough, the synchronous switch of the converter is then fully turned on and the LED driver operates in linear mode. MIC2871 also features a configurable safety timer which automatically shuts down the LED current after the safety timer duration is expired if the programmed LED current exceeds a certain current threshold. These features make the MIC2871 an ideal solution for high-resolution camera phone LED flash light driver applications.

The MIC2871 can be controlled through the single-wire serial interface and/or external control pins. Default flash and torch brightness can be adjusted via an external resistor. A robust single-wire serial interface allows simple control by the host processor to support typical camera functions such as auto-focus, white balance, and image capture.

Datasheets and support documentation are available on Micrel's web site at: www.micrel.com.

Requirements

The MIC2871 evaluation board requires a bench input power source that is adjustable from 2.7V to 5.5V and is able to deliver greater than 4.5A at 2.7V.

Precautions

The evaluation board does not have reverse polarity protection. Applying a negative voltage across the VIN terminal to PGND terminal may damage the device. The MIC2871 evaluation board is tailored for a Li-ion range input supply voltage. It should not exceed 5.5V on the input.

Getting Started

1. **Connect external supply to the VIN terminals.**

   Apply desired input voltage to the VIN (J1) and ground (J2) terminals of the evaluation board, paying careful attention to polarity and supply range. Since the default setting of the low battery detection threshold voltage is 3.6V, the supply voltage should be set to within 3.6V to 5.5V when testing the MIC2871 without using the software through the single-wire interface (the low-battery detection threshold can be set to another value or disabled through software). An ammeter may be placed between the power supply and the evaluation board input terminals. Ensure that the supply voltage is monitored at the input terminals. The ammeter and /or power lead resistance can reduce the voltage supplied to the input.

2. **Enable/Disable the MIC2871.**

   The MIC2871 evaluation board has an enable (DC) pin (TP1 right pin). The MIC2871 is enabled in idle (standby) mode when the DC pin is asserted HIGH. Setting a jumper at TP1 can connect the DC pin to VIN. If this pin is driven low for more than 405µs, the IC is shutdown. Alternatively, the IC can be enabled or disabled by software through single-wire interface.

3. **Enable/Disable the flash mode.**

   The FEN1 (J6) and FEN2 (J7) are the flash mode enable pins. A low-to-high transition at either one of these two pins initiates the flash mode and the safety timer. Setting jumpers at TP2 and TP3 can connect FEN1 and FEN2 to VIN respectively. If FEN1 pin or FEN2 pin is left floating, it will be pulled-down internally by built-in 1µA current source when the device is enabled. Alternatively, the flash mode can be enabled or disabled by software through single-wire interface.

Ordering Information

Part Number	Description
MIC2871YMK EV	MIC2871 Evaluation Board
MICUSB Dongle EV	I^2C Serial Programmer Board

Getting Started (Continued)

4. Graphic user interface support.

Graphical user interface software can be used with the MICUSB Dongle EV allowing configuration and testing of the MIC2871 with a standard computer. For more detail, refer to the *Evaluation Software* section.

Evaluation Board Description

Figure 1. MIC2871 Evaluation Board

Flash Mode

The maximum current level in the flash mode is 1.2A. This current level can be adjusted through an external resistor connecting to the FRSET pin according to Equation 1:

$$I_{LED(MAX)} = \frac{20500}{R_{FRSET}} \qquad \text{Eq. 1}$$

Alternatively, the default value of 1A is used when the FRSET pin is grounded.

The flash mode current can be initiated at this preset FRSET brightness level by asserting FEN1 or FEN2 pin HIGH, or by setting the flash control register (address 1) through the single-wire interface, for the desired flash duration, subjected to the safety timeout setting. The flash mode current is terminated when the FEN1 and FEN2 pins are brought LOW and the flash register is cleared.

Flash mode current can be adjusted to a fraction of the maximum flash mode current level by selecting the desired percentage in the flash control register through the single-wire serial interface. The flash current is the product of the maximum flash current setting and the percentage selected in the flash register.

Torch Mode

By default, the maximum torch mode level is one-fourth (1/4) of the maximum flash mode current. The torch mode operation is activated by setting the torch control register (Address 2) for the desired duration through software via the single-wire interface at the DC pin. The torch mode current is terminated when the torch register is cleared or when the configurable safety timer expires.

Like the flash mode current, the torch mode current can be set to a fraction of the maximum torch mode level by selecting the desired torch current level percentage in the torch control register (Address 2) through the single-wire serial interface.

The torch current is the product of the maximum Torch current setting and the percentage selected in the torch register.

Configurable Safety Timer

The safety timeout feature automatically shuts down the LED current after the safety timer duration is expired if the programmed LED current exceeds a certain current threshold. Both the current threshold and the timer duration are programmable via the safety timer registers (Addresses 3 and 5).

Low-Battery Voltage Detection (LBVD)

When the VIN voltage drops below the LBVD threshold (default = 3.6V) in flash or torch mode, the LED current driver is disabled. The LED driver can be resumed by raising the VIN above the LVBD threshold and toggling the DC enable control signal. The LBVD threshold is adjustable thru the LBVD control register (Address 4).

Overvoltage Protection

When the output voltage rises above the OVP threshold, MIC2871 is latched off automatically to avoid permanent damage to the IC. To clear the latched off condition, either power cycle the MIC2871 or assert the DC pin LOW.

Short-Circuit Detection

Each time before enabling the LED driver, the MIC2871 performs the short-circuit test by driving the flash LED with a small (2mA typical) current for 200µs. If ($V_{OUT} – V_{LED}$) < 1.7V at the end of the short-circuit test, the LED is considered to be shorted and MIC2871 will ignore the flash and/or torch mode command. Note that the short-circuit test is carried out every time prior to flash and torch mode but the result is not latched.

Thermal Shutdown

When the internal die temperature of MIC2871 reaches 155°C, the LED driver is disabled until the die temperature falls below 140°C.

Single-Wire Interface

The single-wire interface allows the use of a single multiplexed enable and data pin (DC) for control and communication in GPIO limited applications. The interface is implemented using a simple mechanism allowing any open drain or directly driven GPIO to control the MIC2871.

The MIC2871 uses the single-wire interface for simple command and control functions. The interface provides fast access to write only registers with protection features to avoid potentially erroneous data writes and improve robustness. When DC is in a low state and no data is detected for an extended period of time, the MIC2871 will automatically go into a low-power SHUTDOWN state, simultaneously resetting internal registers to default states.

Overview

The single-wire interface relies on a combination of bit edges and the period between edges in order to communicate across a single wire. Each word is transmitted as a series of pulses, with each pulse incrementing an internal data counter. A stop sequence consisting of an inactive period is used to latch the data word internally. An address and data framing format is used to improve protection against erroneous writes by enforcing address and data field lengths as well as the timing duration between them.

Timing is designed such that when communicating with a device using a low cost on chip oscillator, the worst case minimum and maximum conditions can be easily met within the wide operating range of the oscillator. Using this method guarantees that the device can always detect the delay introduced by the communication master.

Idle States and Error Conditions

In shutdown mode, the MIC2871 is in a reset condition with all functions off while consuming minimal power. Register settings are reset to default state when coming out of shutdown state. In idle mode, all register settings persist and all MIC2871 functions continue in their current state. Table 1 summarises the difference between the two idle modes:

Table 1. Differences between Idle Modes

DC	Shutdown	Idle
	Low	High
I_{SUPPLY} (all functions off)	1µA	230µA
Register State	Default	Persist
Start-Up Time	1µs	100ns

Idle mode is entered automatically at the end of a communication frame by holding DC high for $\geq T_{END}$, by enabling the device by bringing DC high when in shutdown mode, or when an error is detected by the single-wire interface logic.

Shutdown mode can be entered at any time by pulling down DC for $\geq T_{END}$, discarding any current communication and resetting the internal registers. If a communication is received before the shutdown period but after the T_{LAT} period, the communication is discarded. This state is also used to create an internal error state to avoid erroneously latching data where the communication process cannot be serviced in time. Additionally, each register has a maximum value associated with it. If the number of bits clocked in exceeds the maximum value for the register, the data is assumed to be in error and the data is discarded.

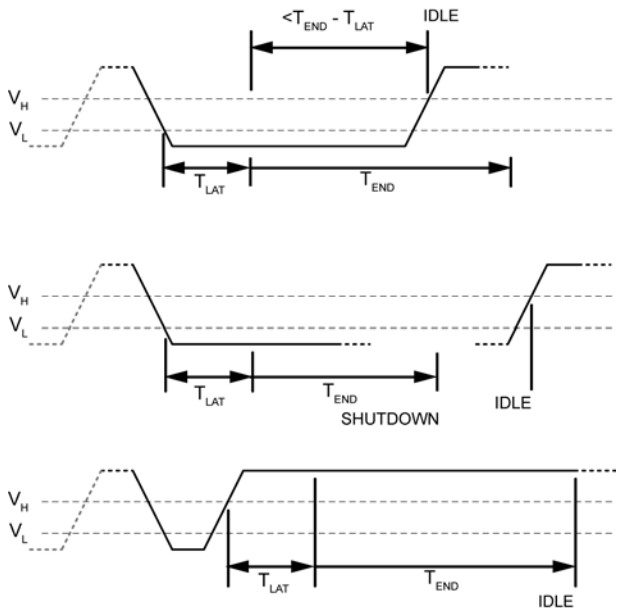


Figure 2. Abort, Shutdown, and Idle Timing Waveforms

Communication Details

The serial interface requires delimiters to indicate the start of frame, data as a series of pulses, and end of frame indicated by a lack of activity. The start of frame is the first high to low transition of DC when in idle mode. The first rising edge resets the internal data counter to 0.

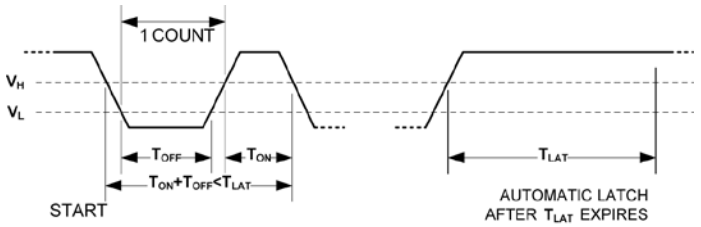


Figure 3. Data Word Pulse Timing

A pulse is delimited by the signal first going below V_L and then above V_H within the latch timeout T_{LAT}. During this transition, minimum on (T_{ON}) and off (T_{OFF}) periods are observed to improve tolerance to glitches. Each rising edge increments the internal data register. Data is automatically latched into internal shadow address and data registers after an inactivity period of $>T_{LAT}$.

To send register write commands, the address and data are entered in series as two data words using the above pattern, with the second word starting after the first latch period has expired. After the second word is entered, the IDLE command should be issued by leaving the DC pins high for $\geq T_{END}$.

After receiving the stop sequence, the internal registers decode and update cycle is started, with the shadow register values being transferred to the decoder. Figure 4 shows an example of entering a write of data 5 to Address 3.

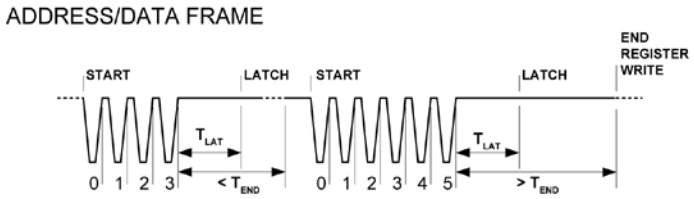


Figure 4. Communication Timing Example of Entering Write for Data 5 to Address 3

Only correctly formatted address/data combination will be treated as a valid frame and processed by the MIC2871. Any other input, such as a single data word followed by T_{END}, or three successive data words will be discarded by the target hardware as an erroneous entry. Additionally, any register write to either an invalid register or with invalid register data will also be discarded.

MIC2871 Registers

The MIC2871 supports five writeable registers for controlling the torch and the flash modes of operation as shown in Table 2. Note that register addressing starts at 1. Writing any value above the maximum value shown for each registers will cause an invalid data error and the frame will be discarded.

Table 2. Five Writeable Registers of MIC2871

Address	Name	Maximum Value	Description
1	FEN/FCUR	31	Flash Enable/Current
2	TEN/TCUR	31	Torch Enable/Current
3	STDUR	7	Safety Timer Duration
4	LB_TH	9	Low-Battery Voltage Detection Threshold
5	ST_TH	5	Safety-Timer Threshold

Flash Current Register (FEN/FCUR: default 0)

The flash current register enables and sets the flash mode current level. Valid values are 0 to 31; values 0 – 15 will set the flash current without enabling the flash (such that it can be triggered externally), values 16 – 31 will set the flash current and enable the flash. The flash current register maps into the internal FEN and FCUR registers as shown in Table 3. Table 3 also describes the relationship between the flash current as a percentage of maximum current, and the FCUR register setting.

Table 3. Flash Current Register Mapping into Internal FEN and FCUR Registers, and Relationship between Flash Current as % of Maximum Current and the FCUR Register Setting

Value		FEN/FCUR[4:0]	
Dec.	**Binary**	**FEN[4]**	**FCUR[3:0] % of I_{MAX}**
0	00000	0	100.00
1	00001	0	88.96
2	00010	0	79.04
3	00011	0	70.72
4	00100	0	63.04
5	00101	0	56.00
6	00110	0	49.92
7	00111	0	44.64
8	01000	0	39.68
9	01001	0	35.52
10	01010	0	31.68
11	01011	0	28.16
12	01100	0	25.12
13	01101	0	22.40
14	01110	0	20.00
15	01111	0	17.92
16	10000	1	100.00
17	10001	1	88.96
18	10010	1	79.04
19	10011	1	70.72
20	10100	1	63.04
21	10101	1	56.00
22	10110	1	49.92
23	10111	1	44.64
24	11000	1	39.68
25	11001	1	35.52
26	11010	1	31.68
27	11011	1	28.16
28	11100	1	25.12
29	11101	1	22.40
30	11110	1	20.00
31	11111	1	17.92

Torch Current Register (TEN/TCUR: default 0)

The torch current register enables and sets the torch mode current level. Valid values are 0 to 31; values 0 – 15 will set the torch current without enabling the torch (such that it can be triggered by setting the internal TEN register value to 1), values 16 – 31 will set the torch current and enable the torch. A value of 0 at the internal TEN register will disable the torch. The torch current register maps into the internal TEN and TCUR registers as shown in Table 4. Table 4 also describes the relationship between the torch current as a percentage of maximum current, and the TCUR register setting.

Table 4. Torch Current Register Mapping into Internal TEN and TCUR Registers, and Relationship between Torch Current as % of Maximum Current and the TCUR Register Setting

Value		TEN/TCUR[4:0]	
Dec.	Binary	TEN[4]	TCUR[3:0] % of I_{MAX}
0	00000	0	100.00
1	00001	0	88.96
2	00010	0	79.04
3	00011	0	70.72
4	00100	0	63.04
5	00101	0	56.00
6	00110	0	49.92
7	00111	0	44.64
8	01000	0	39.68
9	01001	0	35.52
10	01010	0	31.68
11	01011	0	28.16
12	01100	0	25.12
13	01101	0	22.40
14	01110	0	20.00
15	01111	0	17.92
16	10000	1	100.00
17	10001	1	88.96
18	10010	1	79.04
19	10011	1	70.72
20	10100	1	63.04
21	10101	1	56.00
22	10110	1	49.92
23	10111	1	44.64
24	11000	1	39.68
25	11001	1	35.52
26	11010	1	31.68
27	11011	1	28.16
28	11100	1	25.12
29	11101	1	22.40
30	11110	1	20.00
31	11111	1	17.92

Safety Timer Duration Register (STDUR: default 7)

The safety timer duration register sets the duration of the flash and torch mode when the LED current exceeds the programmed threshold current. Valid values are 0 for the minimum timer duration to 7 for the maximum duration.

Table 5. Safety Timer Duration Register Setting and Safety Timer Duration

Value		FDUR[2:0] (binary)	Timeout (ms)
Dec.	Binary		
0	000	000	156.25
1	001	001	312.5
2	010	010	468.75
3	011	011	625
4	100	100	781.25
5	101	101	937.5
6	110	110	1093.75
7	111	111	1250

Low-Battery Threshold Register (LB_TH: default 7)

The LB_TH register sets the supply threshold voltage below which the internal low battery flag is asserted and flash functions are inhibited. Table 6 shows the threshold values that correspond to the register settings. Setting 0 is reserved for disabling the function, and settings between 1 and 9 inclusively enable and set the LB_TH value between 3.0V and 3.8V with 100mV resolution.

Table 6. Low-Battery Threshold Register Setting and Supply Threshold Voltage

Value		LB_TH[3:0]	V_{BAT} Threshold (V)
Dec.	Binary		
0	0000	0000	Disabled
1	0001	0001	3.0
2	0010	0010	3.1
3	0011	0011	3.2
4	0100	0100	3.3
5	0101	0101	3.4
6	0110	0110	3.5
7	0111	0111	3.6
8	1000	1000	3.7
9	1001	1001	3.8

Safety Timer Threshold Current Register (ST_TH: default 4)

Safety timer threshold current determines the amount of LED current flowing through the external LED before the internal LED safety timer is activated. Setting ST_TH to 0 disables the safety timer function, and setting the register to values 1 to 5 set the safety time threshold current 100mA to 300mA in 50mA steps.

Table 7. Safety Timer Threshold Current Register Setting and Safety Timer Threshold Current

Value		ST_TH[2:0]	Safety Timer Threshold Current (mA)
Dec.	Binary		
0	000	000	Disabled
1	001	001	100mA
2	010	010	150mA
3	011	011	200mA
4	100	100	250mA
5	101	101	300mA

Evaluation Kit Overview

The MIC2871 can be operated as a standalone board or as a modular system where the evaluation board is connected to a PC via single-wire-to-USB interface board (MICUSB Dongle EV).

Connecting the USB-to-Single-Wire Adapter

When interfacing the MIC2871 evaluation board with the MICUSB Dongle, carefully match the GND pin of the evaluation board with the GND pin of the dongle (as shown in Figure 5, the MICUSB Dongle should be faced up). On the MIC2871 evaluation board, the GND pin is the 4th pin of the connector receptacle (JP1) as counting from the left side. The MICUSB Dongle has GND labeled on both sides of the adapter board.

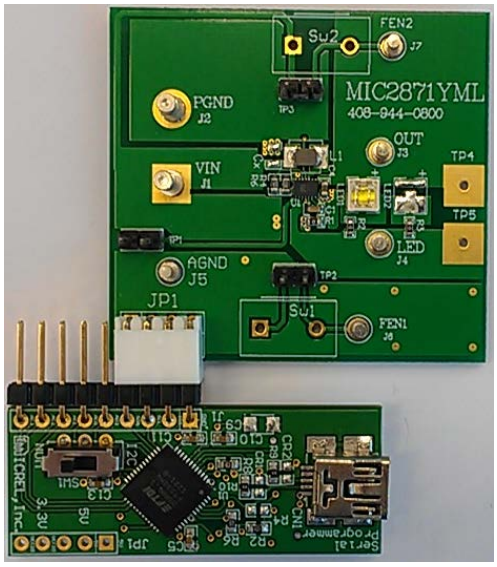


Figure 5. MIC2871 Evaluation Board Interfaces with the MICUSB Dongle EV (adapter top side faces up)

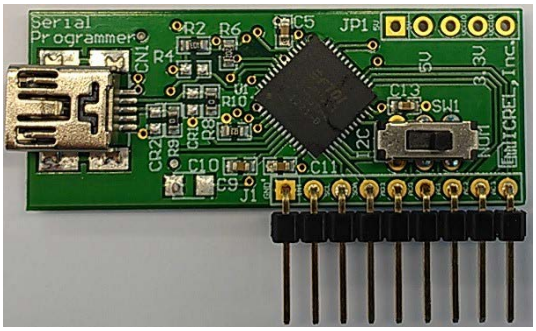


Figure 6. Top Side of the Adapter with the Mini Slide Switch Toggled to NOM Position

MIC2871 Evaluation Software

The MIC2871 evaluation software provides a graphic user interface (GUI) to program the MIC2871 evaluation board. A complete application note on the installation and operation of the evaluation software and the USB adapter user manual can be downloaded from Micrel's web site at www.micrel.com. The evaluation software can write to registers inside the MIC2871 IC device via the single-wire interface for enabling or disabling the device, torch mode, flash mode, and flash inhibit; changing the WLEDs' brightness in torch mode and flash mode; changing the safety timer duration and LED current threshold; enabling/disabling breath and strobe special effects.

Getting Started

1. Download the MIC2871 evaluation software and run setup.exe file. This step may take some time and require an internet connection to update the computer to .NET Framework 3.5.
2. Install the MICUSB Dongle EV driver from FTDI. Double-click on the file CDM20828_setup.exe. The latest driver can be downloaded from the FTDI website: www.ftdichip.com.
3. After installing the driver, locate the virtual COM port created by the FTDI driver in the Device Manager Menu, under Ports (COM & LPT). The corresponding port will have FTDI listed as the manufacturer.
4. Connect the MIC2871 evaluation board to the PC via the MICUSB Dongle EV. Power the MIC2871 evaluation board VIN input.
5. Set the mini slide switch SW1 on the MICUSB Dongle EV. The SW1 should be toggled to the NOM position as shown in Figure 6.
6. Open the MIC2871 evaluation software in Programs under the Start Menu.

Evaluation Software

The MIC2871 evaluation software graphic user interface (GUI) is shown in Figure 7 and Figure 8. When the evaluation software is just started, it is default in offline mode as shown on the right of the top menu bar in Figure 7. The offline mode is only for running the software without the communication or connection with the MIC2871 evaluation board.

To control the MIC2871 evaluation board with the software GUI, the user firstly has to click the "Test" button. If the connection from the PC to the dongle and then to the MIC2871 EVB is fine as instructed in "Connecting the USB-to-Single-Wire Adapter" sub-section and in steps 4 and 5 in the "Getting Started" sub-section, the "Target OK" will be shown up at the status bar at the bottom of the GUI as shown Figure 7.

If the connection is not good, the "Target Not Detected" will be shown up at the status bar and the user has to check with the cable connections before proceeding to the next step. When the "Target OK" status is shown, the user can click on the "Offline Mode" at the menu bar to change it to "Direct Editing Mode". When the "Direct Editing Mode" is shown up at the top menu bar and the "Direct Editing Mode Active" is indicated at the status bar as shown in Figure 8, the software GUI allows the user to control the operation of the MIC2871 evaluation board.

Introduction to the GUI Panel

At the left side of the GUI panel, user can check with the MIC2871 registers information and perform write operation to the IC registers.

At the right side of the GUI panel which is the MIC2871 control panel, user can perform the following MIC2871 operation:

1. Check or uncheck the "Enabled" option to enable or disable the MIC2871 device.
2. Adjust the flash brightness with the slide bar from 100% to 18% of the maximum LED current in flash mode in 16 steps. The maximum is on the left and the minimum is on the right.
3. Fire flash or reset flash by clicking the "Toggle Flash" button.
4. Check or uncheck Flash Inhibit "Enable", "Driver Enable" or "Low Current" options.
5. Adjust the torch brightness with the slide bar from 100% to 18% of the maximum LED current in torch mode in 16 steps. The maximum is on the left and the minimum is on the right.
6. Set or reset torch by clicking on the "Toggle Torch" button.
7. Change the LED safety timer duration setting from 156ms to 1250ms with 8 options; Change the LED safety timer LED current threshold from 100mA to 300mA in 50mA step. The LED safety timer can also be disabled by setting the LED current threshold to the "Disable" option. Please refer to Table 5 and Table 7 for details.
8. Set the Low-Battery Threshold voltage from 3.0V to 3.8V in 0.1V step. The Low-Battery Threshold function can be disabled by choosing the "Disabled" option.
9. Click the "Breath" button, "Strobe" button, and set delay time options for special effects demonstration.

Setting of Single-Wire Interface Data Rate

The data rate of the single-wire interface communication can be set at the pull-down menu from the "SWI" menu at the top menu bar as shown in Figure 9. User can set the data rate to 100kHz, 1MHz, 3MHz, or 6MHz from the pull-down menu.

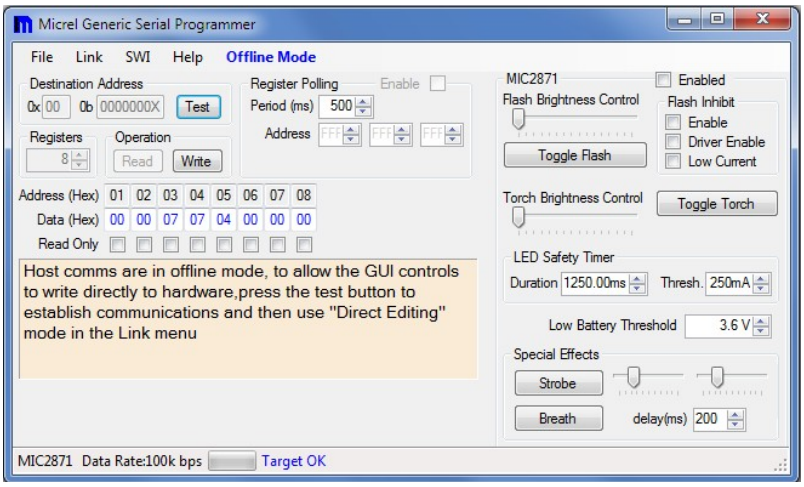


Figure 7. MIC2871 Evaluation Software GUI in Offline Mode

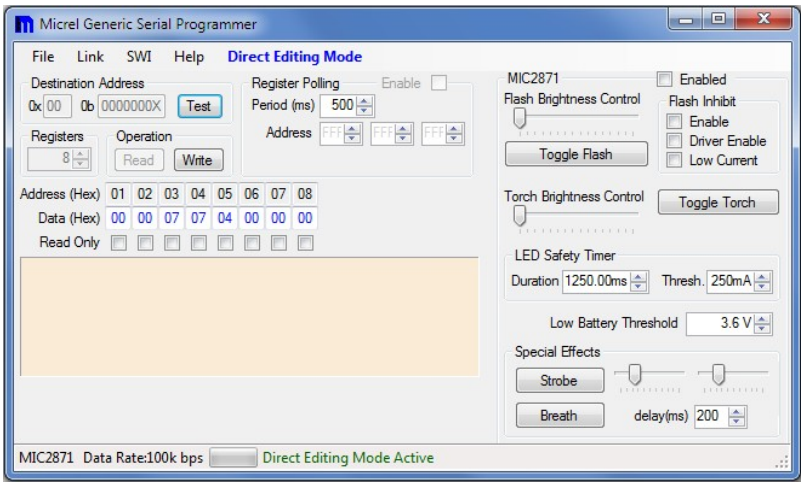


Figure 8. MIC2871 Evaluation Software GUI in Direct Editing Mode

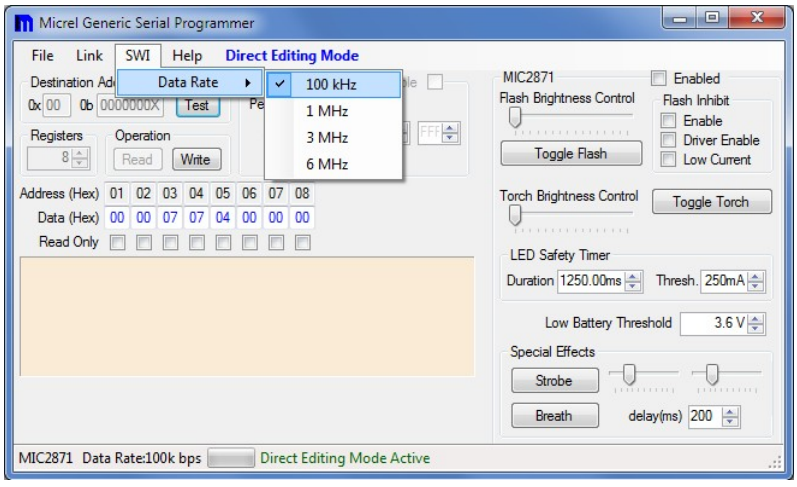
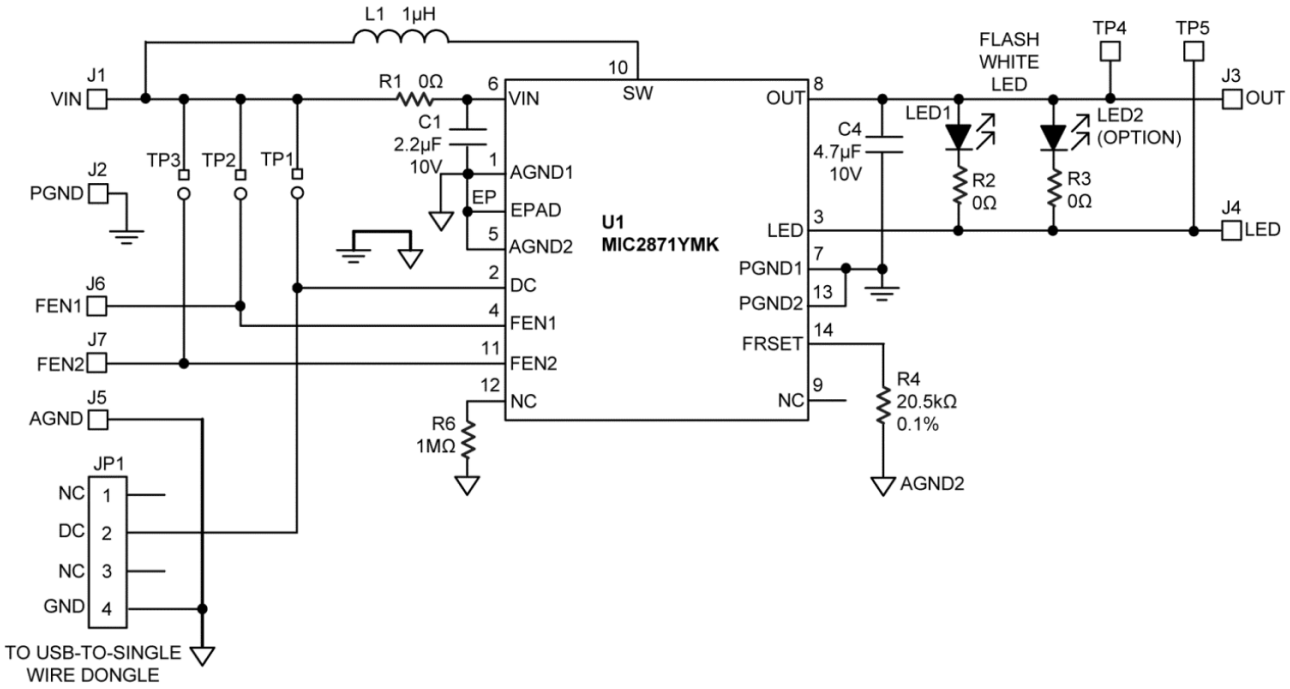


Figure 9. Setting Data Rate from Pulldown Menu

Evaluation Board Schematic



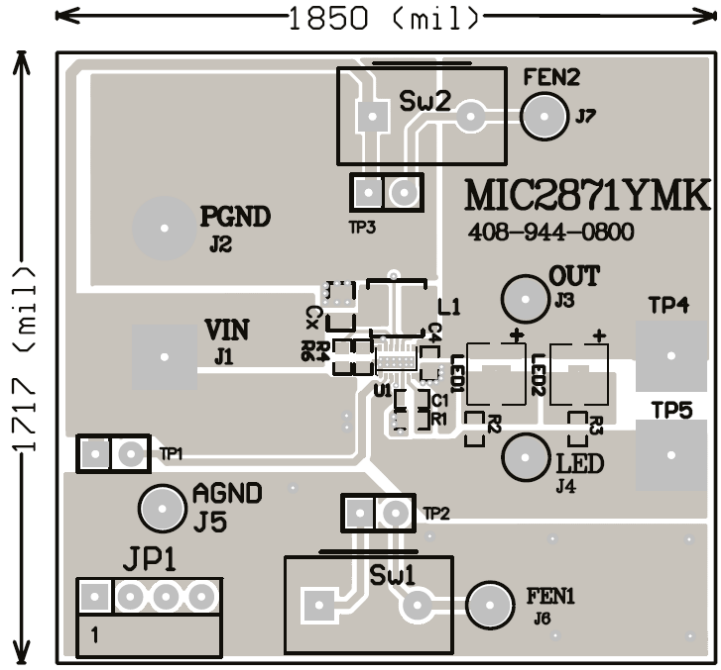
Bill of Materials

Item	Part Number	Manufacturer	Description	Qty.
C1	GRM188R61A225KE34D	Murata[1]	Ceramic Capacitor, 2.2µF, 10V, 10%, X5R, 0603	1
C4	LMK107BJ475KA-T	Taiyo Yuden[2]	Ceramic Capacitor, 4.7µF, 10V, 10%, X5R, 0603	1
L1	PIFE25201B-1R0MS-39	Cyntec[3]	Inductor, 1.0µH, 3.55A, 2.5mm × 2.0mm × 1.2mm	1
LED1	SLSW6R007	Samsung[4]	High-Power Flash LED, 4mm × 4mm × 2.2mm	1
	LXCL-MN06-3002	Philips[5]	LUXEON Flash 6 Module, 4mm × 4mm × 2.2mm, 180lux @ I_{LED} = 1A LED	
R1, R2, R3	ERJ3GEY0R00V	Panasonic[6]	Resistor, 0Ω, 1/10W, 5%, 0603	3
R4	ERA3AEB2052V	Panasonic	Resistor, 20.5kΩ, 1/10W, 0.1%, 0603	1
R6	ERJ3GEYJ105V	Panasonic	Resistor, 1MΩ, 1/10W, 5%, 0603	1
U1	**MIC2871YMK**	**Micrel, Inc.[7]**	**1.2A High-Brightness LED Flash Driver with Single-Wire Serial Interface**	**1**

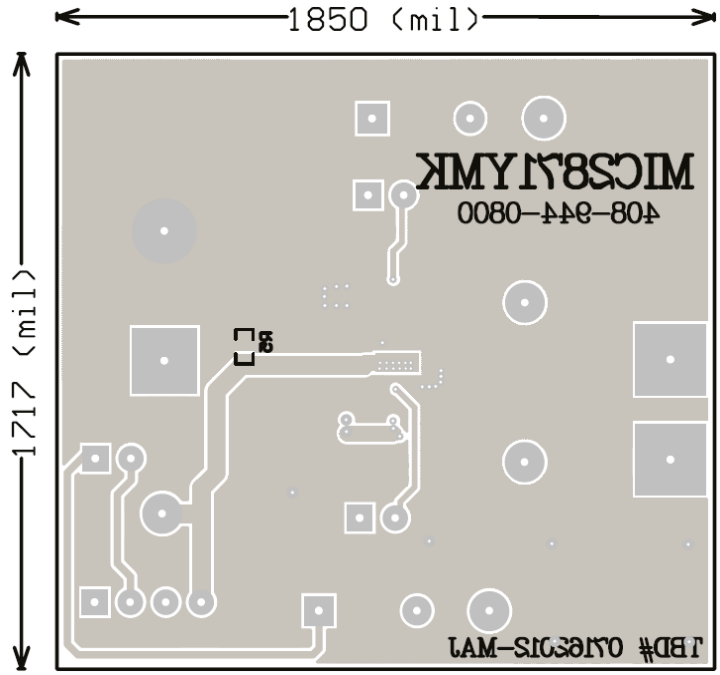
Notes:

1. Murata: www.murata.com.
2. Taiyo Yuden: www.t-yuden.com.
3. Cyntec: www.cyntec.com.
4. Samsung: www.samsung.com.
5. Philips: www.philipslumileds.com.
6. Panasonic: www.panasonic.com.
7. **Micrel, Inc.: www.micrel.com.**

PCB Layout Recommendations



Top Layer



Bottom Layer

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