OPEnS Power 3v3
Board Revision: 7.1
Document Revision: 1
Date: April 15, 2018
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Abstract

The OPEnS Power board is a simple, low cost circuit board that can be attached to an Adafruit Feather M0 microcontroller and a DS3231 real time clock breakout board to enable shutting off power to the microcontroller until a timed or sensed event wakes it up. The powered-down current draw of the system, minus any external circuits attached to the battery, is reduced to the order of 100 microAmps*. The board operates by applying two interrupt signals, one high-true and one low-true, to a flip flop integrated circuit to wake the device up. The flip flop latches the enable pin of the Feather's 3.3V regulator on or off. A digital output pin on the Feather is used to set the flip flop to latch the regulator off.

The OPEnS Power board is best suited for projects that require operating-time that are greatly shorter than their standby times. The lowest possible standby current achievable on the M0 without the OPEnS Power board is just under 1000 uA. By using the OPEnS Power board and assuming the on-time is far greater than the standby time, the battery life of the Feather M0 project can be increased by a factor of 10.

* Based on previous iterations of OPEnS Power. New iteration should be tested for exact value.

Characteristics

Characteristic	**Condition**	**Min**	**Max**	**Units**
VCC		TBD	5.5	V
CP Logic HIGH	VCC = 2.3-5.5V	0.7 VCC		V
CP Logic LOW	VCC = 2.3-5.5V		0.3 VCC	V
RTC_INT Logic HIGH	VCC = 4.2V	0.7 VCC		V
RTC_INT Logic LOW	VCC = 4.2V		0.3 VCC	
INT_2 Logic HIGH	VCC = 4.2V	2.5		V
INT_2 Logic LOW	VCC = 4.2V		1	V
3v3 Reg EN Output Logic HIGH	VCC = 4.2V	TBD		V
3v3 Reg EN Output Logic LOW	VCC = 4.2V		TBD	V
Quiescent Current*	CP = LOW		TBD	uA

*Does not include quiescent current from circuits using battery voltage on Feather M0 board.

Theory of Operation

The OPEnS Power board uses a flip flop integrated circuit (IC) to turn on and off the 3.3V regulator on the Feather M0. The flip flop IC's input pin D is permanently attached to the battery source. The logic state of the input is copied to the output, Q, when the clock pulse (CP) pin receives a rising edge from the M0. When CP receives a falling edge, nothing happens. The flip flop is powered from the battery and decoupled with a 100nF capacitor. The battery voltage pulls up the C-bar input through a 10k resistor. The C-bar input latches the Q output to ground whenever it is pulled low. The output remains low, ignoring any CP rising edges, until C-bar is pulled high.

The low-true interrupt meant to be connected to the DS3231 Real Time Clock's (RTC) alarm output is directly tied to the C-bar pin. A second interrupt pin, INT_2, is high-true and is connected to the gate of an N-channel MOSFET. The MOSFET's source pin is tied to ground and its drain pin is connected to C-bar so that a high voltage on the INT_2 signal will pull C-bar low. It is possible to read the state of C-bar through GPIO_READ by using input_pullup() in the Arduino IDE. A diode between this pin and C-bar protects the state of C-bar when the M0 is powered off.

The Q output is a low-true signal but the 3.3V Regulator's Enable pin is high-true. The Q output is connected to the gate of a P-channel MOSFET to invert its logic. When Q is high, the source and drain of the MOSFET are essentially disconnected and the regulator enable pin is tied to ground. When Q is low, the source and drain are essentially shorted and the regulator enable pin receives the battery voltage through a 500 ohm resistor.

Application

Connections

The application of the OPEnSPower 3.3V board is simple. An Adafruit Feather M0 board should be connected to the board. The default Read and CP pins are A4 and A5, respectively, if their jumpers are soldered. If their jumpers are not soldered, different pins can be chosen by soldering a wire to the flip-flop side of each jumper. The current draw of these signals is very small and so wire-wrap is acceptable.

A 3.7V LiPo battery should be connected to the Feather's battery receptacle. The battery source is connected to the OPEnSPower board through the Feather's BAT pin.

Finally, the RTC_INT pin should be connected to a low-true interrupt signal to wake up the device. This is usually the DS3231's SQW pin, and an alarm should be set before shutting the

M0 down. A high-true interrupt signal can be connected to INT_2. Generally, such a device would have its own power supply and its ground should be connected to the M0 and OPEnSPower ground.

Software

Assuming the DS3231's SQW pin is connected to the RTC_INT ("INT-") pin of the OPEnSPower board, the control scheme is very simple.

1. Wake up the device if it is off by shorting the RTC_INT pin to ground.
2. Read volatile variables from Flash storage or wherever they are stored between power cycles.
3. Perform desired functions.
4. Save volatile variables to persistent storage location.
5. Reset RTC alarm and set new alarm time for the system to wake up.
6. Shut the device off by pulling GPIO_CP high on the M0.

Schematic

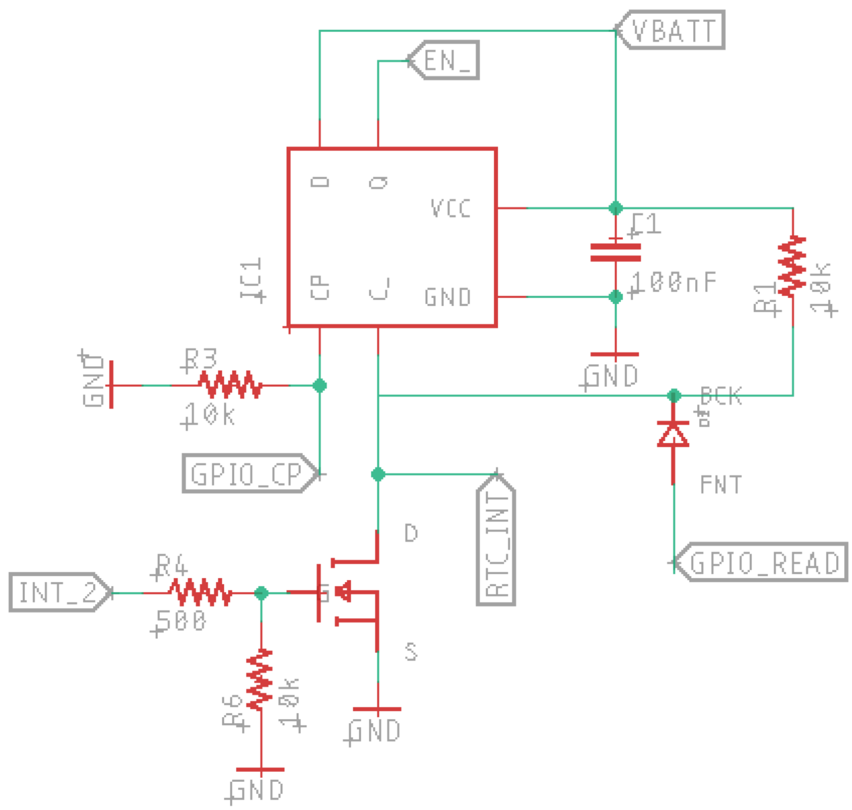

Figure 1: The flip flop control circuit is shown in EAGLE CAD.

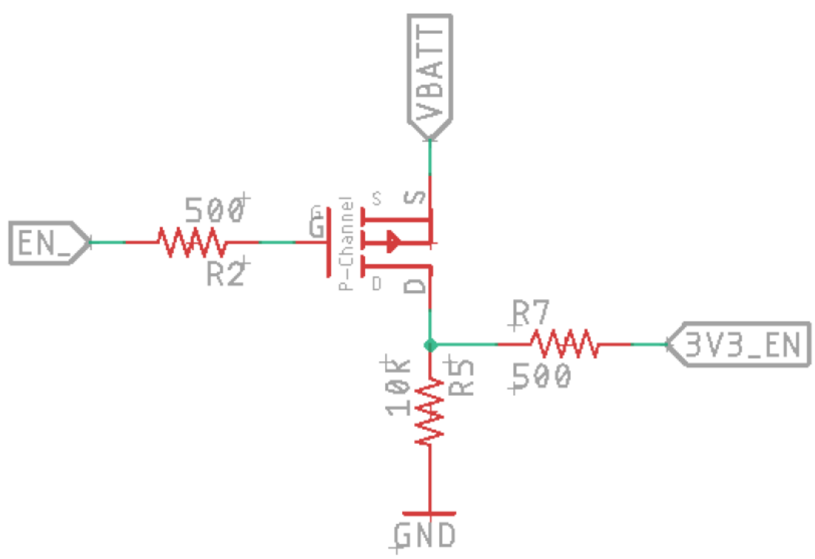

Figure 2: The output of the flip flop circuit, "EN_", is inverted with a P-channel MOSFET.

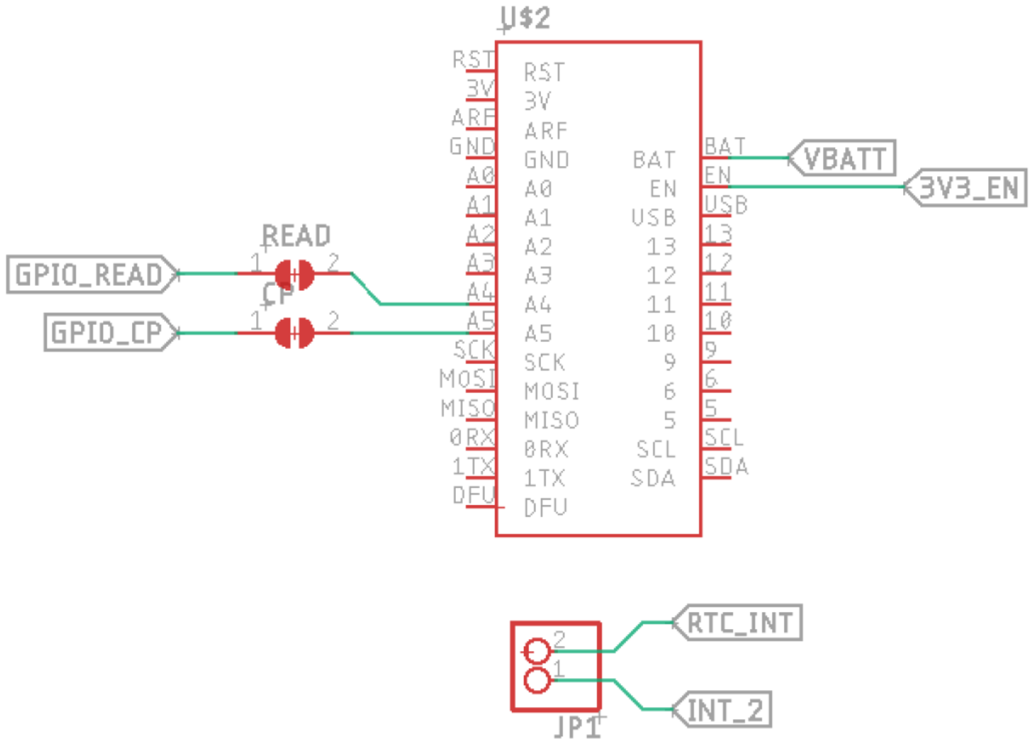

Figure 3: The Feather M0 is connected to READ, CP, VBATT, and 3v3_EN.

Board Image From OSHPark

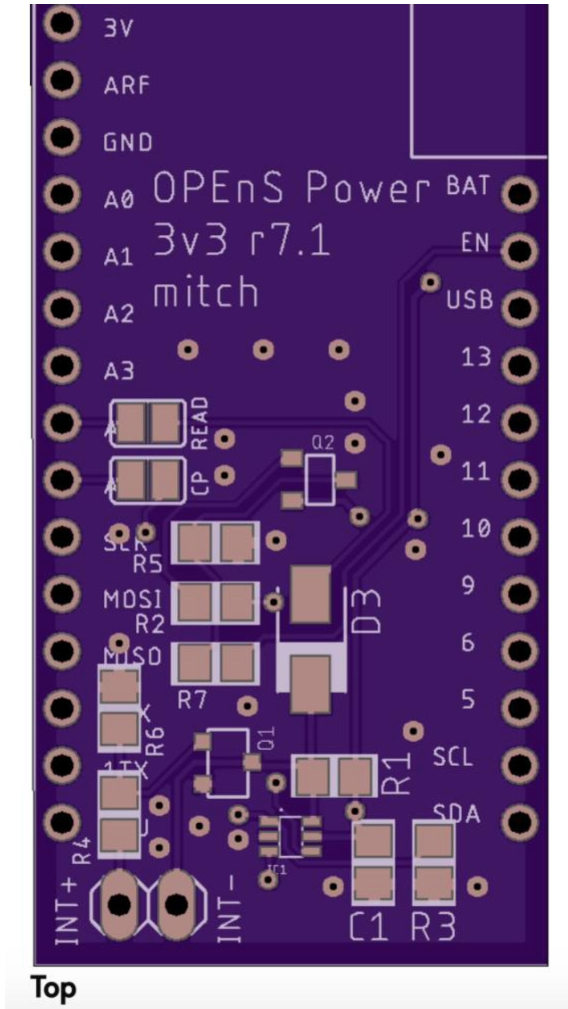

Figure 4: Top view of board after submitting to OSHPark for printing. Before operating, the CP and READ jumpers should be bridged with solder.

Bill of Materials

Item	Value / ID	Footprint	Quantity	Board ID	Source (Hyperlink)
Resistor	500 Ohm	0805	3	R2, R4, R7	Digikey
Resistor	10 kOhm	0805	4	R1, R3, R5, R6	Digikey
Capacitor	100 nF	0805	1	C1	Digikey
MOSFET, N-Channel	2N7002-7-F	SOT-23-3	1	Q1	Digikey
MOSFET, P-Channel	SSM3J3228R	SOT-23-3	1	Q2	Digikey
Diode	APD340VRTR-G1	DO-214AC	1	D1	Digikey
Flip Flop	NC7SZ175	SC70/SC88	1	IC1	Digikey

Future Development Suggestions

If a more efficient, simpler, or cheaper board is desired in the future, there are several routes that could be investigated. To start, the flip flop circuit could be redone or a new flip flop could be chosen so that the interrupt vectors act to pull the output of the flip flop high rather than low. This would remove the requirement of the inverting P-channel MOSFET circuit. For maximum efficiency, it would be desirable to fully analyze the Feather M0's 3.3V Regulator characteristics and adjust the interrupt vectors' rise and fall times and phase so that a flip flop IC is not necessary at all. It is worth noting that the internal leaking current of a LiPo battery is on the order of 100 uA, so reducing the quiescent current below this level has diminishing effects on overall battery life.

It should also be noted that this board does not disconnect the battery from the system during shutoff. There is a voltage divider on the Feather M0 feeding into an input pin to allow it to read the battery voltage, but the current draw of this divider is about 42 uA. The resistors can be removed to further reduce the system's standby current. The standby current of the 3.3V regulator when EN is low is on the order of 8 uA and so it is not useful to work around it.

Reference Documents

Datasheet of Flip Flop: https://www.onsemi.com/pub/Collateral/NC7SZ175-D.PDF

Datasheet of Feather M0 3.3V Regulator:
http://www.mouser.com/ds/2/146/SPX3819_DS_R200_082312-17072.pdf

Boards for OPEnS Lab are generally ordered from the 2-layer PCB Pool of OSHPark:
https://oshpark.com/