Reviewing the Mayfly 1.1 ~ Neil Hancock Apr/6 2022

The new Mayfly 1.1 has some great new features, though they may not be very visible to begin with. I'm going to give a personal perspective on the value of some of these features, and on what might be missing.

The Mayfly series has been designed by Shannon Hicks for the Stroud Water Research Center's (SWRC) open software environmental leader ModularSensors package. This hardware and software is the logger "glue" between sensors, and pushing the data wirelessly to a cloud location – like https://monitormywatershed.org/

SWRC demonstrates technical leadership in using rugged environmental sensors/transducers to automate measurements in the real physical world for water temperature, water depth, turbidity, PH and other physical parameters in specialist instruments.

Mayfly 1.1 provides +11.2V @100mA

There are a number of new features to Mayfly 1.x. I'm going to focus on the powering as this is one of my technical specialties. There are many improvement but there are also some software enhancements needed to make it work reliably. If you want to have a system that uses +12V transducers, then read on. If your system has simple low power (5V or 3.3V) sensors, a good solar aspect, and the battery (4400mAh) is always topped up, never goes under a measured Vbat of 4.0V, and has worked very well so far, then you won't see a lot of difference with Mayfly 1.1.

The nominal +12V, boosted from the LiPo battery, enables real-world sensors/transducers to interface to the internet. The new release of Mayfly 1.1 does this by supplying a switched +12V power, an enhanced Xbee modem interface, and enhanced LiPo battery charging from Solar Power. Fantastic to see.

I use "transducers" to mean a sensor that is external to the system, and "sensor" when it's a simpler interface.

This +12V is on both 2x10 black headers, and selectable for the 4pin Grove and Qwicc connectors.

The key for a low total cost, operating reliably remotely in the field, is integrated Mafly with solar powering and storing the power in a LiPo rechargeable battery AND matching the usage to the battery AND managing the power usage in software. That is ensure the **Power Demand** of transducers, efficiently matches available power. A large solar panel, with standard +12V lead acid battery storage can cost way more than the Mayfly. The recommendation for a Mayfly is 4400mAh battery(s), with a 3-to-10Watt Solar Panel.

One difficulty with any electronic package of hardware and software is figuring out what works, and estimating what the "Technical Debt" of the system might be. On the one hand the Arduino systems are designed to be EASY to start – which is fantastic. However, once a system is started, it needs to be reliable. Reliability is a big challenge – it's what you think should just have worked, but for some tiresome reason it doesn't. Arduino rarely talks about reliability of software and hardware and powering – they are difficult subjects.

Technically difficult areas are often discussed as “Use Cases”. One “Use Case” example: Having a dead battery, and the sun is coming up. A weak solar signal starts to charge the battery, and the modem or power hungry transducers turn on. It all worked with a fully charged 4.2V LiIon, but now the battery is low and discharged. The old Mayfly 0.x failed with this scenario; it lacked a good solid USB 0.5A to get the battery charged to a useable state

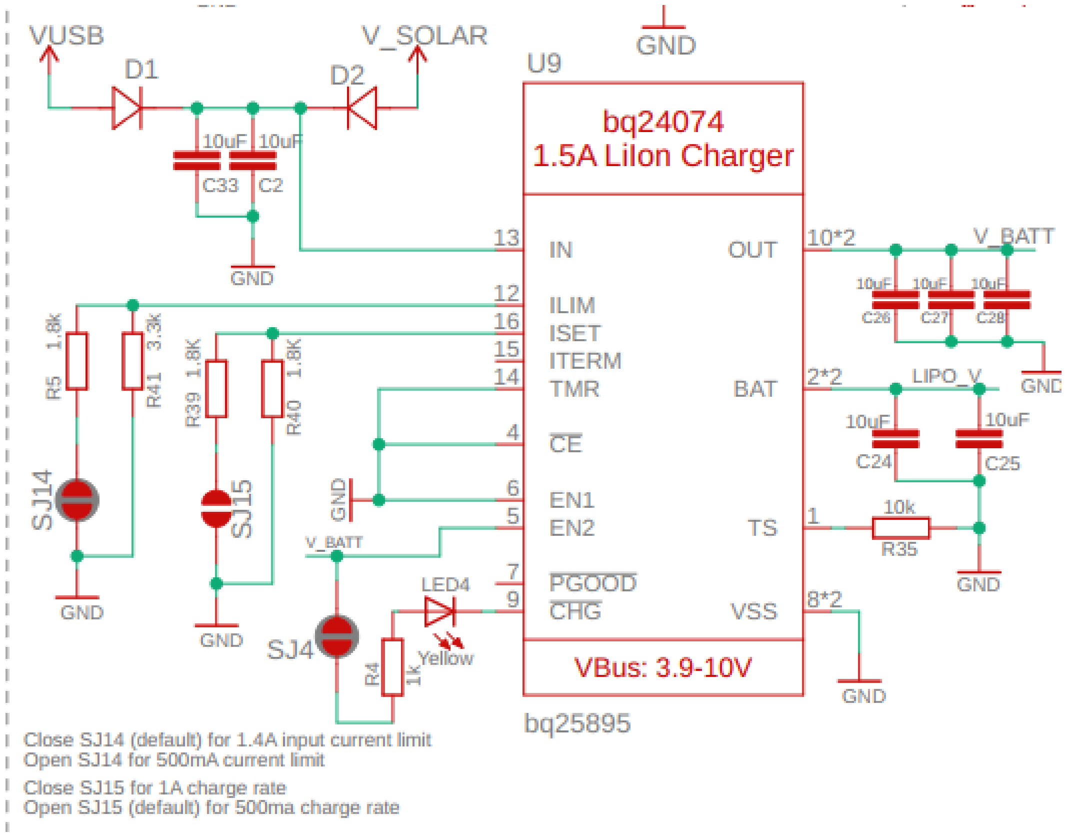
Exciting new powering subsystem

This is where the Mayfly 1.x new powering subsystem is very exciting, with its more reliable powering. This consists of (A) LiPo Charger (B) voltage regulators – or Low Drop Out (LDO) regulators.

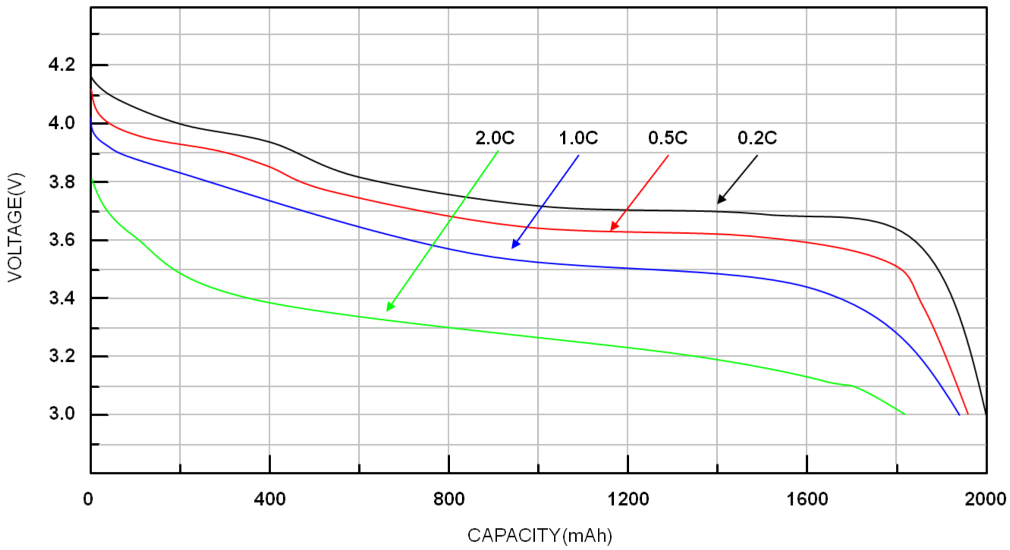
For (A) There is a new BQ24074 – or “Linear Battery Charger with PowerPath”. This is configured to be able to manage 1.5A (7.5W @ 5V) from the Solar Panel, of which 1A can be used to charge the battery or the provide it to V_BATT. The V_BATT can supply from the LiPo battery up to 4.5A, which is inline with 1C from a 4400mAh.

(B) There is a revamped LDOs “XC6220B331MR” – dropout or overhead is ~0.1V@300mA . There are three LDO regulators so that the processor mega12844 powering is isolated from the others, the Xbee can now be turned ON/OFF and the 3V3_SW is separate. The 3V3_SW drives the 5V_SW and 12V_SW

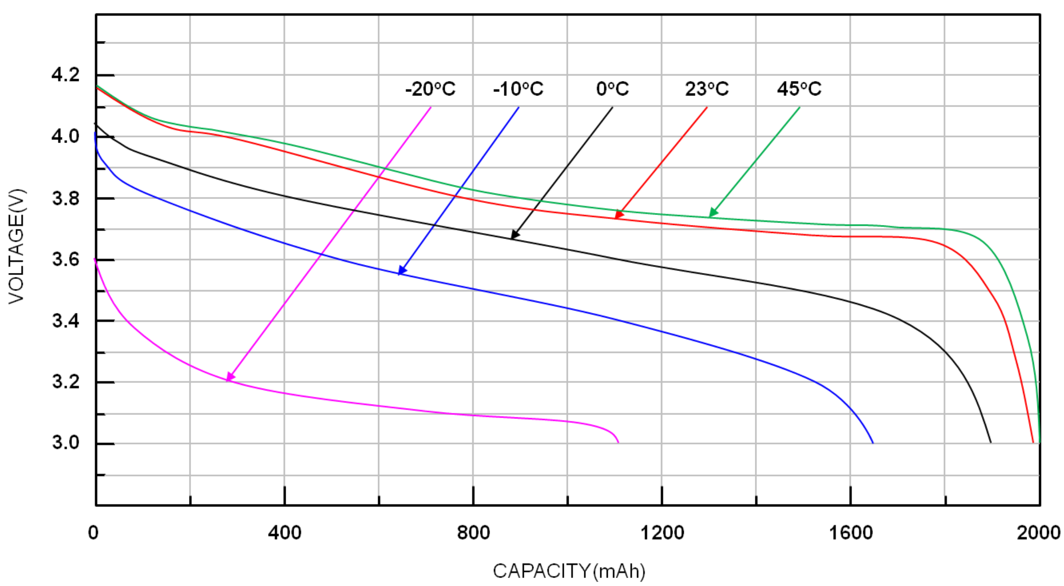
The BQ24074 PowerPath – technically called Dynamic Power Path Management, is more reliable powering of the processor and subsystems, when there is a discharged LiPo battery. Now with the PowerPath the processor and internal power boost circuits are given as much power as is available, and only left-over power is used to charge the battery. That’s the simple version – read the data sheet for a more technical in-depth explanation, especially if you have power hungry sensors.


VUSB
V_SOLAR
D1
D2
GND
U9
bq24074
1.5A LiIon Charger
10uF
10uF
C33
C2
GND
13
IN
OUT
10*2
V_BATT
10uF
10uF
10uF
C26
C27
C28
12
ILIM
16
ISET
15
ITERM
14
TMR
BAT
2*2
LIPO_V
GND
R5 1.8k
R41 3.3k
R39 1.8K
R40 1.8K
4
CE
10uF
10uF
C24
C25
6
EN1
5
EN2
TS
1
10k
R35
GND
SJ14
SJ15
V_BATT
GND
GND
7
PGOOD
LED4
9
CHG
VSS
8*2
SJ4
R4
1k
Yellow
VBus: 3.9-10V
GND
bq25895
Close SJ14 (default) for 1.4A input current limit
Open SJ14 for 500mA current limit
Close SJ15 for 1A charge rate
Open SJ15 (default) for 500ma charge rate

In addition, the Mayfly 1.1 has a set of voltage regulators that work better with low LiIon voltage down to I calculate ~3.395V. For an electronic designer, it's very sad, but real world devices are pretty complicated and often technical tradeoffs need to be made, and it can be difficult to explain. Powering a system is simple, when the power usage can be ignored. Running off a solar powered LiPo rechargeable batteries is complicated when a lot of power is used up. For the recommended Adafruit battery "ICR18650 4400mAh 3.7V", fully charged LiPo are 4.2V, and then it provides power at a nominal voltage sinking to 3.7V. As it supplies more power its voltage drops, to about 3.3V. Then it drops quickly to 3.0V and the battery disconnects to prevent damage to the battery. The diagram below is a typical LiIon discharge curve (it shows for 2000mAh, and I expect it to be the same curve for the 4400mAh). For most Mayfly applications the "0.2C" or 0.2*4400= 880mA is the easiest curve to use:



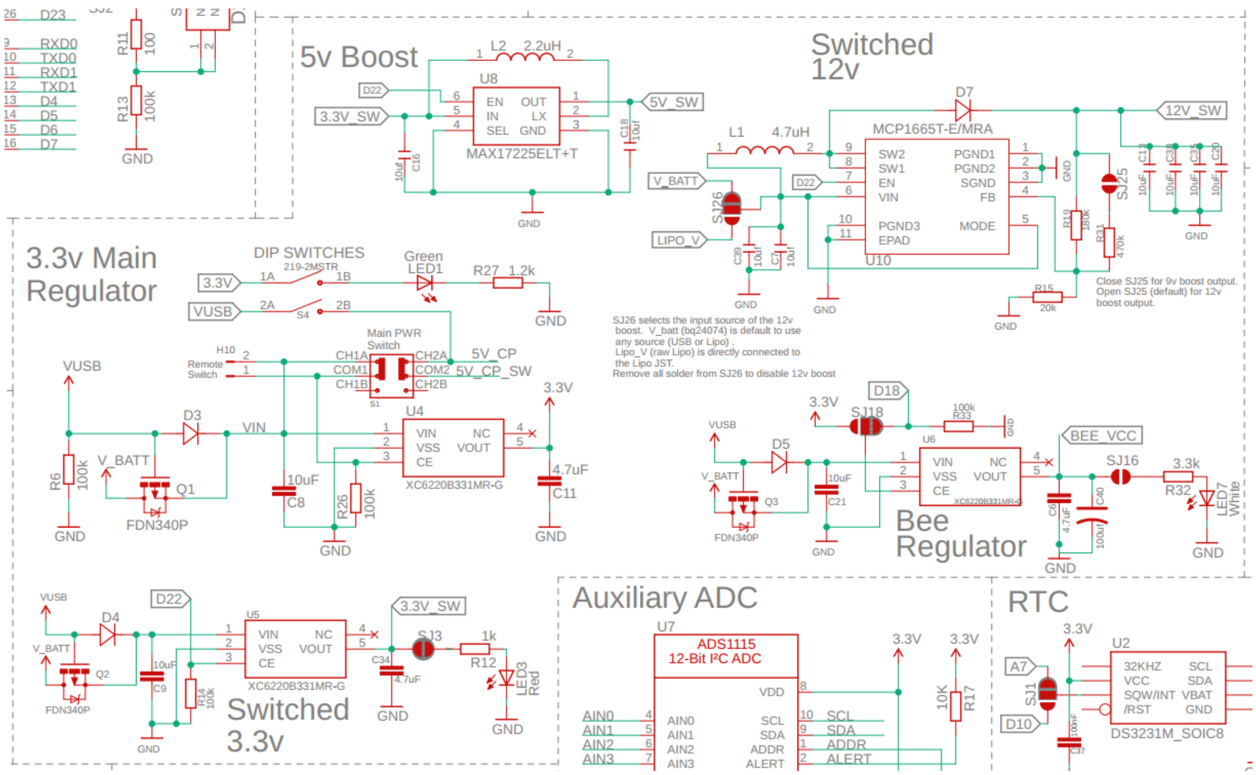
If its cold, then that LiPo voltage can drop even more.



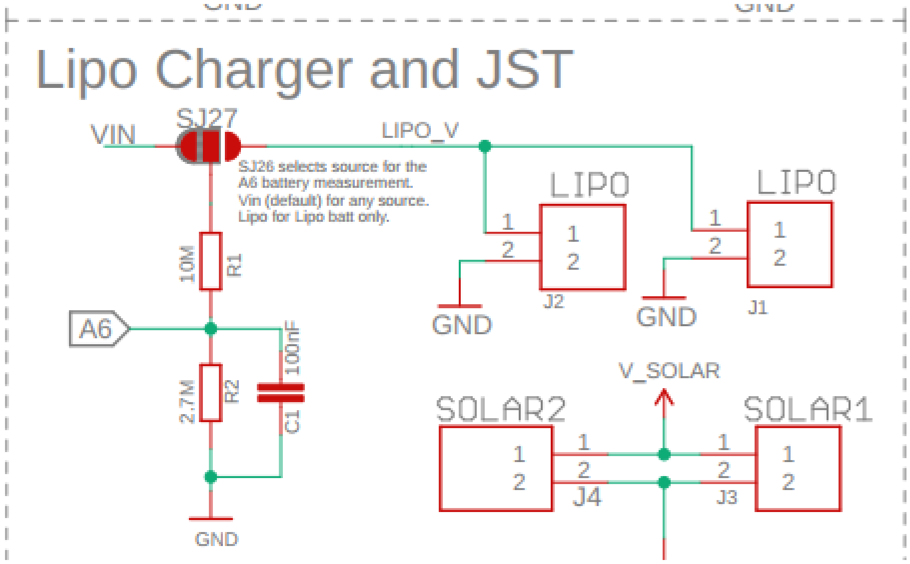
So if the Mayfly is to run the whole year, working at 0C say, then the Power Demand calculations need to be made as if its 0C the whole year.

Mayfly powering from the LiPo

The Mayfly powering circuit which must work of the lowest likely LiPo voltage , has a “voltage budget” as the processor uses a standard 3.3V, with electronic 3.3V Low Drop Out regulators to manage from the LiPo (4.2V)→ 3.3V



I hope I have shown it's valuable to accurately measure the LiPo voltage when it's sinking from 3.7 to 3.5, especially the 3.5V. The LiPo voltage can be measured via the ADC A6 ~ called Vbat. A complicated circuit winkle is the Analog to Digital Converter that measures battery voltage, uses the processors 3.3V as a reference. So as the LiPo voltage drops at some point, it could be 3.395V – remember that 0.095V dropout for the LDO – the voltage measurement becomes nonlinear by the nature of the design. .



The value of measuring the LiPo voltage is to determine when it is too low to support some power activity.

For the default SJ27 setting Mayfly 1.1 measured the supplied voltage after PowerPath – which could be more elevated or less than the battery voltage by +/0.13V – however it's complex. For the lowest battery measurement, it could be that the Vbat becomes inaccurate/non-linear/undefined under 3.45V

For better accuracy the SJ27 default can be de-soldered and re-soldered to read directly from the LIPO_V

Matching Power Demand to Battery Capacity

For reliable powering, the power demand needs careful management when the Vbat is descending under 3.7V and above say 3.5V. If the Power Demand is too much for the battery to supply, it is likely to cause the processor to reset.

With measuring the LiPo battery voltage, there is a measurement error range, that is for a reported measured voltage, the actual voltage is going to be a range of voltages. For the Mayfly1.1 I calculate the following

Reported Vbat		
	Actual LiPo Range	
Vbat	VLIPO-	VLIPO+
3.700	3.548	3.852
3.650	3.500	3.800
3.600	3.452	3.748
3.500	3.357	3.644
3.400	3.261	3.539

That is when using a reported Vbat of 3.5V, the actual voltage may be between **3.357**V and 3.644V. For power demand the lower value needed to be used. To stay above a real battery voltage of 3.5V, a measured Vbat of 3.65V needs to be used.

From making measurements with the Mayfly 1.1 Vbat, it still is not as good as the ADC 10bit circuit would suggest. My measurements show it is 'noisy' and somewhat non-linear. With some software "filtering" enhancements I hope to make it good enough to be reliable for measuring LiPo battery when it's discharging from 3.7V→3.4V. See this issue for measurement data.
https://github.com/EnviroDIY/EnviroDIY_Mayfly_Logger/issues/32

A "use case" is for the system to work through periods of no solar – say two weeks of limited solar – till it has no more power, and then wait patiently for solar to return. The requirement is to accurately measure the battery voltage and then as the voltage, and available power is more limited, gracefully use the power in an optimally reliable way. Unfortunately, my measurements, with the Mayfly1.1, the Vbat has 0.2V noise spike and the accuracy is +-0.1V. See
https://github.com/EnviroDIY/EnviroDIY_Mayfly_Logger/issues/36

These noise spikes reduce confidence in accurately measuring real battery voltage, versus the ADC reported battery voltage. If you want to measure accurately a reported threshold of say 3.6V, then you may need to use a threshold of 3.9V.

A software solution is do software based "noise filtering" and that improves the effective accuracy. The objective is to accurately measure a low voltage, so the filtering takes 8 samples (@15minutes this is two hours) and chooses the lowest value of reported voltage in the sampling period (2hours).

For a software filter see https://github.com/neilh10/ModularSensors/issues/75#issuecomment-1074111497

The new +12V

Now getting to the new nominal +12V system – it's a great feature – 100mA @ 11.2V, with power limitation capability. I should say at the outset there is trail of +12V discussion here.

https://github.com/EnviroDIY/YosemitechModbus#power-supply

As an EE design engineer, I know moving the technical needle can be challenging. The Mayfly 1.0 +12V circuit didn't work as expected, IMHO probably an inductor issue, and then with the worldwide shortage of devices a whole new design was used for Mayfly 1.1. **Kudos** to Shannon for getting a new circuit out so quickly. Though unfortunately, it isn't perfect, and has a stated 11.2V @100mA

The +12V powering can be used to power SDI-12 circuits or a Modbus instrument.

For Modbus interfaces a special RS485 board is needed, and I hear some are in the works. There are also a number of community boards one of which I designed for my use. (Sorry to everyone who might have wanted one, it was a limited circulation board, and it's a $$ risk and work to build excess in case other people want it)

I would like to thank the SWRC, Shannon and Sara for making all the technology open source. I've done a fair number of enhancements on my fork and I'm happy to commit it back to the main ModularSensors should there ever be the bandwidth to absorb it.

More Work

I still need to discharge a LiPo battery completely and then slowly charge it to see how the filtered Vbat voltage is read.

Crystal Ball Gazing – white paper discussion

Looking to the future, hopefully there could be a Mayfly with a switched +12V power circuit that can produce 600mA @ +12V from a LiIon battery at 3.8V ,and be used for a number of transducers. https://github.com/EnviroDIY/Mayfly-Modbus-Wing/issues/3

Currently ModularSensors, turns on all the sensors in parallel. This could lead to excessive power demand, where individual transducers are OK, but not three or four of them together. A software solution could be for smarter sensor management by ModularSensors in serializing the sensor power turn ON. This could allow the heavy powered transducers to still be matched to the same power supply.

See https://github.com/EnviroDIY/Mayfly-Modbus-Wing/tree/master/knh002-MayflyWingShield

Guarantee Delivery of Readings to MMW

A plug for some work I've done, is "Guarantee Delivery" of readings to MMW. This allows better power management by not using the power-hungry modem when the LiIon drops to say 3.8V. Available power is then reserved only for powering the sensors, and stores the readings on the uSD waiting for the battery voltage to increase. When the battery is charged backup, the stored readings are reliably delivered to the cloud (MonitorMyWatershed.org). In addition, this "Guarantee Delivery" feature ensures that if the wireless connection can't be made, the readings are delivered at a later time when the wireless connection is made.

I'm working on scaling a deployment of Insitu LT500 sensors which require +8V, and using the Insitu Modbus default baud 19200, and Even parity for it to be easy to connect and install. The same program is used for each Mayfly and configured for MonitorMyWatershed on the microSD in a file ms_cfg.ini The is going to be easier with Mayfly 1.1, though with my own circuit for the Modbus/RS485 interface.

Neil Hancock

Discussion on enviroDIY.com or https://github.com/neilh10/ModularSensors/discussions

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