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TOLERANCES

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TITLE

OPERATING MANUAL
MODEL 786

SCALE	SIZE	FSCM	SHEET	DRAWING NUMBER	REV.
N / A	A	61651	1 OF 23	15-049	-

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1 Overview

The 786 is a high current driver designed primarily for diode pumped passively Q-switched lasers.

1.1 Description

The 786 is preferentially designed for battery operated portable applications. As such, minimization of size, weight, power consumption and cost were the primary design drivers. The driver consists of 4 subsystems. See Figure 1: Block Diagram These are:

1. The power system.
2. The driver system.
3. The pulse truncation system.
4. The monitor system.

1.1.1 The Power System

The internal battery resistance and the associated power wiring resistance can cause a significant voltage drop during the pulse and should be minimized. The laser voltage drop is less than 2V normally. The rest of the electronics requires more voltage. By capturing the higher battery voltage between shots and using it to operate the low current electronics, the battery life can be extended. It is also supplied for use as a bias source for an optional photo detector to respond to the T_o event. See Figure 1: Block Diagram

1.1.2 The Driver System

The customer supplies a TTL to 5V CMOS pulse to the Pulse input of the unit. The input pulse is digitally combined with the signal from the pulse truncation circuit and applied to the clipper. The clipper accepts the 3-4V digital pulse from the input circuitry and clips it to an analog voltage pulse corresponding to the selected current. This level is set by a trim pot, but can also be set with a fixed resistor. This choice is determined by the customer at time of order. The fixed resistor is only practical for OEM use and is recommended for high shock and vibration environments. The clipped voltage is applied to the input of an analog current source. This current is applied directly to the laser diode. See Figure 1: Block Diagram

1.1.3 The Pulse Truncation System

The pulse truncation system was included in the system to aid in extracting the maximum service life from the battery. The input can be used in three ways.

First, the current output from a photo-diode can be applied. When the laser fires, the current pulse from the photo-diode causes any remaining pumping current pulse to be truncated. The power which would be used to continue pumping after the laser fired is saved. The circuitry is optimized for this method.
Second, an external TTL level or higher pulse of 200nS min width may be applied to achieve the same truncation.

Third, a 2.4 to 5V DC level may be applied to the input for use as a laser inhibit. It will prevent the driver from producing a current pulse until lowered to the '0' level. See Figure 1: Block Diagram

1.1.4 The Monitor System

The monitor system is a current source output providing a scaled version of the current pulse. The primary use is to monitor the current during setup and for test purposes. The current source output is used to render the output immune to the ground line drops during the pulse. To use it install a 100 ohm resistor from the output to the ground to be used by the measurement setup. Read the voltage across the resistor. 1V=10A. If using a scope, set the input to 50 ohms, and connect directly to the output and ground via 50 Ohm coax. Calibration is 50mV/A. See Figure 1: Block Diagram

1.2 Available OEM Options

These options are available in OEM quantities only. Due to the need to incorporate at assembly time and the need to modify test software for the special case. Consult factory with your requirements.

1.2.1 Fixed Current Setting

The trimpot can be replaced and a fixed resistor used to set the current to a customer selected value. This variant has considerably better ruggedness than with the variable resistor.

1.2.2 T_o Input Optimization

The input is already optimized for photo-diode input, so not much can be accomplished there. If the T_o input is not to be used, the circuit can be depopulated for cost minimization. It will also make the driver much more noise immune. If a logic signal is to be the input, the circuitry can be optimized for any logic family. Finally, if an analog signal is used, it can be optimized for the source impedance and voltage. The only limitation is that there must be enough energy in the signal to operate the circuit.

1.2.3 Connector Removal

The 5 pin connector can be removed to reduce height and cost. Connections can be made on the small pads under the connector position, if this is preferred.

1.2.4 RoHS Compliance

The standard version is not manufactured with a RoHS compliant process however; this option is available as the individual components are all RoHS compliant.

1.2.5 Extended Operation

The pulse minimum width of the output pulse is limited by the rise and fall times. Nearly all other parameters are limited by the maximum pass FET junction temperature of 125°C for any given cooling method (see Table 2). There is a maximum power dissipation which can be accommodated. Any combination of current, pulse width, rep rate, laser drop, and ambient temperature, which is inside the allowance, is acceptable.

To operate above 10 Amps, a factory modification would be required.

To increase the output compliance voltage, the following would be required:

1. Have factory perform a “two-supply” modification.
2. In the system, connect the VCC pin to a 5V (max.5.25V) power supply. Pin will draw 5ma max.
3. Connect the high current power and ground to a low impedance source (such as battery pack, see Para. 4.1.3 Choosing the Battery. The voltage must be at least 1 Volt above the laser drop at the specified current. Maximum voltage is 20V.

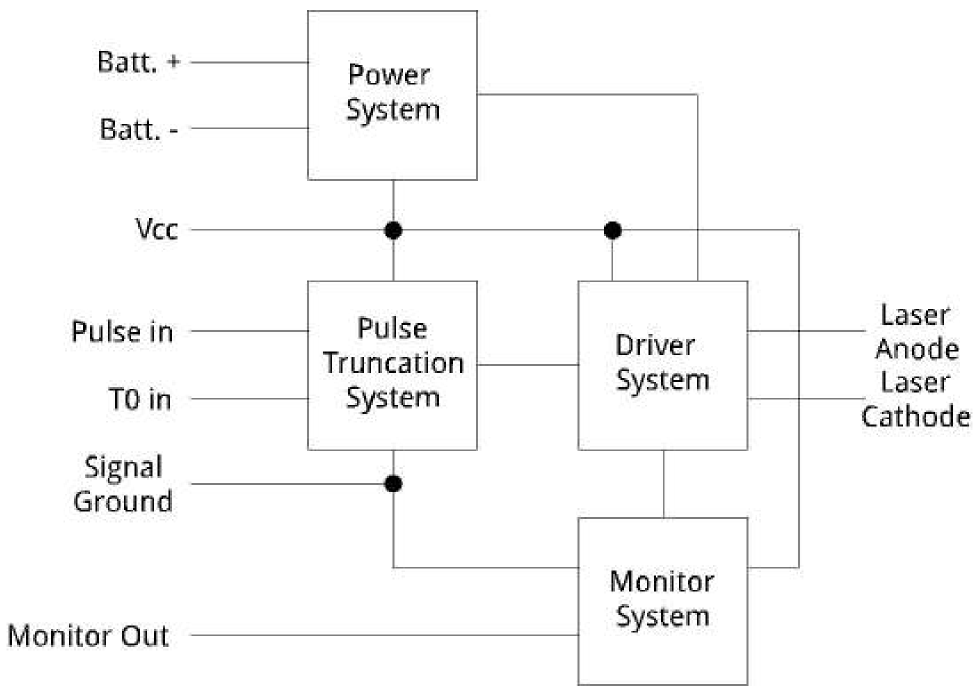

Figure 1: Block Diagram

2 Handling

2.1 Precautions

2.1.1 Static Sensitivity

The driver is sensitive to static. It should be handled only at static safe work stations.

2.1.2 Back Side of Assembly

Note that the large pad area on the back of the board is **NOT** ground. This surface is the primary heat sink for a power FET and is electrically tied to the Drain of the FET. Shorting this pad to ground while operating **WILL** destroy the laser and may possibly destroy the driver as well.

2.1.3 Laser Devices

Please heed all laser safety practices. The diode pumped passively Q-switched lasers and laser diodes which can also be driven can put out sufficient power to damage skin and eyes. Do not apply power to this driver until you are certain everyone in view from the laser location is suitably protected.

2.1.4 Batteries

The unit is designed to operate from a single lithium ion primary or secondary cell 3V to 3.7V nominal output or two lithium ion primary cells nominal output 1.5V each. Be watchful when handling these batteries. Accidental shorting can cause metal current path to heat to red hot in seconds and some battery types can explode. When recharging secondary batteries, make certain that the charging setup adheres to the current and voltage limitations for each battery chemistry. Some of the batteries can explode if overcharged or charged at too high of a current.

2.2 Mounting the Driver

The driver can be mounted for cooling by 3 different methods:

1. Natural convection cooling
2. Forced air cooling
3. Direct Conduction cooling

See Table 2 for limits of power dissipation with various cooling schemes.

Item	Qty	Source
Washer Flat #2 X .140” OD X .010” THK.	4	Seastrom 5710-7-10
Machine Screw 2-56 X 5/16”	4	McMaster-Carr 91737A053
Spacer, nylon 6-6 #2 X 1/8” OD X 1/8”_LG	4	McMaster-Carr 94639A147

Table 1: Mounting Hardware

Position	Cooling	Power[3]	FET Temp	Rise	Thermal Resistance
Long side down, output to the left	Convection	1.56W	104.4	78.8	50.5°C/W
On end, output down	Convection	1.64W	106.8	81.2	49.5°C/W
On end, output up	Convection	1.68W	107.4	81.6	48.6°C/W
Face up	Convection	1.54W	105.8	80.2	52.1°C/W
Face up, air from long side	Forced[1]	1.88W	90.9	63.5	34.7°C/W
Face up, air from load end	Forced[1]	1.82W	88.8	63.2	34.7°C/W
Face up, air from above face	Forced[1]	1.80W	80.6	55.0	30.5°C/W
Face up, no standoffs, insulator	Conductive[2]	1.68W	50.8	25.2	15°C/W
Mounting surface vertical, insulator	Conductive[2]	1.70W	50.6	25.0	14.7°C/W

Table 2: Power Dissipation and Cooling

1. 100 lin-ft/min ±35, turbulence prevented more accurate measurement.
2. Mounted centered on 2.75” X 6” X .06” thick 6063-t651 aluminum panel with .010” Gap Pad 23000S30 as insulator.
3. Changes in power caused by changes in state of battery charge from test to test.

2.2.1 Natural Convection

The unit can be mounted in any position but if natural convection is to be used for cooling, the maximum cooling efficiency is obtained by mounting to a vertical bulk head. The preferred orientation is with the laser mounting pads up and the component side away from the bulkhead. Mount using hardware from Table 1. The lower most and upper most edges need at least ¼” to any object which can interfere with the airflow.

2.2.2 Forced Air

The unit can be mounted in any position. Orientation relative to the air flow is inconsequential. The spacing between the mounting surface should be increased to improve the air flow under the part. Longer screws and standoffs can be obtained from the source in Table 1. The screws need to be fillister head to fit the board properly. If space is premium, the hardware from Table 1 can be used and the board inverted. Two additional washers should be used under each standoff to accommodate the connector and tolerances. It would be necessary to generate clearance and access to the trimpot. This arrangement has better cooling than when mounted normally. It should be mentioned that the inverted mounting leaves the back surface exposed and consequently more easily shorted by accident. Under no circumstances should the board's back side be covered with any material if air cooling is being employed.

2.2.3 Conduction Cooling

Conduction cooling is the most efficient and robust method for cooling the unit. It is highly recommended for high stress environments (shock and vibration). It consists of using a high thermal conductivity mounting surface, and a soft Gap Pad®[1] material between the board and the surface. Should be .01 to .02 thick and have some form of cut through resistant reinforcement. No standoffs are used, but care needs to be taken that the screw pressure does not cause excessive flexing of the board. Not only does this cause a lot of stress on the components, but it may cause the center of the board to lift off the thermally conductive material. The result would be possibly fractured components, failed solder joints, or severe overheating. If this is problematic, with the selected material, washers can be installed under the board corners to provide a firm contact pad to bump the screw. The washers should be sized to give .003” - .005” of compression to the material.

2.2.4 Summary

There are so many combinations of current, voltage, temperature range, shock and vibration, available space and construction materials that trying to select a cooling method for any arbitrary packaged application is not possible. It is necessary to evaluate the options carefully and test under worst case conditions to guarantee a reliable OEM application. Use the Power Dissipation and Cooling Table to determine a starting place. The figures in Table 2 reflect the best that can be expected under the various conditions as this data was not taken in a sealed enclosure with other surrounding, heat generating electronics.

[1] Trademark of The Bergquist Company

3 Electrical Interface

3.1 Power Connections

3.1.1 Location

The main power and ground connections are solder pads on either side of the connector. See Figure 2.

3.1.2 Use

Attach the connections directly to the pads with polarity as shown. See Figure 2. Size the wires (switches, relays) to prevent excessive drop at the peak pulse current. Excessive voltage drop may reduce battery life, but has no detrimental effect on the driver. A table of wire resistance/foot for stranded wire is included (Table 3) for your assistance in choosing a wire type. Wires with higher stranding counts have more flexibility.

3.2 Signal Connector

3.2.1 Type

Miniature five contact housed connector Samtec P/N T1M-5-GF-S-RA. A mating connector with molded leads 12” long is included with the driver. Customized cables are available from Samtec[1].

3.2.2 Pin out

Pin:

1. Photo-detector Anode or Electrical T_o
2. Photo-detector Cathode Bias Source
3. Trigger Input
4. Analog Ground
5. Current Monitor Output

[1] Samtec USA P.O. Box 1147 New Albany, IN 47151-1147 Email info@samtec.com http: //www.samtec.com

3.2.3 Signal Description

Photo-Detector Anode or Electrical T_o

This input is optimized for T_o produced optically via a reverse biased photo-detector. This is a high impedance current source. When the source impedance is high the gain at the input is increased to maximum, 0.01V/µA. Attachment of a low impedance voltage source to this input would cause the amplifier to saturate even at near zero volts. To prevent this, the amplifier gain is compressed to below unity for a zero Ohm source. The result is that quite a large signal is required from a voltage source. This subject will be dealt with more thoroughly in the usage section. The purpose of the input is to truncate the current pulse as soon as the laser has fired. Additional pumping at that point is a waste of battery power.

Photo-Detector Cathode Bias Source.

This output is a 2.5V to 4V low impedance voltage source intended for reverse biasing of a photo-diode. It is meant for very small load currents. It is isolated from the input power supply voltage and filtered, but not regulated. It is meant to separate the T_o input from the sudden drop in the line voltage when the laser fires. That edge, under certain conditions, could couple through the diode capacitance and cause an unwanted pulse truncation.

This connection can also be utilized to supply a boosted voltage for the driver electronics to enable high current low temperature use. See 4.1.3 Choosing the Battery. This is not the same as "two supply" operation. See 1.2.5 Extended Operation. In this configuration the boosted voltage must be ≥ the highest battery voltage, not to exceed 5.25V.

Note: Some laser manufacturers tie the photo-diode cathode directly to the laser diode anode. Do not connect the common connection to this output. Malfunction and possible driver damage will result.

Trigger Input

This input drives two high speed Tiny Logic devices shunted by 1K Ohm (approximately 1K/10pf). The input pulse amplitude can be up to 5V max. A minimum logic '1' level of 2/3 of the battery output is required. The minimum "high" logic level falls with the battery voltage. This should prevent the missed triggers if the source is operating from the same battery. In the absence of a T_o signal, the pulse width of the current pulse is the same as the input pulse, unless it is truncated by a T_o event. In the interest of battery economy, this width should be set to the maximum pumping width which can be required by the laser source.

Analog Ground

The analog ground should be used as the return for all of the input and output signals.

Current Monitor

This output is a current source with a dynamic impedance of at least 1 Mega Ohm. The output voltage compliance is about 2 Volts when the battery is nearly exhausted and more with fresher batteries. The recommended load is 100 Ohms. The load resistor should be placed near the point of measurement and grounded in the host system near the ground for the measurement device. Alternatively, the resistor can be connected to the analog ground pin and the voltage measured differentially. For testing and inspection, the output can drive a 50 Ohm scope input directly. The calibration is then 50mV/A.

3.3 Laser Diode Connections

3.3.1 Location

The laser connections are a pair of solder pads on the opposite end of the board from the input connector, see Figure 2

3.3.2 Usage

Soldering the laser pump diode cathode and anode directly to their corresponding pads gives the best performance. In many cases that is not possible to do in real systems. If cabling is required, keep the cable as short as possible. Consider the use of flat cable with the conductors back to back, particularly if the cable must be long. This arrangement will reduce the inductance in the cable. If round wire must be used, route the wires side by side to reduce inductance. This is not as effective with round conductors as flat, but still worth the effort. Use as large of a wire as practical to keep down the resistance. The wire resistance should be below 20mOhms for each wire. See Table 3. Twisting the pair at about 4 turns per foot will help keep the wires together, but excessive twisting will increase the wire length needed to cover the distance and increase both the resistance and the inductance. Excessive resistance will shorten the battery life. Excessive inductance will cause overshoot and ringing in the driver output.

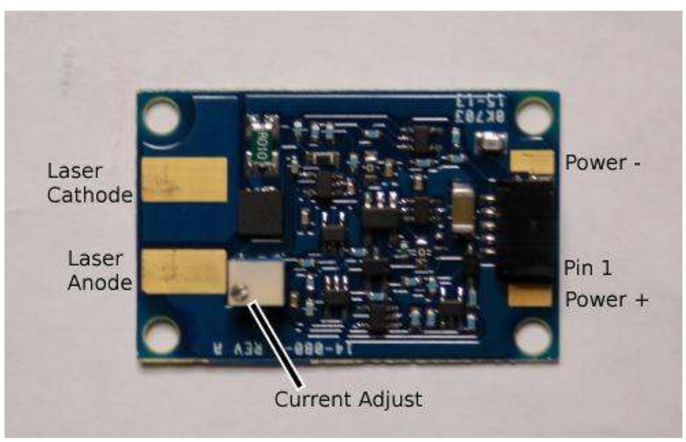

Figure 2: PCB Top View

Table 3: Stranded Copper Wire

		Approx O.D		Area	Weight		D.C. Resistance	
AWG	Stranding	Inches	mm	Circular Mil	Oz/Ft.	G/M	mOhms/Ft.	mOhms/M
26	I0/36	0.021	0.5334	250	0.0122	1.126	41.48	136.09
26	19/38	0.02	0.508	304	0.0147	1.369	34.43	112.96
26	7/34	0.019	0.4826	277.83	0.0135	1.251	37.30	122.37
24	7/32	0.024	0.6096	448	0.0217	2.018	23.30	76.44
24	10/34	0.023	0.5824	396.9	0.0192	1.787	26.09	85.60
24	19/36	0.024	0.6096	475	0.0229	2.13	21.08	69.16
24	41/40	0.023	0.5824	384.4	0.0186	1.726	25.59	83.96
22	7/30	0.03	0.762	700	0.0339	3.155	14.74	48.36
22	19/34	0.031	0.7874	754.11	0.0365	3.393	13.73	45.05
22	26/36	0.03	0.762	650	0.0315	2.932	15.94	52.30
20	10/30	0.035	0.889	1000	0.0484	4.502	10.32	33.86
20	19/32	0.037	0.9398	1216	0.0589	5.476	8.63	28.31
20	26/34	0.036	0.9144	1031.94	0.0499	4.643	10.05	32.97
20	41/36	0.036	0.9144	1025	0.0496	4.613	10.02	32.87
18	7/26	0.048	1.2192	1769.6	0.0858	7.976	5.86	19.23
18	16/30	0.047	1.1938	1600	0.0774	7.202	6.48	21.26
18	19/30	0.049	1.2446	1900	0.092	8.557	5.46	17.91
18	41/34	0.047	1.1938	1627.29	0.0787	7.321	6.37	20.90
18	65/36	0.047	1.1938	1625	0.0786	7.307	6.39	20.96
16	7/24	0.06	1.524	2828	0.127	12.738	3.67	12.04
16	65/34	0.059	1.4986	2579.85	0.125	11.622	4.02	13.19
16	26/30	0.059	1.4986	2600	0.126	11.711	4.00	13.12
16	19/29	0.058	1.4732	2426.3	0.117	10.938	4.27	14.01
16	105/36	0.059	1.4986	2625	0.127	11.83	3.99	13.09
14	7/22	0.073	1.8542	4480	0.201	20.179	2.31	7.58
14	19/27	0.073	1.8542	3830.4	0.185	17.247	2.70	8.86
14	41/30	0.073	1.8542	4100	0.198	18.452	2.53	8.30
14	105/34	0.073	1.8542	4167.5	0.202	18.765	2.49	8.17
12	7/20	0.096	2.4384	7.168	0.347	32.28	1.45	4.76
12	19/25	0.093	2.3698	6087.6	0.295	27.426	1.70	5.58
12	65/30	0.095	2.413	6500	0.299	29.26	1.75	5.74

4 Using the Driver

4.1 System Decisions (OEM)

4.1.1 Environment

The driver is rated to operate from -40°C to +60°C. First determine the real temperature range. This will establish whether the driver will meet the needed range. If short on the hot end, it may be possible to run the driver at a reduced power rating (lower rep rate, narrower pulses, lower currents) to a higher max temp., consult factory. Another possibility is to monitor the temperature of the power FET and shut down when necessary. This is practical if the application will be intermittent. If short on the cold end, there is no recourse. -40°C is the minimum operating temperature for many of the components. See Table 2.

Next evaluate the shock and vibration environment. In a benign environment, the driver can be used in any of the cooling configurations and in normal factory trim. In more severe environments, the fixed current option should be considered. If dealing with a very aggressive spec. (gun fire vibration, high impact shock, etc), conduction cooled mounting should also be used. See 2.2.3. The driver can also be mounted with an electrically insulating, thermally conductive epoxy. This arrangement is fairly permanent, but with no components on the reverse side, it may be possible to repair in place, if necessary.

Consider the general lay out of the case. Is there already to be a fan? Cooling louvers? Consider the wiring run requirements for both the power source and the laser. Is there more than one potential mounting location? Which is best with all things considered?

4.1.2 Picking the Laser

There are many more constraints on laser selection than are controlled by the driver, so this component will probably already be selected. If not, select a group of lasers which can satisfy all of the optical requirements. Lasers with on board photo-diodes, are advantageous. Weigh the relative merits and cost of the selections, including the cost of supplying the photo-diode function external to the laser package. If battery life is not a major consideration in this application, the function can be eliminated to reduce cost, complexity, and weight. The cost in terms of battery life is 10-30% depending on the type of battery to be used. When the final selection is made, determine the drive current and the maximum worst case pulse width needed. Set up the pulse drive for the width value. Set up the driver for the current value (See 4.1.5 Setting the Current), or order the fixed set option from the factory with this parameter.

4.1.3 Choosing the Battery

Can the driver be run from a power supply?
A typical power supply is not agile enough to follow the pulsed load current. In a worst case scenario, the regulation circuitry could become resonant with the pulse rate and build to large voltage swings. This would be rare, but possible. The logical progression is to have large enough bulk caps to pull the pulse from. Assume a 3ms pulse at 10A. Further assume the maximum drop allowed is .5V from the peak supply voltage. The required cap would be 60mF or 60,000 µF. This also assumes there is no drop in the wiring, or ESR in the caps! This assembly would be too large for portable equipment, if made of electrolytic caps, and quite expensive in super caps (possibly also too large). It is possible to make this work for a large bench set up, but we have not succeeded for a number of reasons using lab supplies we tried. For testing we need 12A and 10ms pulses, so the problem is exacerbated. Solution: put a small rechargeable Li-ion cell in parallel with the supply instead of a cap. This solution works agreeably well. You could probably remove all of the bulk caps from the power supply. In OEM applications, the power supply needs only to be sized to supply the average current and removal of most (all) of the bulk caps will save some of the space and cost of the battery. One caveat is that disabling the power supply does not turn off the unit. The battery also removes the need for a soft start for the power supply, because the output will rise to the battery voltage before drawing any current. We use this arrangement in our test system. The best battery for this usage is one of the A123 cylindrical cells as these have the lowest series resistance, and will work to -40°C.

One useful trick, when operating with a power supply/battery combo, is to set the output voltage at about 2.7V. With line power, the improvement is probably moot, but when using a second on board battery or external vehicle battery, the difference in “main” battery life will be significant. The battery voltage will decay to this value, and afterward the overall system efficiency will be improved greatly as the driver efficiency improves with lower voltage. Also, since the power dissipated in the driver is reduced, the driver cooling requirements will be reduced. Alternatively, the power can be increased via current, pulse width, and/or rep rate. See Para. 1.2.5 Extended Operation.

The balance of the discussion will assume the battery being chosen will be the only power source.
When choosing a battery chemistry and type, there are too many conflicting requirements at the system level for us to be formulaic in our methods. Do we use primary or secondary batteries? Do we allow for both types? Charge in place, or remove for charging? Will the battery type support the required temperature range? Are the batteries widely available (particularly in the case of primary batteries)? What will be the operating time between recharges (secondary) and or replacement (both types)? Initial cost? Replacement cost? What is the recharge time (secondary)? Are there any special safety requirements? These decisions are probably the most important ones from the standpoint of customer satisfaction.

A table has been prepared of different battery types and chemistries operating the driver only over temperature. The table includes combined weights and recharge information where applicable. See Table 4. In the table, no attempt was made to compensate for self heating in the batteries. The parameters chosen for the pulse were pulse width 4ms, peak current 6A. The laser load was an ER-902. [1]

[1] Product of MegaWatt Lasers P.O. Box 24190, Hilton Head Island, SC 29925 http://www.megawattlasers.com

The list is by no means exhaustive. It is expected that the balance of the system will be operated from the same battery. The data may be misleading if the balance of the system has a power drain that is similar to the drivers. The intention is to show comparative data on a number of different technologies and chemistries and not to proclaim any particular battery "best" for all situations. As mentioned previously, the driver efficiency increases with reduced voltage. It should be noted that, as the temperature deceases, several characteristics of the driver and battery change together in a way to cause performance difficulties. The battery voltage falls. The ESR increases. The laser diode drop increases. The Vcc blocking diode drop increases. These changes combined with the various battery chemistries produces two different types of functional failures. Battery specifications can also limit the temperature range.

The first of the functional failures is produced by the battery low temperature ESR and is exacerbated by the wiring resistance around the loop, from battery to driver, from driver to laser, from laser back to driver and from power ground to battery. To deal with the first type of failure, you can reduce the wiring resistance or change to a different battery or both. Recently, a family of super caps (DMF) has been released by muRata.
http://www.murata.com/en-us/products/capacitor/edlc/dmf
This is the first capacitor to have high enough capacitance and voltage, low enough ESR and small enough size to be practical for extending battery performance in the driver. With the cap in parallel with the battery the total ESR becomes:

$$\frac{1}{\left(\frac{1}{esr_b}+\frac{1}{esr_c}\right)}$$

Use of this cap will increase the available current and/or lower the operational temperature of any battery not temperature limited by spec. or safety considerations. The cap should be mounted as close to the driver as practical.

The second type of failure results from a drop in the open circuit battery voltage. This combines with the higher voltage drop in the Vcc blocking diode to starve the electronics for voltage. This mode primarily affects only lower voltage cells. Unfortunately LiFePO4 cells have the premium resistance to the first problem but is a lower voltage cell. The most appropriate way to deal with this problem is to change the function of the photo-diode bias pin. By connecting a 3.3 to 5V power source to the pin the electronics will operate from this source and the laser will operate from the battery. The Vcc voltage should be equal to or higher than the highest battery voltage to keep the Vcc blocking diode in the blocking state. If the host device does not contain a suitable power supply, a small dedicated supply is illustrated here (Figure 4: Aux. Power Supply Schematic). The current drain is low enough for the supply to be mounted anywhere in relation to the driver. No output cap is needed on the power supply output, as there is a 100uF on the driver.

4.1.4 Caveats in Wiring

If the T_o input is to be driven by a photo-diode, the wiring between the diode and the driver will be highly susceptible to interference from radiated noise. For lasers which have the diode internal, one potential solution is to shield the wire carrying the signal. Use of a miniature coax with the shield tied at the driver end is a suitable arrangement. The increase in capacitance to the wire will reduce the apparent sensitivity, but most lasers will output a large enough signal to overcome this. If the photo-diode is outside the laser enclosure, then several methods can be used to eliminate false T_o signals. The option discussed above can still be used. The effectiveness of it will depend on how the optical signal is tapped. All of the premium pick off sites are inside the laser case. However, sufficient energy can usually be tapped from the reflection from some optical device in the laser path. Second option works for either source. Process the signal near the laser to a higher voltage and lower impedance signal, and apply that to the driver input.

The third possible solution is to mount the photo-diode near the driver and pipe the light in from where it is picked up.

When an internal photo-diode processes the laser signal, the typ. 3-5ns pulse is stretched to 20ns or more. This is caused by the light being spread out over the whole die and not concentrated in the active area. The carriers generated in the non-active area are not subject to the high electric field in the active area. As such they drift into the active area very slowly, causing the pulse to be stretched. The driver uses low current devices which are not capable of seeing a 5ns pulse, so this stretching is required. The power levels are also quite high. When implementing an external photo-diode set up, observe that the stretch and power levels are needed. Generally this means that use of a small diameter fiber will be insufficient.

Note that if a TTL level voltage signal is to be used for T_o, the pulse width should be a minimum of 200ns, if DC coupled. AC coupling the signal will avoid pushing the quiescent point into the low gain area, and gives much greater sensitivity. Noise sensitivity is also increased.

4.1.5 Setting the Current

It is very difficult to measure the laser current directly. The current monitor should be used to measure the current. Connect the current monitor output directly into an oscilloscope input with a 50Ω load. The resulting calibration is 50mv/A. Set the pot counter-clockwise 8 or more turns.

Begin pulsing. Adjust the pot clockwise until the pulse amplitude is at the desired current. It is not important that the laser fire during the set up.

4.1.6 Setting up the Pulse Width

Arrange test equipment to detect the individual laser pulses.

For lab use with a small temp range, set up at room temperature. Begin with low rep rate. Set the pulse width wide enough to permit laser firing. Gradually reduce width until laser begins to miss. Note width. Increase width by 50%. Raise rep rate to either max power or max rate for the laser, whichever is lower. Allow to run at that rate until laser temperature stabilizes. Slowly reduce the pulse width, as before. When laser begins to miss, note width. Pick the longer of the 2 noted widths and add 10%. This will yield the best compromise for battery life in situations where the T_o input is not used.

For OEM use the worst case pulse width is needed to be sure all lasers will fire. If using the T_o input, disconnect for the setup. Set up unit in an environmental chamber. Test for the min width at each temperature extreme and +25˚C, also with low and limit rep rate. Take the worst case width and add 20%.

5 Battery Tests

The tables below are for a group of batteries tested to determine how the battery architecture and chemistry affect the operation over temperature and how the various described techniques can improve the results. Battery data is also listed for comparison purposes.

5.1 Batteries Tested

In addition to the batteries in the table a Saft LO29SHX was evaluated. It was not included in the table because it would not support 3A pulses at 25 °C(voltage droop). However, with a rated temperature of -60, and the release of the muRata DMF capacitor, this battery may be viable to -40°C. It is a primary battery with 3.75AH capacity. Low output voltage will require use of Vcc supply.

5.2 Notably Absent

The intention was to test an A123 ARN 26650M1-B battery. The 'B' is a key item. This is a new chemistry which results in much lower ESR. This battery is 26mm in diameter as opposed to 18mm for the one tested with 4 times the pulse current capacity. Capacity is 2.5AH. It is expected that this battery would deliver 10A pulses at -40°C with no capacitor or Vcc supply.

Tadrian batteries seem to be preferred by the military battery users. The ESR is much too high to operate with these batteries without a cap. As no suitable caps were available during the testing period, no Tadrian batteries were tested however; these may be a viable solution with the new muRata cap.

5.3 Floating on Supply

Only the A123 APR 18650M1A was tested floating on a power supply. In principal, any secondary battery which can accept the average current as a charging current could be used this way. The power supply used was a lab supply HP 6253A.

The tests were run at -40°C, and 25°C. The tests were run until the droop during the pulse stabilized. This operating time and shots were not determinable. The combination was able to sustain 6A continuous at -40°C, and 11.5A continuous at 25°C. 11.5A is the driver maximum with the current pot fully clockwise. The room temperature tests were run with a different load, to accept the higher current. The -40°C test required very low resistance wiring between the battery and the driver to allow 6A. During these tests, no Vcc supply was used. The power supply was set at 3.5V. Using lower voltages will work only at higher temperatures. The charge level on the battery needs to be held up to keep the ESR low.

5.4 Observations

During many of the tests, it was necessary to shut down over night. During that time the battery was removed from the test fixture and stored at room temperature. Very significant 'recovery' took place during the rest. The effect was much more evident during the low temperature tests. The recovery consisted of an increase in output voltage and a drop in ESR. We did not investigate further. The implication is that slower rep rates and/or intermittent operation may allow larger shot counts for a given batter or possibly higher pulse currents.

Table 4: Battery/Driver Performance

I.D.	Battery	Manufacturer	Type[1]	Chem.	Weight	Volume	Rated A/H	Rated Voltage
1	APR 18650M1A	A123 Systems	Cyl.(S)	LiFePO4	39g	16.7cc	1.1	3.2
2	LFP123A	K2 Energy	Cyl.(S)	LiFePO4	19g	7.25cc	0.6	3.2
3	L91[2]	Energizer	Cyl.(P)	LiFeS2	29g. (2)	16cc (2)	3	1.5 (3.0 for 2)
4	TP250-1SPP25J	Thunder Power RC	LiPo(S)	LiCoO2	7g	5.75cc	0.25	3.7
5	2ea APR 18650M1A in parallel	A123 Systems	Cyl.(S)	LiFePO4	78g	33.4cc	2.2	3.2

I.D.	Charge Time	Quick Charge	Life(chg.)[4]	Temp. Range	Safety	Discharge Limit
1	1.5A, 3.6V, 45m	4A, 3.6V, 15m	>2000	-30°C to 60°C	Second	2.7V
2	.3A, 3.65V,	.6A, 4.2V,	>1000	-20°C to 60°C	Third	2.7V
3	-	-	0	-40°C to 60°C	Best[3]	2.7V
4	.25A, 4.2V,	1.2A,4.2V,	?	10°C to 55°C	Worst	3.0V[5]
5	3A, 3.6V, 45m	8A, 3.6V, 15m	>2000	-30°C to 60°C	Second	2.7V

1. (P) primary cell, non-rechargeable (S) secondary cell, rechargeable.
2. 1.5V per cell, 2 in series required to operate the driver.
3. Most hazards are associated with recharging, shorting, or mechanical damage.
4. Assumes 100% charge at recommended rate and discharge completely in 1 hour (1C).
5. LiPo Mfg. cautions “do not discharge below 3.0V”.

Table 5: Battery Temp Test

I.D.	-40°C		-20°C		0°C		+25°C		+60°C	
	Shots	Time	Shots	Time	Shots	Time	Shots	Time	Shots	Time
1	10,027	16.7M[7]	386,502	10.7H[5]	399,996	11.1H[5]	-	-	-	-
1	-	-	-	-	200,453	4.4H[1]	203,000	5.64H[1]	202,613	5.63H[1]
2	-	-	-	-	106,644	2.96H[5]	132,841	3.69H[2]	106,097	2.94H[2]
3	-	-	-	-	-	-[6]	863,329	24H[3]	714,168	19.8H[5]
					+10°C[4]				55°C[4]	
4	-	-	-	-	40,547	1.13H[1]	48,369	1.34H [1]	44, 074	1.43H[1]
5	545,750	15.16H[8]	-	-	-	-	-	-	-	-

1. Set to 6A, delivered 6A
2. Set to 6A, delivered 3.16 to 4.2A
3. Set to 6A, delivered 3-4.6A
4. Mfg. recommended safe temp range
5. Set to 3A, delivers 3A. Stopped at 1% Pulse compression
6. Dropped to less than 3A in <1 minute.
7. Set to 3A, delivered 3A, Stopped due to Vcc droop
8. Set to 3A, delivered 3A, Used Vcc supply

6 Mechanical

6.1 Size

1.250” X 0.800” X 0.205”

6.2 Weight

2.1 grams

Figure 3: Outline

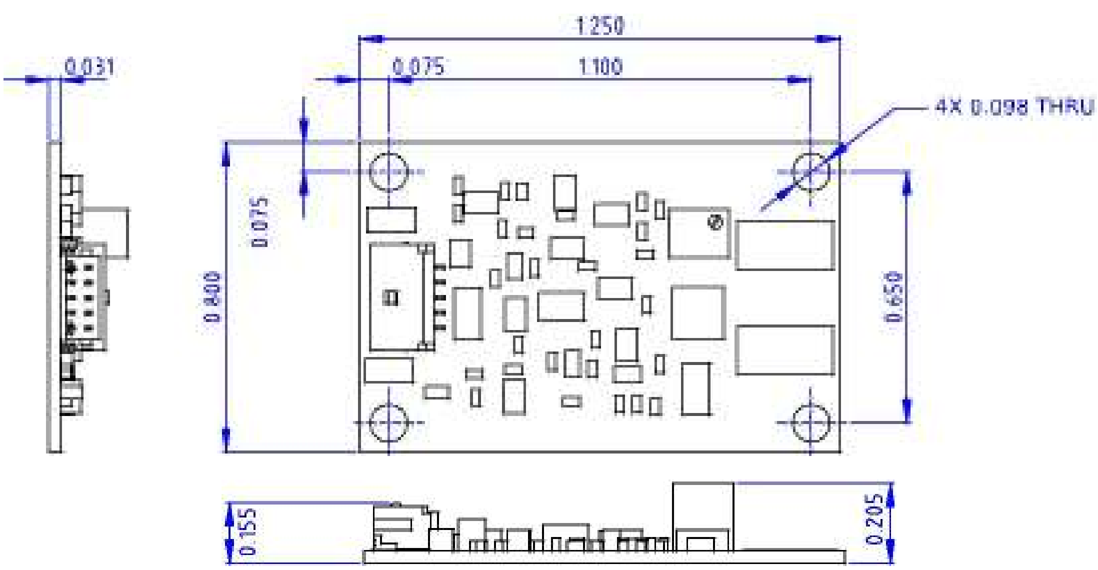

Figure 4: Aux. Power Supply Schematic

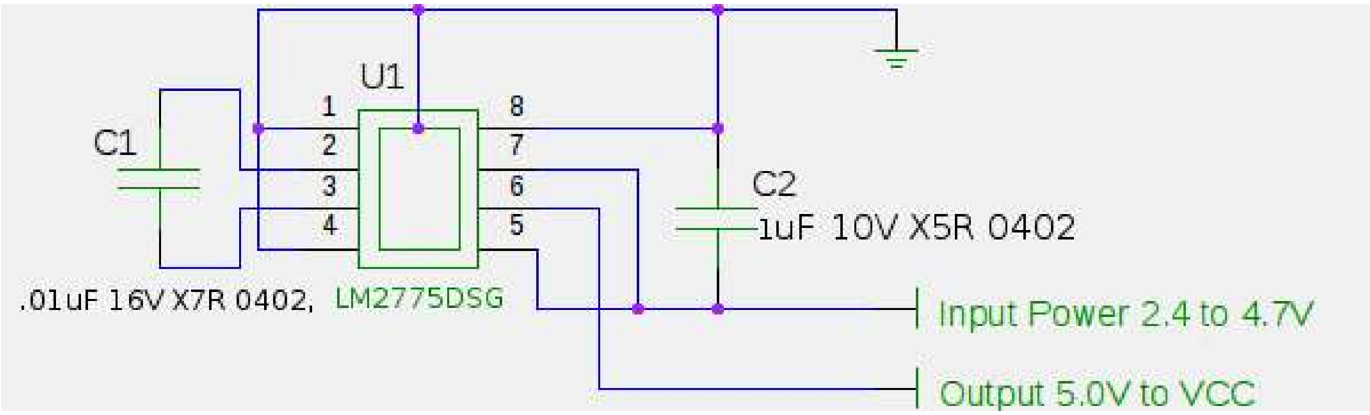

Figure 5: Aux. Power Supply Layout