

FD2-VD Photon Detector Cold Electronics Workshop

Development of DC/DC converters at LBL

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April 13



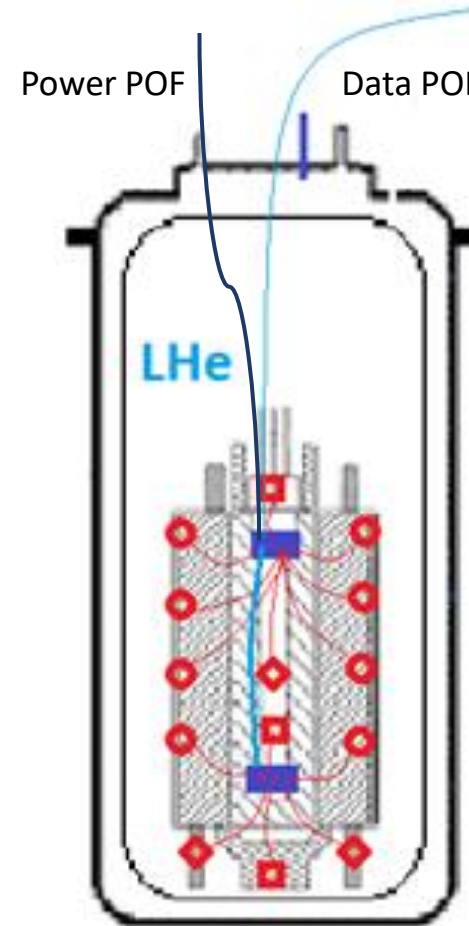
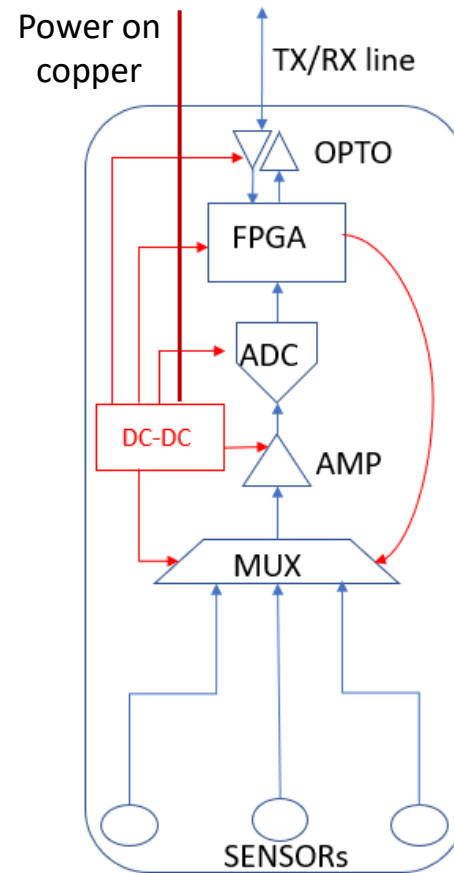
OBJECTIVES

- Development of low noise cryogenic DC-to-DC step-up converter;
- Long term operation;
- High thermocycle rate durability;
- Use of COTS components with proven track of long term cryogenic operation;
- Operation on LHe, LAr, and LN;
- Two architectures will be presented:
 - Transformer step-up with voltage multiplier
 - Photovoltaic

DC-to-DC converters at LBNL

Power:

- Voltage multiplier/Trafo
- Switched Capacitor+LDO
- Photovoltaic
- COTS LDO



- ◆ Strain Gauge
- Voltage Taps
- Temperature Sensor

COTS Components at LBNL

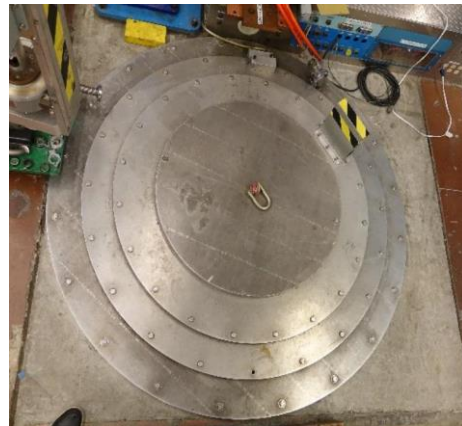
Projects:

- MAJORANA
- Superconductive Magnets
- LEGEND (9 years operation on LAr from GERFA)
- CUORE

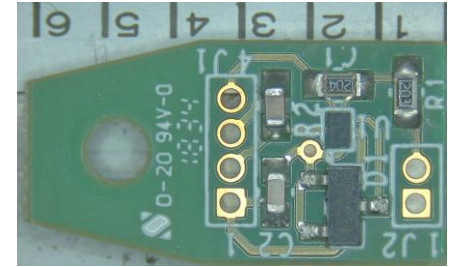
LN Test



LHe Test



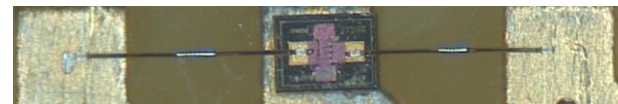
- **ADCs**
 - 24b / 20kSPS
 - 12b / 10MSPS
 - 4b / 500MSPS
- **Amplifiers** (up to 500MHz)
- **Diodes** (HV protection 1A)
- **FPGAs** (28nm- 45nm)
- **Laser Diodes Optical Isolators**
- **Voltage Regulators**
 - LDO and SW capacitor
- **Transistors**
 - JFET
 - HEMT
 - MOSFET
- **Passives**
 - Capacitors and resistors



Slow Amplifier
(Acoustic Instrumentation)

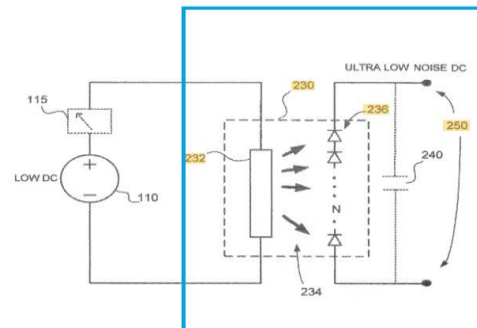
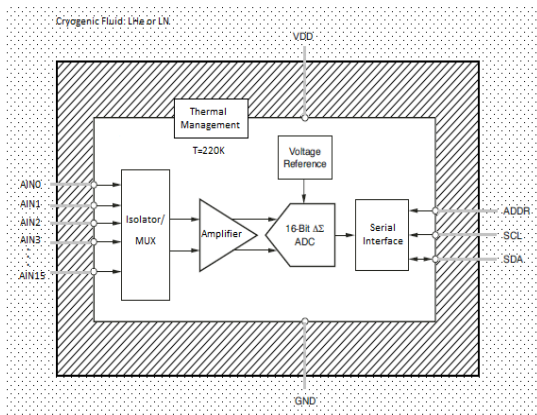


Fast Amplifier -500MHz



Reverse Cryostat

Active Cryogenic Electronics Envelope

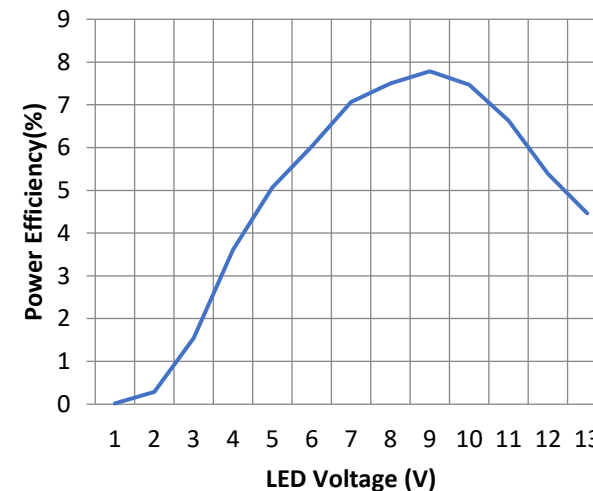


Power Over Fiber

Patent 10240875 (2015)

- Photovoltaic → LDO
- For LHe Operation
- Internal Temperature (70k to 100k)
- 16 analog channels
- 3000V input multiplexed isolation
- 16 bit ADC providing 1 MSPS per channel
- Low noise ADC, SFDR >100dB
- 3 wires digital interface
- Automatic temperature control
- Internal voltage reference
- 250mW maximum power dissipation
- Non-magnetic components

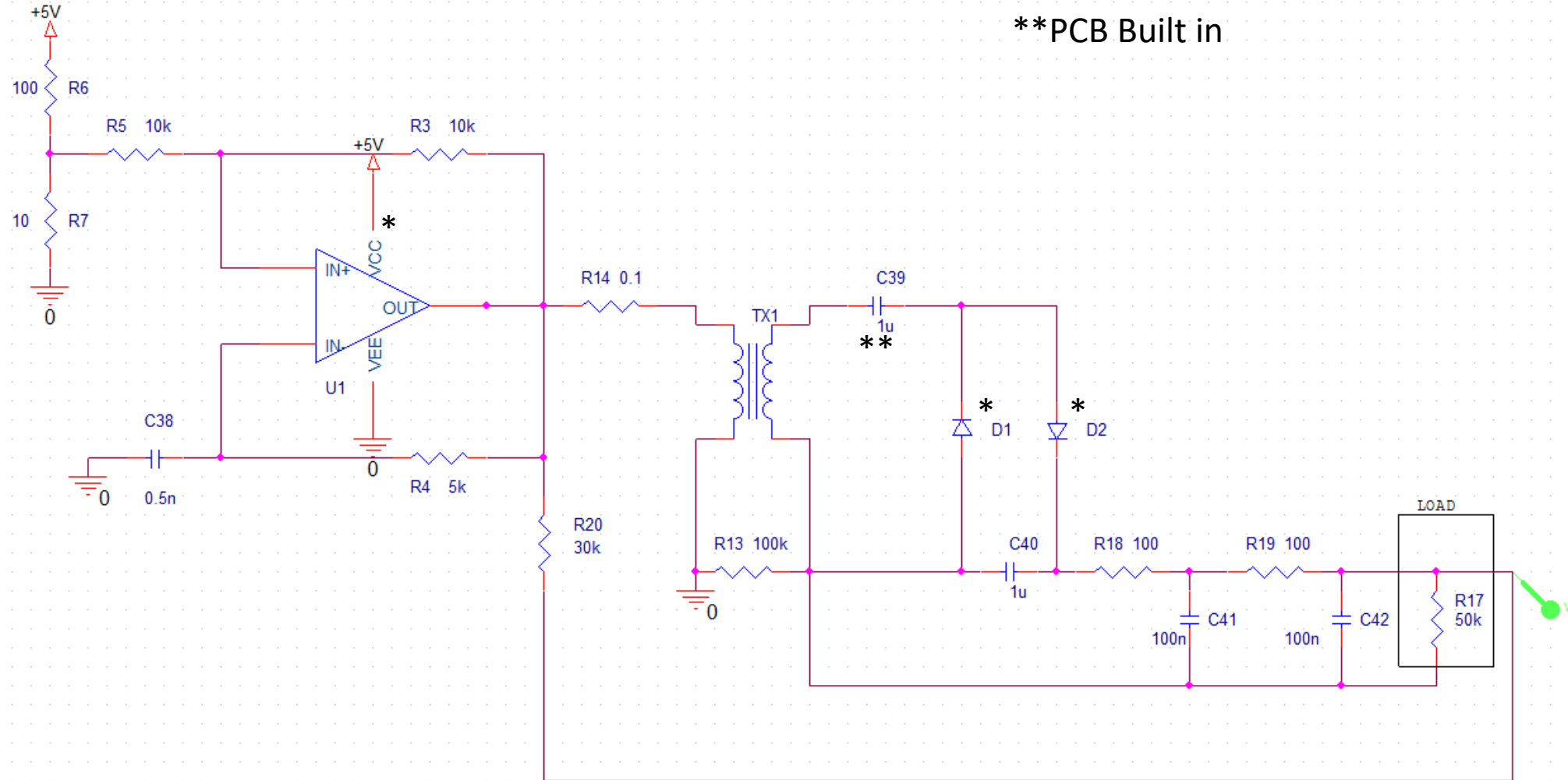
Electro-Optical Power Converter
LED: AA1010SE28Zc 80nm shift at LHe



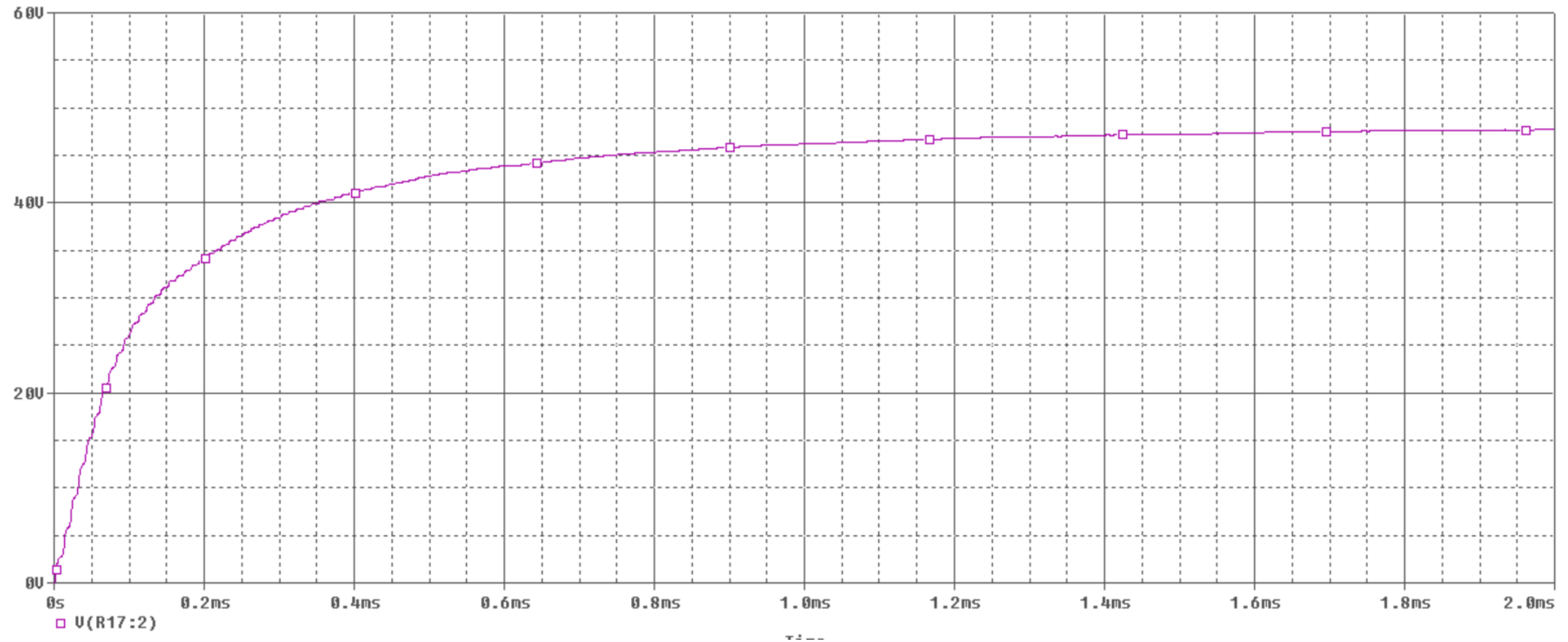
Trafo/Voltage Multiplier DC-DC Cryogenic Regulated Converter

*Components from GERDA/LEGEND 9 Years at LAr

**PCB Built in

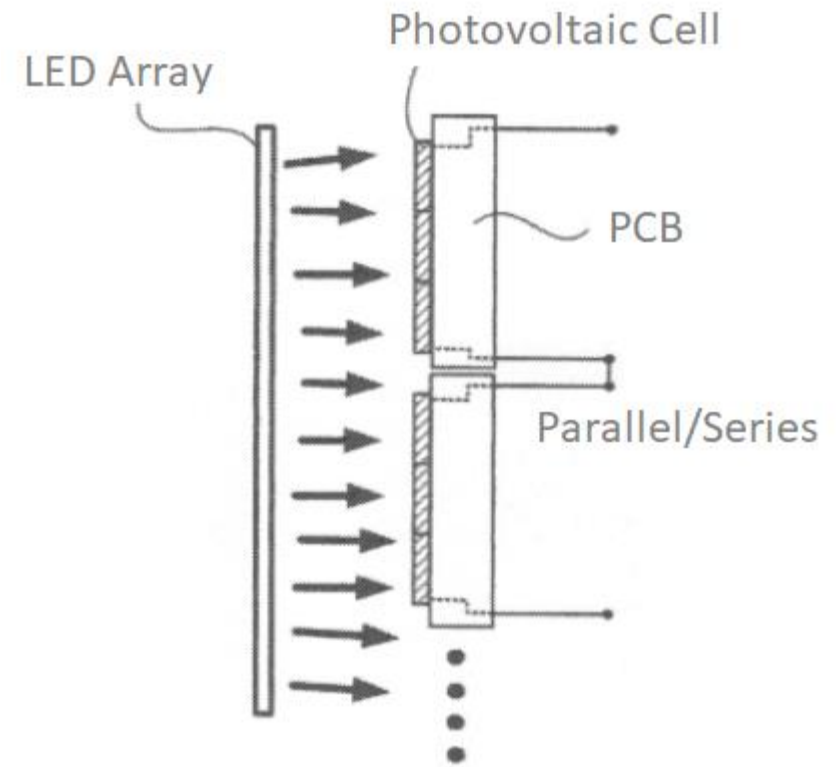
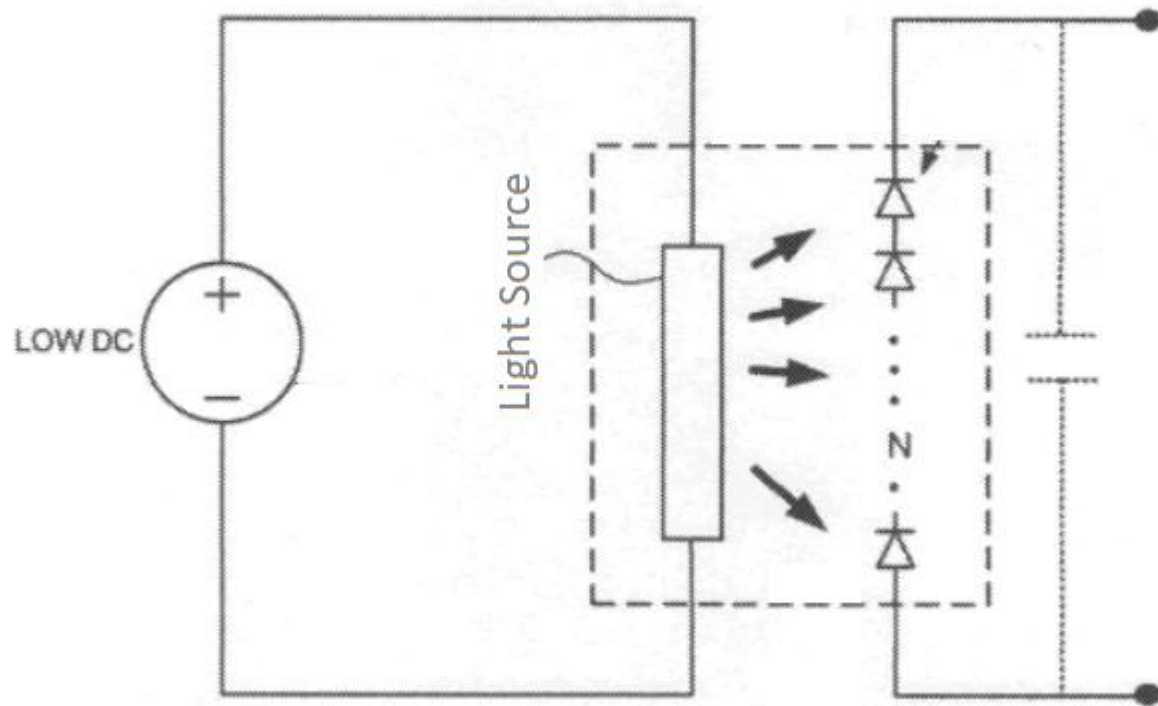


Trafo/Voltage Multiplier DC-DC Cryogenic Regulated Converter



- Noise better than 5mV at 1mA, Oscillator at 1MHz

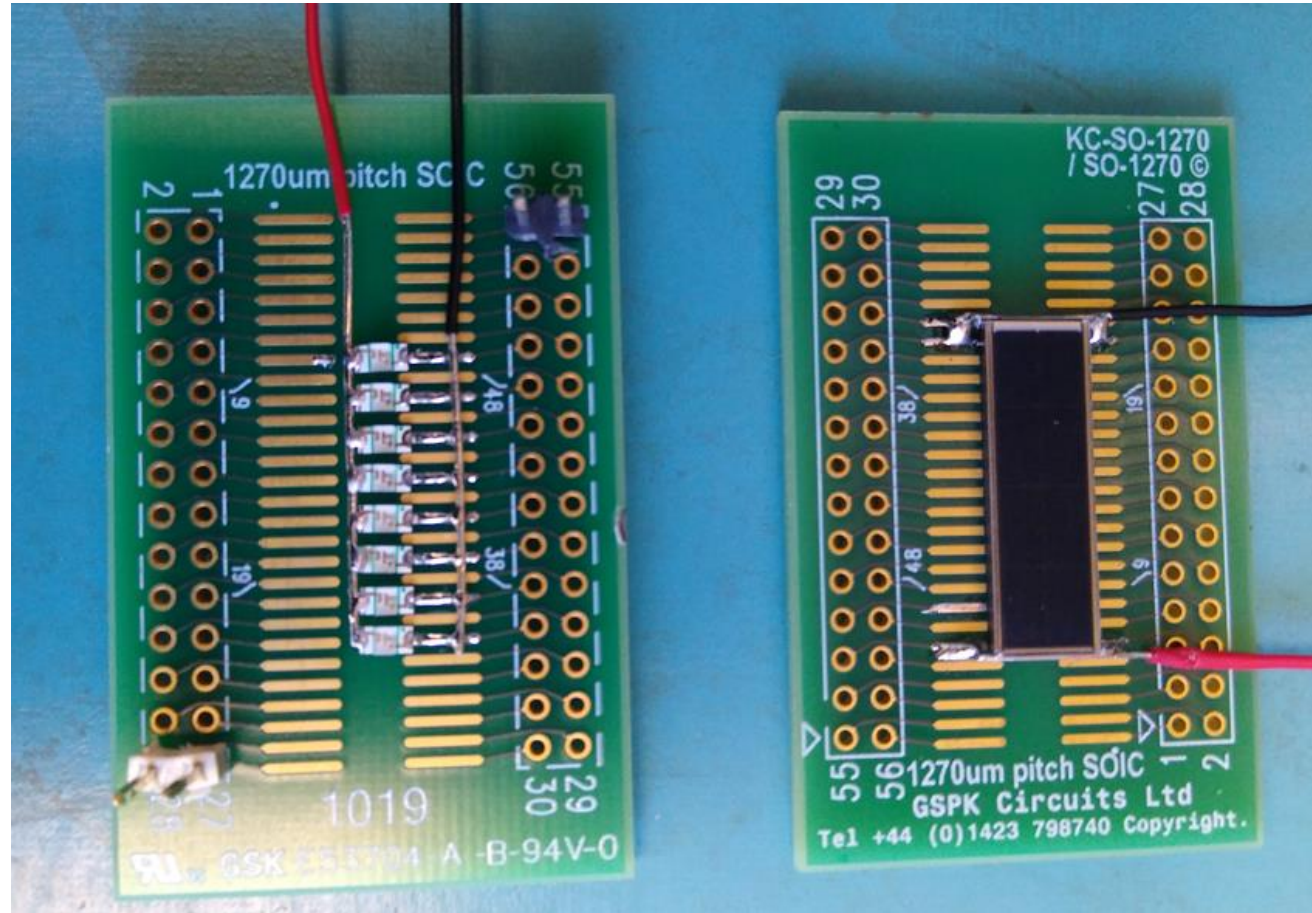
DC-DC Cryogenic Photovoltaic Converter



DC-DC Cryogenic Photovoltaic Converter

Prototype:

- LED Array 660nm
- 8 x Silicon photodiodes array
- COTS LDO
- At LN (77k) 610nm
- 1.1 mA, 8V
- Diode voltage up from 0.7V to 1V (bandgap shift)



DC-DC Cryogenic Photovoltaic Converter for 48V

48V Prototype:

- 80 cells, 1.5mA
- 46V-50V Regulated
- ~5% efficiency (48mW from 1W)
- Noise better than 100nV at 1mA (LN)
- Cells available that are qualified by the manufacturer for cryogenic operation (E.g. Alter Technology)



DC-DC Cryogenic Photovoltaic Converter for 48V



SZR05A0A x 3 LEDs - LED Red 625nm

Load=1Mohms							
Vp(V)	Ip(mA)	P(mW)	Vs(V)	Is(mA)	P(mW)		
1.6	10	16	0.71	0.00071	0.0005041		
1.7	20	34	1.3	0.0013	0.00169		
1.8	110	198	1.73	0.00173	0.0029929		
1.9	400	760	1.93	0.00193	0.0037249		
2	760	1520	1.97	0.00197	0.0038809		
2.2	1750	3850	1.99	0.00199	0.0039601		
Load=50						efficiency(%)	
1.7	5.5	9.35	0.05	1	0.05	0.534759358	
1.8	144	259.2	0.57	11.4	6.498	2.506944444	
1.9	360	684	1.31	26.2	34.322	5.017836257	
2	700	1400	1.75	35	61.25	4.375	
2.2	1300	2860	1.77	35.4	62.658	2.190839161	

STWBT16-C-Q050-HA

WARM							
Load=50							
Vp(V)	Ip(A)	P(W)	Vs(V)	Is(A)	P(W)	efficiency(%)	
2.65	0.044	0.1166	0.1	0.002	0.0002	0.171526587	
2.75	0.104	0.286	0.32	0.0064	0.002048	0.716083916	
2.9	0.153	0.4437	0.76	0.0152	0.011552	2.603560965	
3	0.209	0.627	1.1	0.022	0.0242	3.859649123	
3.1	0.273	0.8463	1.46	0.0292	0.042632	5.037457166	
3.2	0.345	1.104	1.64	0.0328	0.053792	4.872463768	
3.3	0.217	0.7161	1.72	0.0344	0.059168	8.262533166	
3.05	0.27	0.8235	1.4	0.028	0.0392	4.760170006	
3.15	0.27	0.8505	1.52	0.0304	0.046208	5.433039389	
3.25	0.337	1.09525	1.56	0.0312	0.048672	4.443916914	
3.35	0.4	1.34	1.58	0.0316	0.049928	3.725970149	

STW8T16-C-Q050-HA

Vp(V)	Ip(A)	P(W)	Vs(V)	Is(A)	P(W)	efficiency(%)
4.4	0.732	3.2208	0.136	0.00272	0.00036992	0.011485345
4.44	0.803	3.56532	0.504	0.01008	0.00508032	0.142492679
4.45	0.822	3.6579	0.64	0.0128	0.008192	0.223953635
4.46	0.841	3.75086	0.848	0.01696	0.01438208	0.383434199
4.47	0.863	3.85761	1.1	0.022	0.0242	0.627331431
4.48	0.88	3.9424	1.3	0.026	0.0338	0.857345779
4.49	0.897	4.02753	1.55	0.031	0.04805	1.19303891
4.5	0.919	4.1355	1.84	0.0368	0.067712	1.637335268
4.51	0.936	4.22136	2.012	0.04024	0.08096288	1.917933557
4.52	0.96	4.3392	2.46	0.0492	0.121032	2.789269912
4.53	0.973	4.40769	2.6	0.052	0.1352	3.067366353
4.54	0.993	4.50822	2.84	0.0568	0.161312	3.578174978
4.55	1.014	4.6137	2.88	0.0576	0.165888	3.595552377
4.56	1.028	4.68768	2.88	0.0576	0.165888	3.53880811
4.57	1.05	4.7985	2.9	0.058	0.1682	3.505262061
4.58	1.07	4.9006	2.9	0.058	0.1682	3.432232788

EXTRA

	295K	2.046	307	1.66	0.000503	3K3	3300	
	77K	2.2	1.7	3.5	3.5E-07	3K3	10000000	
	77K	2.3	3.4	3.9	3.9E-07	3K3	10000000	
	77K	2.4	3.7	4	4E-07	3K3	10000000	
	77K	2.5	6.3	4.316	4.32E-07	3K3	10000000	
	77K	2.6	6.9	3.382	3.38E-07	3K3	10000000	
	77K	2.7	10.3	4.626	4.63E-07	3K3	10000000	
	77K	2.8	18.7	5.024	5.02E-07	3K3	10000000	
	77K	2.9	35.2	5.48	5.48E-07	3K3	10000000	
	77K	3	68.8	6.127	6.13E-07	3K3	10000000	
	77K	3.05	106	6.6	6.6E-07	3K3	10000000	
	77K	3.08	124	6.8	6.8E-07	3K3	10000000	
	77K	3.05	100	1.5	0.000405	3k7	3700	
	77K	3.07	124	1.9	0.000514	3k7	3700	
	77K	3.1	154	2.3	0.000622	3k7	3700	
	77K	3.13	204	2.82	0.000762	3k7	3700	