AND8192/D

Charge Pump Based Multiple LED Driver

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APPLICATION NOTE

Abstract

This application note describes a multi−functional system, capable of generating and controlling the power needed to utilized three features available in modern cellular phones. In addition to larger displays, with full color capability, flash and torch features have now been added to support the embedded camera and the night path finder. These features are made possible by using an ultra bright LED powered by standard battery cells.

BASIC CIRCUIT DESCRIPTION

Since the LED have a forward drop voltage ranging from 3 V to 4.5 V, depending upon the forward current, a straightforward connection to a standard battery is not feasible as depicted Figure 1. A boost structure must be used to make the power supply voltage compatible with the LED.

On the other hand, combining three functions in the same system creates a special case since the converter must be capable of driving the wide current load needed for the different functions. The typical currents used to drive the LED, summarized in Table 1, range from a low 1 mA to 350 mA when the flash is activated. Moreover, unlike the xenon photo flash, the LED system must have a relatively long pulse of light to properly illuminate the scene. Typically, a xenon pulse has a 1 ms flash duration, the LED system being in the 100 ms to 200 ms range. Consequently, the converter must be designed to support such a large demand.

High powered LED capable to sustaining up to 800 mA are under development and drivers for these devices should be available within a few months.

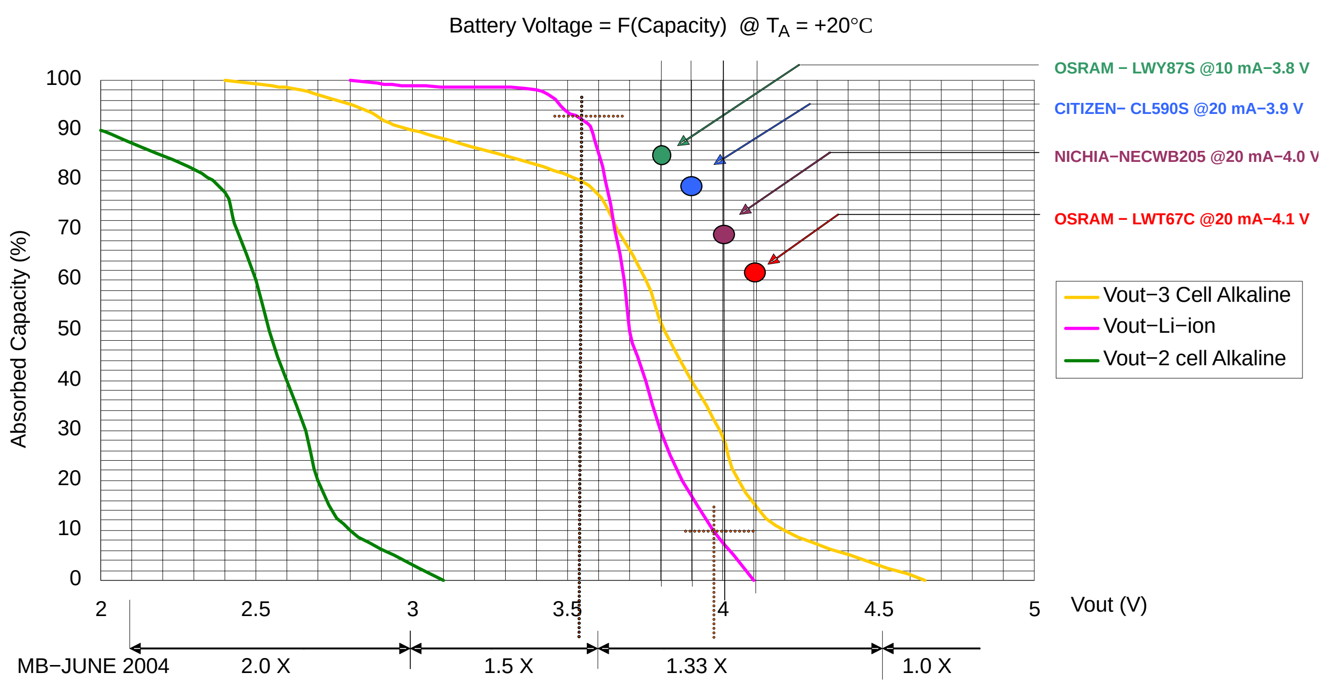


Figure 1. Typical Lithium−Ion Battery Voltage and White LED

Table 1. White LED Typical Applications

LED	Backlight	Torch	Flash
OSRAM LWY85S	1 mA – 10 mA		
OSRAM – LWT67C	1 mA – 20 mA		
OSRAM		100 mA	
OSRAM – LWW5SG			350 mA
CITIZEN − CL590S	1 mA – 20 mA		
NICHIA−NECWB205	1 mA – 20 mA		
LUMILED			800 mA

Along with the amount of current the converter provides, it is worthwhile to note the thermal behavior of both the silicon and the power LED.

According to the OSRAM's data sheet, the Dragon LED (LWW5SG) should have a maximum 4.5 V forward drop with 350 mA current. The power absorbed by the load will be 1.57 W and, assuming a 75% efficiency of the DC/DC converter, will translate to almost 2 W of input power. Consequently, some 400 mW will be dissipated as heat into the silicon and, according to the NCP5603 data sheet, the chip temperature will increase by $R_{\theta JA}$ x Pin = 85 x 0.4 = 34°ΔC. Such a temperature increase is acceptable since, even under the worst case +85°C ambient temperature, the junction will be below the maximum rating defined for this chip.

However, we must take into account the low battery situation: in this case, the efficiency of the converter can decrease and we end up with 60% efficiency, yielding almost 54°ΔC temperature increases. At this point, the silicon can rise above 125°C, under extreme high ambient temperature, and the global long−term reliability of the chip will be impaired. This can be avoided by either reducing the thermal resistance (using a heatsink by means of the PCB layer) or by ensuring the duty cycle is short enough to properly cool off the chip between pulses.

Generally speaking, the High Intensity LED are power limited and care must be observed to avoid any thermal run out during normal operation. This is particularly true for the flash mode in which, as depicted above, nearly 1.6 W are dissipated into the LED junctions. Because the junction to ambient thermal resistance is limited by the packaging of the LED, a good thermal contact to a dedicated layer on the printed board is essential. The LWW5SG specifications give a maximum 9°C/W junction−to−case thermal resistance, capable of limiting the temperature of the silicon to the 100°C maximum specified in the OSRAM data sheet. After dissipating 1.6 W, the maximum thermal to air resistance acceptable by the chip can be calculated as:

$$R_{\theta JA} = \frac{T_{jmax} - T_{amb}}{P_{chip}}$$

$$R_{\theta JA} = \frac{100 - 85}{1.6} = 9.37^{\circ}C/W$$

Since the $R_{\theta JC}$ is 9°C/W, it is practically impossible to achieve a 0.38°C/W case to ambient thermal resistance and the only alternative is to limit the operating ambient temperature.

Assuming T_{amb} = 60°C, then $R_{\theta JA}$ = (100−60) / 1.6 = 25°C/W.

In this case, the case−to−ambient thermal resistance is 25 − 9 = 16°C/W, a value more realistic, although not so easy to achieve with a room limited PCB.

NCP5603 operates without special treatment in terms of thermal sinking and a simple copper flag is built underneath the QFN package as depicted Figure 3.

The schematic of the multiple application, Figure 2, illustrates the three functions:

- Backlight→ four LED in parallel, dimming capability.
- Torch → one LED, no output adjustment.
- Flash → one power LED, pulse width adjustable.

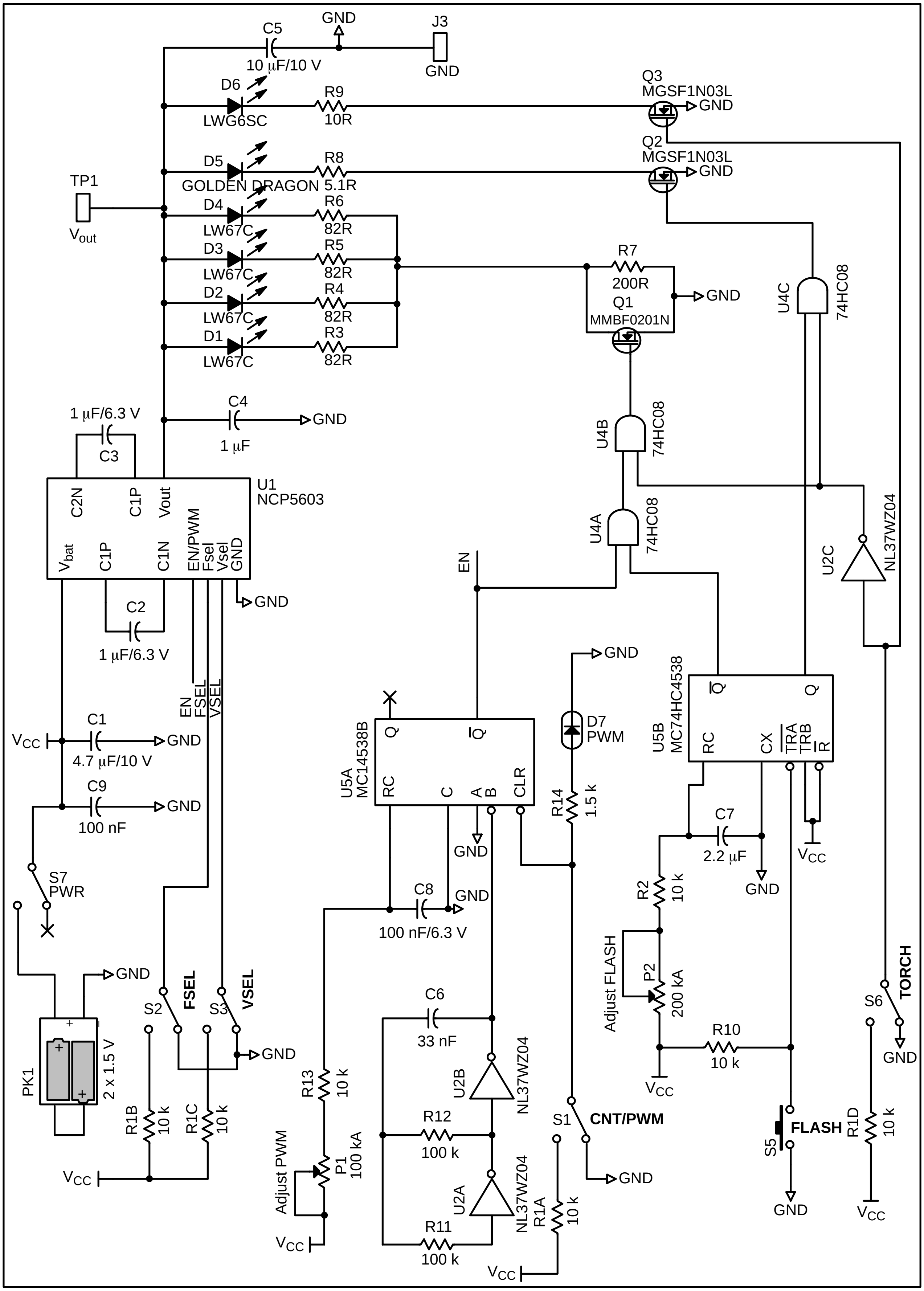
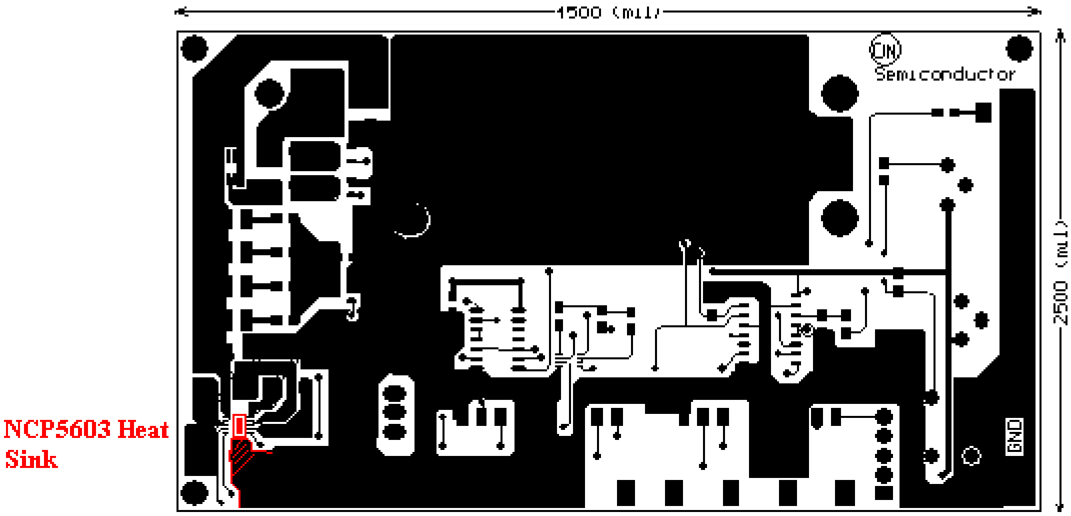
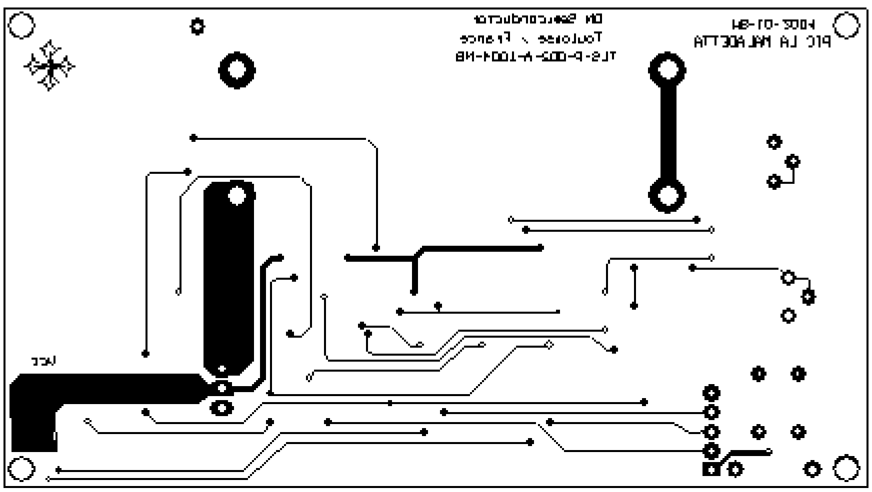


Figure 2. Multiple LED Driver Application



TOP Layer



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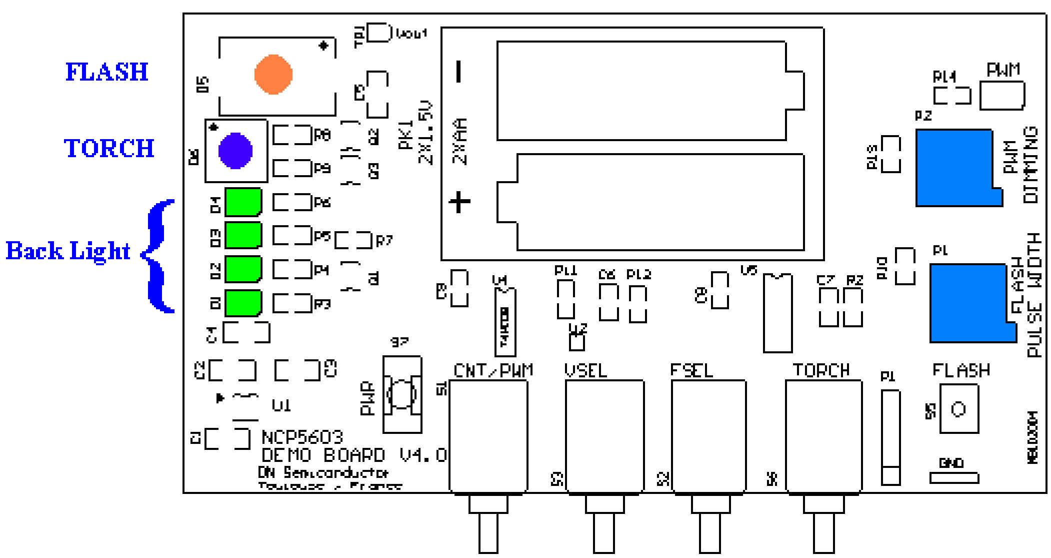

Figure 3. Printer Circuit Board GERBER Files (scale 1:1)

The system is powered by two AA cells in series, assembled in a standard battery holder, the operating mode being selected by the S1, S5 and S6 switches. Since the total current is limited by the DC/DC converter, the backlights LEDs are automatically deactivated when either the Torch or the Flash are selected. Moreover, the Flash is not available while the Torch is running.

An extra feature, backlight dimming, is provided by switch S1 is associated with potentiometer P1. When the switch is connected to ground, the NCP5603 enabling pin EN is high and the brightness is maximized. When the switch S1 is flipped to the Vcc position, the RESET of U5A is released and the EN pin is clocked High / Low by the clock generated by U2A / U2B. Simultaneously, diode LED D7 turns ON to identify the PWM mode of operation. The duty cycle of the U5A / $\overline{Q}$ output is manually adjusted by potentiometer P1 to set the brightness of the four associated LED.

The efficiency of the system has been evaluated at room temperature (see Table 2), the results being fully within the NCP5603 data sheet specifications.

Table 2. Demo Board Efficiency

V_{bat}	I_{bat}	V_{out}	I_{out}/LED	I_{out} Total	Yield	Comments
3.50 V	2.3 mA	0 V	0 mA	0 mA	–	No Load
3.50 V	132 mA	4.42 V	16.5 mA	66 mA	63.14%	
3.50 V	170 mA	4.92 V	21.4 mA	85.6 mA	70.78%	
3.10 V	131 mA	4.42 V	16.5 mA	66 mA	71.83%	
3.10 V	169 mA	4.92 V	21.4 mA	85.6 mA	80.38%	
3.10 V	300 mA	4.92 V	142 mA	142 mA	75.12%	Torch operation

The inrush current is internally limited by the chip, as depicted Figure 4, and no uncontrolled current takes place when the system starts up from scratch.

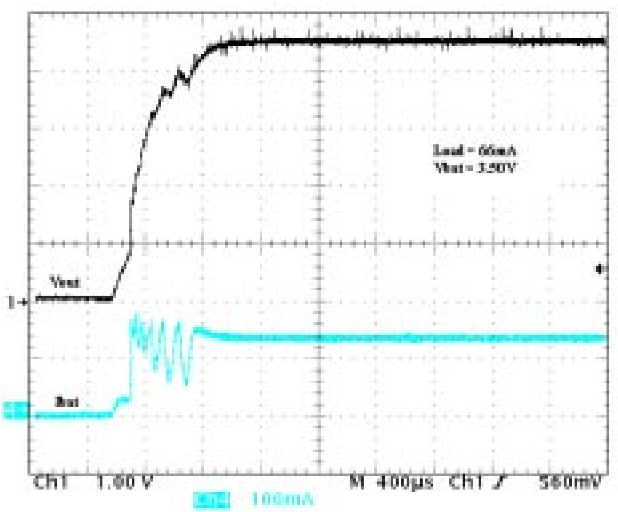

Figure 4. Typical Startup Timing

With a startup time well below 1 ms (from zero to full Vout, see Figure 4), the NCP5603 is fast enough to accommodate a flash application as shown in the demo board.

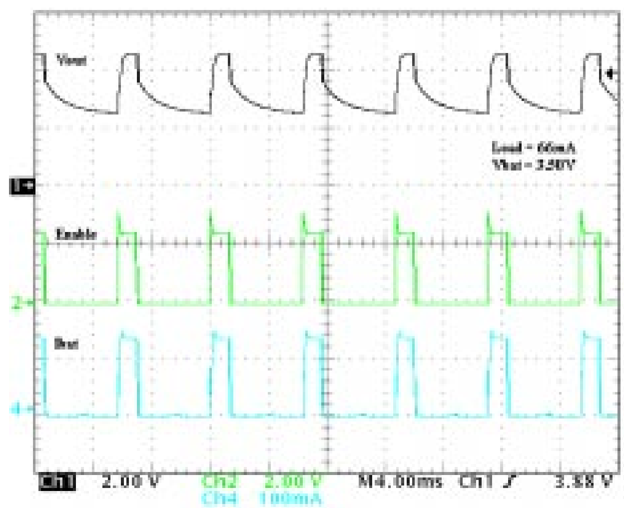

Figure 5. Typical Digital Dimming

Although there is no dedicated pin, the LED brightness can be dimmed by means of the EN digital control. The waveform captured in Figure 5 illustrate this behavior, the PWM being intentionally arranged out of the audio band for a portable system.

NCP5603 – MULTIPLE DRIVE CIRCUIT − Bill Of Material

QTY	Designator	Description	Footprint	Manufacturer	Part Number
1	R1	10 kΩ, pack four independent elements	SIP−5	BOURNS	4605X series
3	R2, R10, R13	10 kΩ	0805	Vishay Draloric	
4	R3, R4, R5, R6	82 Ω	0805	Vishay Draloric	
1	R7	200 Ω	0805	Vishay Draloric	
1	R8	1.2 Ω	0805	Vishay Draloric	
1	R9	10 Ω	0805	Vishay Draloric	
2	R11, R12	100 kΩ	0805	Vishay Draloric	
1	R14	1.5 kΩ	0805	Vishay Draloric	
1	P1	100 kΩ A Potentiometer	VR4	BOURNS	3386F−TW
1	P2	200 kΩ A Potentiometer	VR4	BOURNS	3386F−TW
1	C1	4.7 μF/10 V	1206	TDK	
3	C2, C3, C4	1 μF/6.3 V	1206	TDK	
1	C5	10 μF/10 V	1206	TDK	
1	C6	33 nF	0805	KEMET	
1	C7	2.2 μF	0805	TDK	
2	C8, C9	100 nF	0805	KEMET	
4	D1, D2, D3, D4	LW67C	OSRAM_LED	OSRAM	
1	D5	GOLDEN DRAGON	OSRAM_DRAGON	OSRAM	LWW5SG
1	D6	LWG6SC	OSRAM_LWG	OSRAM	
1	D7	LED	OSRAM_LED	OSRAM	
1	Q1	MMBF0201N	SOT_23A	ON Semiconductor	
2	Q2, Q3	MGSF1N03L	SOT_23A	ON Semiconductor	
1	U1	NCP5603	QFN10_COB	ON Semiconductor	
1	U2	NL37WZ04	US8	ON Semiconductor	
1	U4	74HC08	SO−14	ON Semiconductor	
1	U5	MC14538B	SO−16	ON Semiconductor	
4	S1, S2, S3, S6	Toggle Switch	APEM_CMS	APEM	TL36WS84000
1	S5	Push Button	PUSH_BUT_B	CANNON ITT	KSA 0M210
1	S7	Toggle Switch	CKSWITCH_V	C & K	ET01MD1 CBE
1	TP1	TEST POINT	TEST_POINT	KEYSTONE	5005 (THM)
1	J3	GND	GND_TEST	HARWIN	D3082−01 (tin) D3082−05 (gold)
1	PK1	2 x 1.5V Battery holder, 2 x AA	BPACK2	KEYSTONE	2223

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