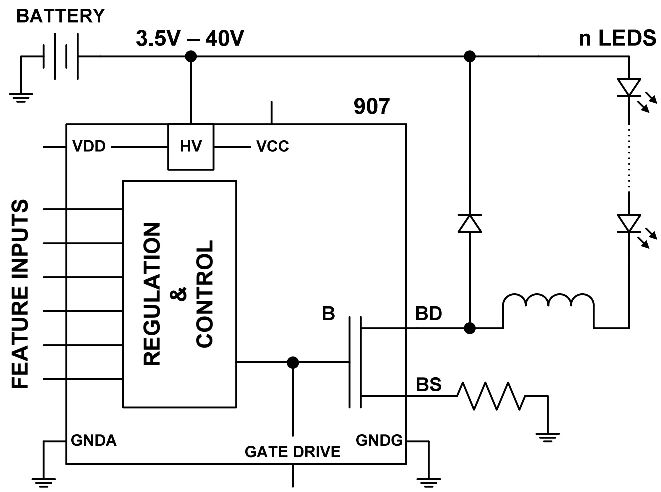
LED DRIVER AND POWER MANAGER

- Portable lighting applications
- 3.5 to 40 volts input
- 128 to 1 brightness control, 15 settings
- Instant full-brightness control
- Constant current output up to 35 volts
- Low battery warning (adjustable)
  - Discharged battery shut-off
- Auto shut-off (enabled by user)
- < 10µA off current
- Internal power FET, 3.5A
- Gate drive for external devices
- Internal 5V regulation
- Special modes: Flashing and SOS



QFN 24 Ld 4x4mm

#	PIN	DESCRIPTION
1	BS1	Source B FET
2	BS2	Source B FET
3	BS3	Source B FET
4	FB	Full Brightness
5	SW0	Switch to GNDA
6	LBD	Low Battery Detector
7	OVP	Over Voltage Detector
8	VDD	Regulated 5V
9	nc9	No Connect
10	D	Decrease Brightness
11	nc11	No Connect
12	GNDA	Supply Return
13	U	Increase Brightness
14	MO	Toggle ON / OFF
15	EN	Enable ON
16	BD3	Drain B FET
17	BD2	Drain B FET
18	BD1	Drain B FET
19	HV	Supply
20	VCC	Regulated 5V
21	nc21	No Connect
22	GNDG	Gate Drive Return
23	BG	B Gate Ext Drive
24	EGE	Enable Ext Gate Drive
-	DAP	Gate Drive Return

The 907 part provides portable lighting products the ability to control brightness over a 128 to 1 range, monitor battery status, and operate as a signaling device. This allows the user to fine tune the light output for the application and maximize battery run-time. The low off-current permits continuous connection to the battery for years of standby operation.

This product combines the features found in systems using discrete parts, a LED driver and micro controller into one 4x4 mm QFN package.

The 907 has been optimized for higher battery voltages with a buck converter. An internal voltage regulator provides a nominal 5 volts for logic operation over a wide range of input voltages.

It has an internal power FET that can drive up to 10 white LEDs in series at more than 1.5 A. It can also drive an external power FET through the BG pin if greater power handling is required. BG is enabled by connecting EGE to GNDG.

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907 Electrical Characteristics

Tj=25C, VH = 6.5 V, VCC shorted to VDD

Parameter	Test Condition	Symbol	Min	Typ	Max	Units
Operating						
Regulator Supply		VH	3.5		40	V
Regulator Output	VH ≥ 6.5, part enabled	VDD	4.6	5.1	6	V
	3.8 ≤ VH ≤ 5.2, part enabled	VDD		VH-0.3		V
	VH ≥ 6.5, part enabled with 3 mA load applied to VCC	VDD	4.5			V
	VH = 4, part enabled with 1 mA load applied to VCC	VDD		3.5		V
Regulator Capacitance	Load capacitance at VCC and VDD total	CVCC	66			nF
Off current into VH, BD	3.8 ≤ VH ≤ 40, BD=VH, and digital inputs at VDD	IOFF	--	6	12	uA
On Current into VH	3.8 ≤ VH ≤ 40, VCC = VDD, tt = 7.67tp, EGE=VCC	IH	0.5	1.5	2.5	mA
Auto Shut-off warning	Enabled with UP + DN,	taw	13	15.5	19	minutes
Auto Shut-off	Detect UP, DN	tauto	--	taw+2	--	minutes
Beacon flashing rate	Enabled with UP + DN	Fbcn	55	65	75	fpm
Thermal Resistance	Junction to exposed pad	θ_{JC}	--	12	--	C/W
Junction Temperature		Tc	-20		125	C
Buck Converter						
Break down voltage	BVs = 0, IBD = 1 mA	BVbd	42			V
On Resistance	VCC = 3.5V, IBD = 100mA	BRdson		0.21		ohms
	VH = 6.5V, IBD = 100mA			0.18		ohms
Max BD current	BD1 BD2 and BD3 shorted. BS1 BS2 and BS3 shorted. Switch operation.	IBDmax	--	--	3.5	A
Time Period		tp	0.65		13.9	µsec
Charge Time (on)		tc	0.216	--	13	µsec
Leading Edge Blanking		tb	55	68	80	nsec
Fault time		tf	90	188	216	nsec
Sense threshold		BVs		0.2		V
Sense Offset Resistance	Pins 1, 2, and 3 shorted	RBLs		0.022		ohms

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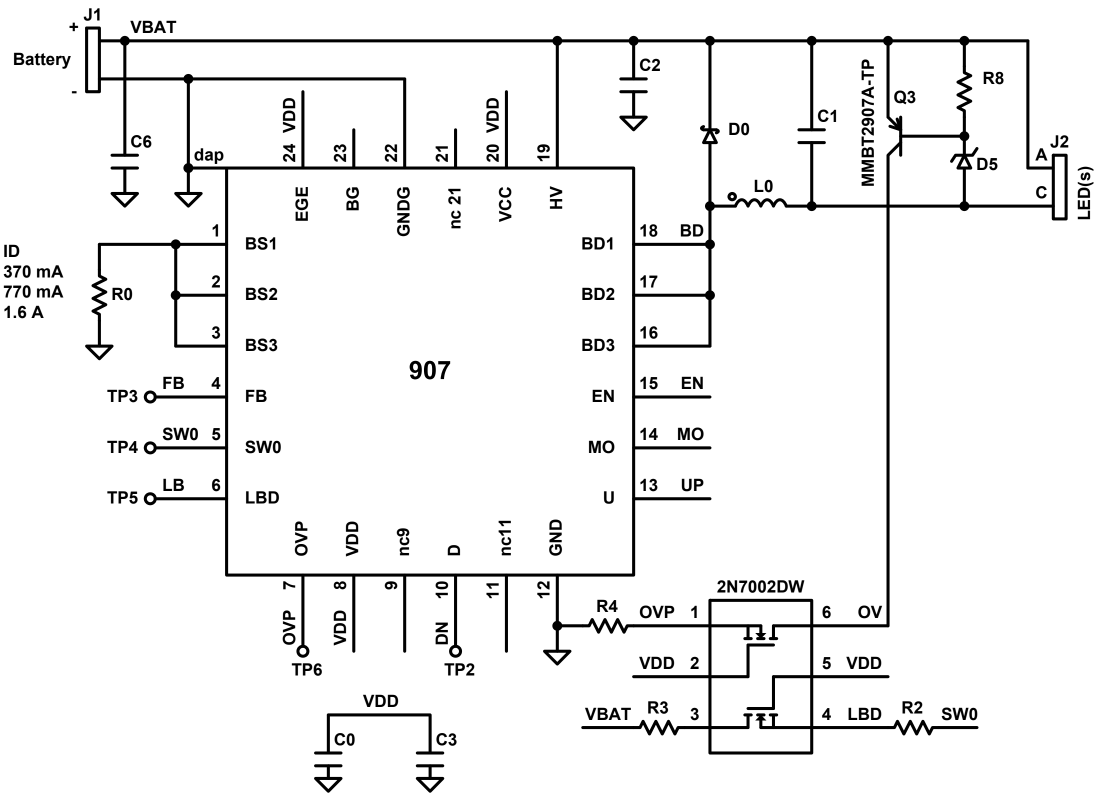
Parameter	Test Condition	Symbol	Min	Typ	Max	Units
Brightness Modulator						
PWM Frequency		Lfp	208	244	280	Hz
PWM Period		Ltp	--	4.1	--	msec
External Gate Drive						
On Resistance BG	IG = 100 mA, VH = VCC = 3.5	GNdson		5	10	ohms
	IG = -100 mA, VH = VCC = 3.5	GPdson		6	12	ohms
Analog						
SW0 on resistance	Isw0 = 5 mA	Rsw0	--	4	10	ohms
LBD warning threshold		VLB		0.5		V
LBD warning debounce		tlb		163		msec
LBD shut-off threshold		VLBx	0.455	0.467	0.479	V
LBD shut-off debounce		tlbx		20		sec
OVP threshold		VOVP		0.5		V
Digital						
EN (enable) Thresholds:						
EN Low Threshold		VL_EN	0.65	0.9	1.3	V
EN High Threshold		VH_EN	0.7	1.0	1.4	V
EN Hysteresis				110.0		
EN Pull-up Current		IL_EN		1.2		uA
EN Debounce		tdb_EN		40		msec
EGE Low Threshold		VL_EGE	0.3VCC			V
EGE High Threshold		VH_EGE			0.7VCC	V
EGE Input Current		I_EGE	-1	0	1	uA
MO, UP, DN, FB threshold		VL		0.9		V
		VH		1.0		V
MO Pull-up Current		IL_MO		11.0		uA
UP, DN, FB Pull-up Current	part disabled	ILOFF		1.2		uA
	part enabled	ILON		12.0		uA
MO Debounce		tdb_MO		40		msec
UP, DN Debounce		tdb_UP, tdb_DN		106		msec

BUCK APPLICATION SCHEMATIC

R0	IP	ID
0.27	0.74 A	370 mA
0.13	1.54 A	770 mA
0.062	3.22 A	1.6 A



The 907 combines a buck regulator to accommodate varying battery voltage with a PWM brightness circuit to manage the brightness and signaling functions of the LED. This combination assures constant light output over the battery operating range and allows the user to make the trade-off between light output and battery life.

The control loop for the buck regulator is digital. Only one external current sense resistor is required at the BS pins. An internal comparator uses a 200 mV reference to monitor the current through these pins.

This minimizes component count and simplifies the design process for stable operation to selecting values for one resistor, one inductor, and the output capacitor.

The inductor operates near boundary conduction. (Also referred to as borderline or critical conduction mode.) It is charged to twice the LED current and then discharged each cycle. The internal drain voltage is compared with the high voltage input to determine when the inductor is discharged and when to start the next charging cycle.

To protect the LED from an over voltage condition caused by inadvertent open-circuit, an over-voltage-protection (OVP) pin is provided to sense the output voltage. When the LED output voltage is too high, the regulator is disabled. A zener diode with a resistor-transistor network sets the protection voltage.

The circuit also protects against a shorted inductor/LED load by monitoring the charge time. When the set-current is reached in less than 200 nano-seconds, the circuit enters a fault mode to limit the duty cycle to less than 0.1 percent by extending the off time until the fault is cleared.

The battery voltage can be monitored through the LBD pin. When the battery voltage is near its minimum operating voltage, the LED output is modulated to indicate a low battery condition; this warns the user of the low battery condition before reaching the shut-off point. Because the LED current is held constant over varying battery conditions, this is the only indication of a low battery and avoids the typical collapse in light output without warning. It also provides the user the opportunity to change the battery before the product automatically shuts off.

Operating a battery below its cut-off voltage can result in damage to the battery (especially rechargeables) and the product from battery leakage. When the LBD pin drops below its lower limit (shut-off), the product is disabled after approximately 20 seconds. This provides ample warning without compromising battery integrity.

The "Off" current for the 907 is less than 12 uA. The small off current allows the product to supply pull up current for ON / OFF controls with minimal effect on battery life. Continuous battery connection maintains brightness and mode settings. Conduction through the OVP and LBD pin resistor networks is eliminated by using the SW0 pin as their return. When the product is disabled SW0 is open circuit.

Operating Modes

There are two ways to enable the part: Momentary contact closure (MO) and continuous contact closure (EN). Both MO and EN are active low with active pull-up currents and have contact debouncing circuitry. The debouncing time is approximately 40 milliseconds which prevents inadvertent enabling.

EN enables the product when it is low and disables when it is high. MO acts as an electronic toggle switch to enable on the first activation and disable on the second activation. However, MO cannot disable the product when EN is low. If the product was enabled through MO, the EN pin can be used to disable the product by taking EN low and then high.

An automatic shut-off feature can be enabled through the U input and disabled through the D input as discussed later. Cycling EN or MO will re-enable the part.

Signaling operation can be accomplished with momentary contact closure switches for both enable inputs (MO and EN): the EN for "signaling" and MO for continuous "ON/OFF" control.

Signaling can also be achieved by setting the product to minimum brightness and using the FB input as the signaling input, as discussed later.

LED brightness is controlled through one of three inputs: U, D, and FB. All are active low and have active pull-up currents. The U and D have debouncing:

U Increases brightness
D Decreases brightness
FB Switch to full brightness

There are 15 brightness settings from full brightness (100% LED duty) to minimum brightness (0.78% LED duty). The LED modulation rate is approximately 244 Hz and brightness steps are near logarithmic. For every two steps the brightness either doubles or decreases by half. By default, the LED is set four steps below full brightness (25%).

Holding U or D active will cause auto stepping of the brightness; this is similar to the volume control of an audio product. The FB input is used to immediately switch to full brightness and can be used for signaling when the brightness is set below full brightness.

The U and D inputs also control other modes of the device (See the State and Mode patterns):

Automatic Shut-Off
Flashing / Beacon
SOS

The automatic shut-off feature disables the product after 18 minutes. Prior to shut-off, the LED light will modulate for two minutes to warn the user of the automatic shut-off. During automatic shut-off warning, activating U or D will reset the timer for an additional 18 minutes without changing the brightness. By default the automatic shut-off feature is disabled. The automatic shut-off feature is always disabled in the Beacon / Flashing or SOS modes.

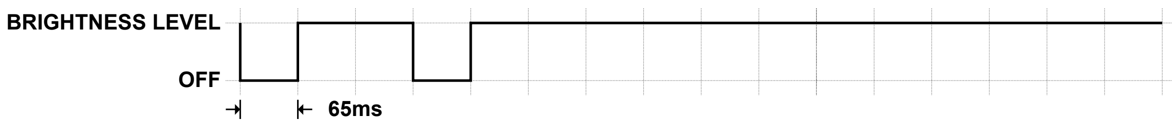
To enable automatic shut-off, the product is set to full brightness by the U input. The U input is then taken high for at least 1 second followed by low for at least 2 seconds. The LED will flash off periodically for a few seconds to indicate the automatic shut-off has been enabled.

To disable automatic shut-off, the product is set to minimum brightness by the D input. The D input is taken high for at least 1 second followed by low for at least 2 seconds. The LED will flash to full brightness periodically for a few seconds to indicate the automatic shut-off has been disabled.

A flashing / beacon mode can be enabled

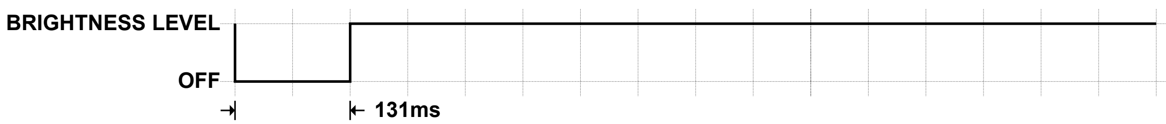
STATE & MODE PATTERNS

LOW BATTERY



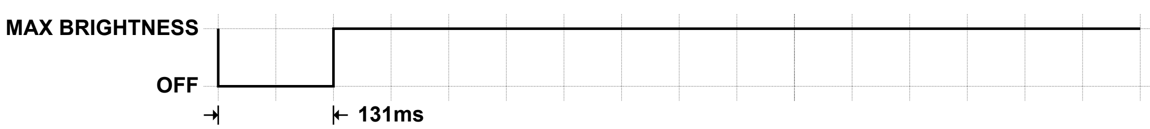
1 SECOND PATTERN
PATTERN REPEATED 4 TIMES UPON DETECTION OF LOW BATTERY, THEN SINGLE PATTERN EVERY 16 SECONDS AFTERWARDS

AUTO SHUT-OFF: WARNING



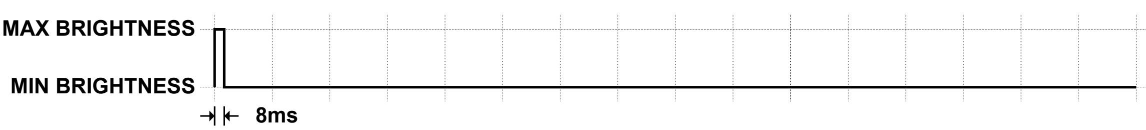
REPEATS PATTERN EVERY 4 SECONDS FOR 2 MINUTES UNTIL SHUT-OFF, OR BUTTON PRESS RESETS TIMER

AUTO SHUT-OFF: ENABLE



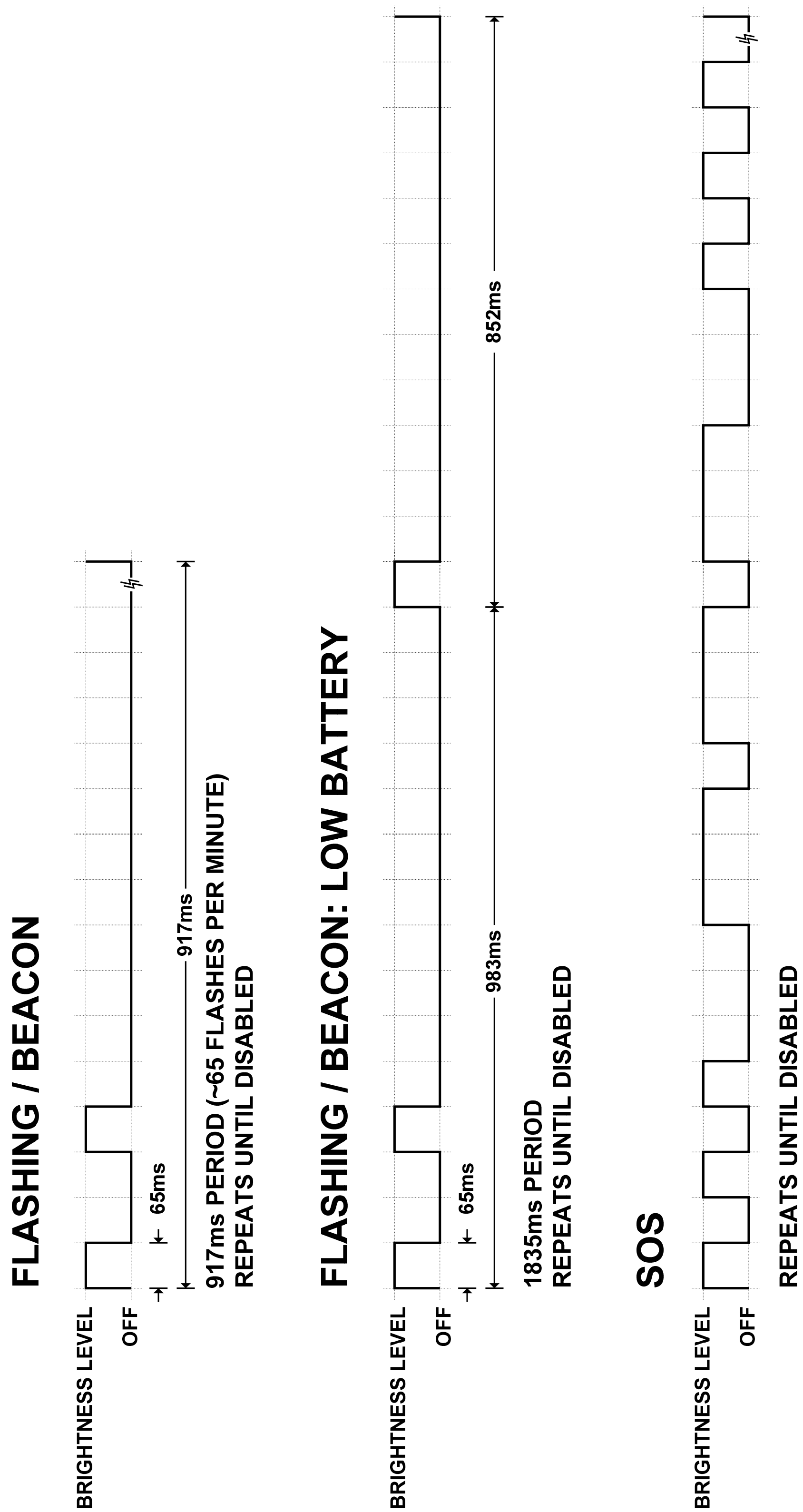
1 SECOND PATTERN
REPEATS 4 TIMES TO SIGNAL AUTO SHUT-OFF ENABLED

AUTO SHUT-OFF: DISABLE



1 SECOND PATTERN
REPEATS 4 TIMES TO SIGNAL AUTO SHUT-OFF DISABLED

STATE & MODE PATTERNS



from any brightness setting by holding both U and D low for at least 2 seconds. The LED will flash approximately 65 flashes (doublet flashes) per minute. The automatic shut-off feature is disabled while in the flashing / beacon mode. A special flashing pattern (described later) is used to indicate a low battery condition. To exit the flashing / beacon mode, U and D are taken high for at least 700 ms followed by low for approximately 1 second.

In the SOS mode the product will modulate the LED to produce the Morse Code for SOS. To enter the SOS mode the product must first enter the flashing / beacon mode described above, then U and D inputs must be high for at least 700 ms. The U and D inputs are then held low for more than 4 seconds. The automatic shut-off feature is disabled while in the SOS mode; low battery is not indicated in this mode. To exit the SOS mode, U and D inputs must be high for at least 700 ms followed by low for approximately 1 second.

Enabling and disabling the part does not clear the last mode or brightness setting. Only removal of power to the VDD pin and shorting VDD to GND for more than 10 ms assures a reset of the mode and brightness to default settings.

Design Considerations

Battery polarity is critical. Your product should provide a means to assure the correct polarity of voltage is applied at all times. Inadvertent reversal of battery polarity will damage the 907 part. The part will present a very low impedance with reversed polarity and could result in a product hazard when used with high-current battery technology.

Heat dissipation is through pins 1, 2, 3, 16, 17, 18 and the exposed Device Attachment Pin (DAP) in the middle of the package.

When the current through any pin is greater than 0.3A, the pin should be connected to a large trace / plane to dissipate the heat. The DAP should have multiple thermal paths to an exposed plane to remove the heat.

The buck regulator is designed to operate near boundary conduction mode. (Also referred to as borderline or critical conduction mode.) The full-brightness LED current is approximately one-half the peak inductor current. An output capacitor filters the inductor current so the LED load "sees" the average inductor current. Large capacitors are not necessary since the buck converter is operated well above 60 KHz.

The inductor value, LED voltage, and battery voltage control the operating frequency of the regulator. The longest period is 16 μs (~60KHz). The longest charge time is 15 μs, followed by 1 μs off time. The shortest charge time is 220 ns. With typical discharge times of 1 to 2 μs, this provides a very wide range of operating conditions and component values.

Inductance values that increase the time period beyond 8 μs should be avoided since this will interact with the LED PWM brightness control at lowest brightness settings.

The battery voltage needs to be greater than the maximum LED voltage by at least twice the sum of the voltage for current sensing and the voltage drop across the power FET. The available voltage to charge the inductor is reduced by the losses of the buck sense resistor, R0, and the drain to source resistance, BRdson. At the peak current, the sense voltage is 0.2 volts. For a single white LED (3.5 volts maximum) operating at 360 mA, the battery voltage should be greater than 4.1 volts for normal operation.

The 907 incorporates a regulator to step down the battery voltage (HV) to approximately 5 volts. The part internally shorts VCC and VDD together through a small trace. An external short on the board is highly recommended.

The step-down regulator works in conjunction with the bypass capacitors (C0 and C3) by switching an internal current source from the HV pin to VCC until the voltage at VCC is above its regulation point. The bypass capacitors should be at least 47 nF each and typically 1 µF total.

The VCC pin provides the gate drive voltage for the internal power FET and the BG pin. Set the low-battery shut-off point for the end-product at or above 3.5 volts. Below 3.5 volts, the on resistance of the internal power FETs may increase significantly because the output of the step down regulator, VCC, may drop below 3 volts.

The part has the ability to drive an external power FET in parallel with its internal FET. The gate drive at BG is enabled when EGE is tied to GNDG. EGE does not have a pull-up current source, so do not let this pin float. To disable BG, tie EGE to VCC. When disabled, the BG driver is a high impedance. However, there are internal diodes from BG to VCC and GNDG.

The current sensing point is internal to the part and consequently there is resistance between the sensing point and the pin-board interface. When calculating the external sense resistance, adjustment should be made for the sense offset resistance.

Over voltage protection (OVP) is required. The OVP pin with a resistor network is used to protect both the LED and the 907 FET from a brief or intermittent open-circuit. Without OVP, an open-circuit will cause the regulator to continuously run and increase the LED voltage until device breakdown and damage occurs in the part.

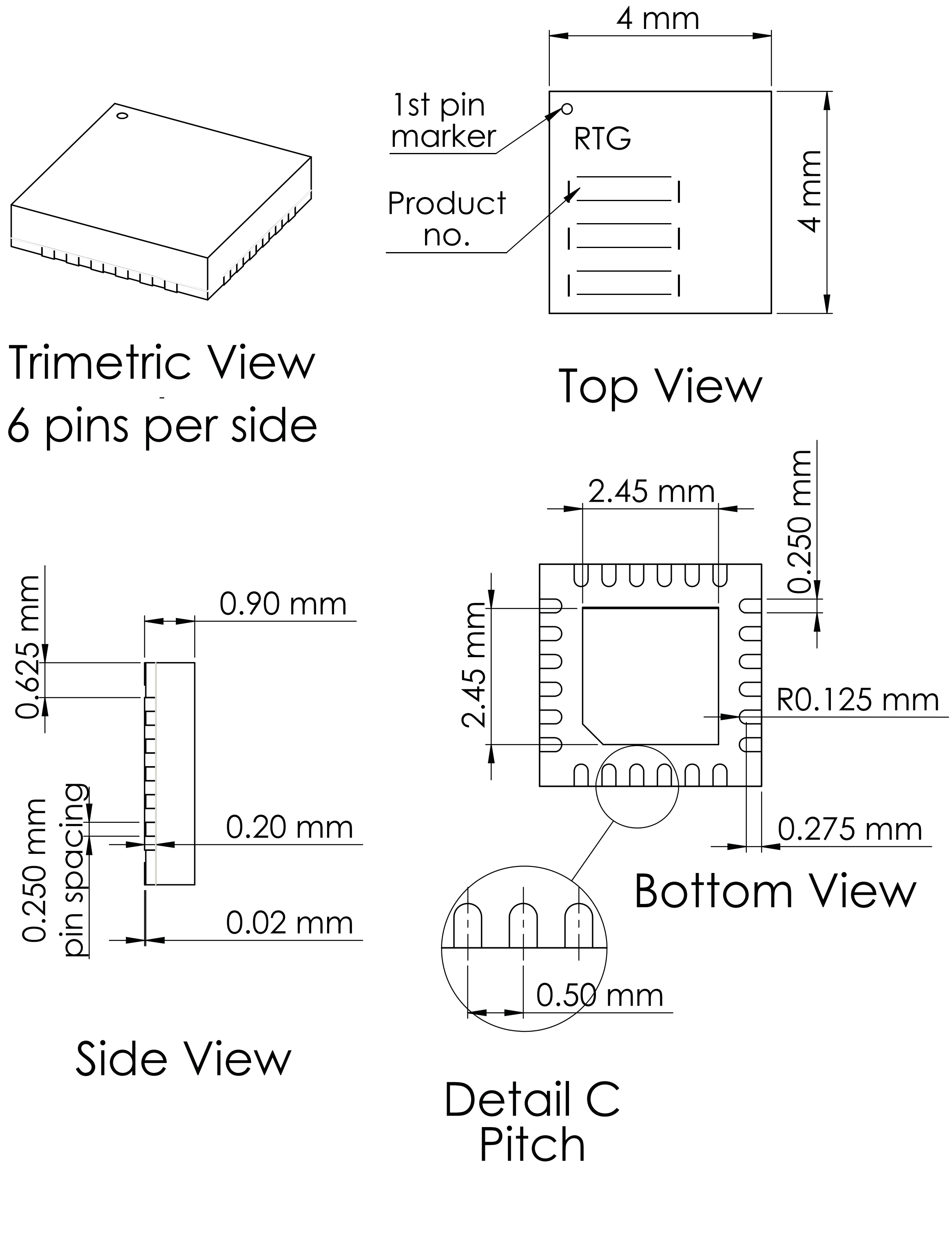
Since the battery voltage is typically above 6.5 volts, it is necessary to include a signal FET in the low battery detection circuit and the over-voltage protection circuits. The gate of the signal FET is tied to VDD to prevent the source from driving the LBD and OVP pins above VDD when the product is disabled (SW0 open circuit). Without the signal FET, the part may be damaged by high voltage from the battery through the resistor networks.

If an optional LED over-voltage sensing circuit is used, the current flowing in the sense network should be minimized to prevent dimming of the LED during the flashing beacon mode; using less than 1/5000 of the full brightness LED current will prevent noticeable dimming.

As mentioned before, the mode and brightness values are retained as long as power is provided to the VDD pin. Although the part performance may degrade below 3.8 volts, the logic inside the part will retain its state with as little as 1.5 volts on HV.

Removing the battery to remove power from VDD may not be an effective way to "reset" the part. To assure a clearing of the logic, the voltage on VDD must be brought to less than 10 mV for more than 10 ms. When using a large filter capacitor for HV, the very slow discharge rate may leave the part in an unstable state as VDD transitions from 1.2 to 0 volts. To assure clearing of the logic state, a bleed resistor in parallel with VDD will be required.

QFN—4X4—24 ld


4 mm
1st pin marker
RTG
Product no.
4 mm
Trimetric View
6 pins per side
Top View
2.45 mm
0.250 mm
0.90 mm
0.625 mm
2.45 mm
R0.125 mm
0.250 mm pin spacing
0.20 mm
0.275 mm
Bottom View
0.02 mm
0.50 mm
Side View
Detail C
Pitch