19-3097; Rev 2; 8/05

EVALUATION KIT AVAILABLE

White LED 1x/1.5x Charge Pump for Main and Sub-Displays

General Description

The MAX1575 charge pump drives up to four white LEDs in the main display and up to two white LEDs in the sub-display with regulated constant current for uniform intensity. By utilizing adaptive 1x/1.5x charge-pump modes and very-low-dropout current regulators, it achieves high efficiency over the full 1-cell lithium-battery input voltage range. A 1MHz fixed-frequency switching allows for tiny external components, and the regulation scheme is optimized to ensure low EMI and low input ripple.

The MAX1575 uses an external resistor to set the full-scale 100% LED current. Two enable inputs, ENM and ENS, are used for simple on/off controls for the main and sub-displays, respectively. By repeatedly pulsing either enable input, the LEDs can be dimmed in multiple steps down to 5%. Once the desired brightness is set, the MAX1575 maintains that brightness setting as long as the enable input is kept high. If an enable input is kept low for more than 2ms, the LED current for the respective display is set to zero. If both enable inputs are kept low for more than 2ms, the MAX1575 enters shutdown.

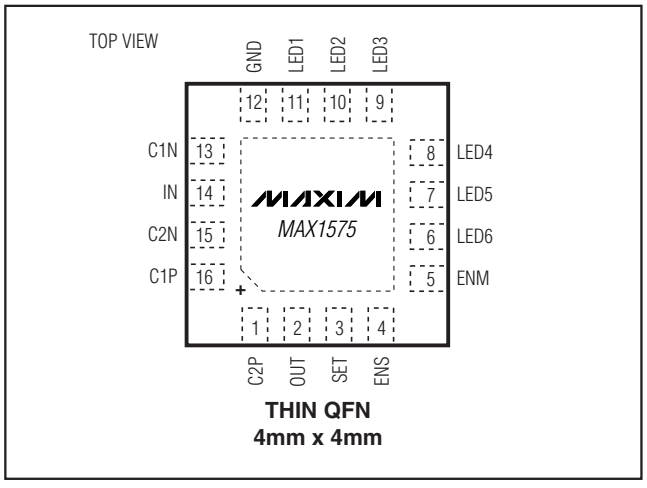
The MAX1575 is available in a 16-pin 4mm x 4mm thin QFN package (0.8mm max height).

Applications

Cell Phones with Main and Sub-Displays

PDAs/Smart Phones with Up to Six White LEDs

Pin Configuration



THIN QFN 4mm x 4mm

Features

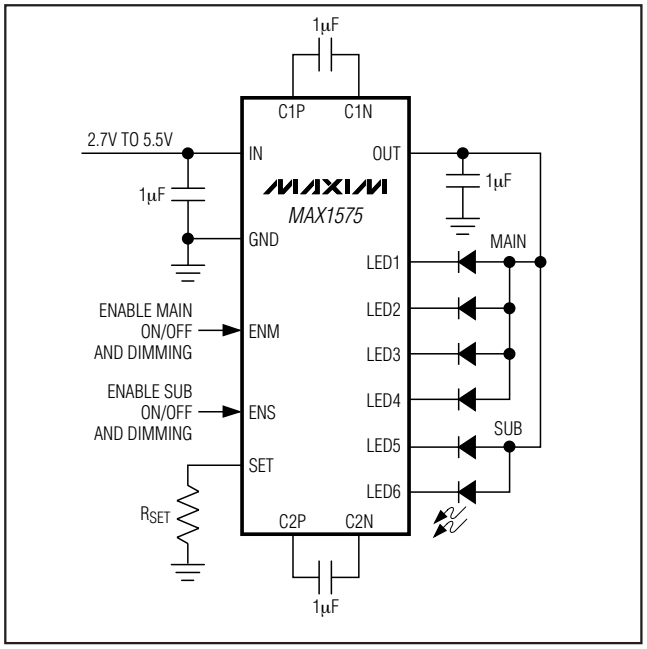
- ♦ **Powers Main and Sub-Display LEDs**
- ♦ **85% Average Efficiency (P_{LED} / P_{BATT}) Over Li+ Battery Discharge**
- ♦ **2% LED Current Matching**
- ♦ **Up to 30mA/LED Drive Capability**
- ♦ **Adaptive 1x/1.5x Mode Switchover**
- ♦ **Low Input Ripple and EMI**
- ♦ **Individual 5% to 100% Dimming Through Single-Wire Serial Pulse Interface**
- ♦ **Low 0.1µA Shutdown Current**
- ♦ **2.7V to 5.5V Supply Voltage Range**
- ♦ **Soft-Start Limits Inrush Current**
- ♦ **Output-Overvoltage Protection**
- ♦ **Thermal-Shutdown Protection**
- ♦ **16-Pin Thin QFN 4mm x 4mm Package**

Ordering Information

PART	TEMP RANGE	PIN-PACKAGE
MAX1575ETE	-40°C to +85°C	16 Thin QFN 4mm x 4mm
MAX1575ETE+	-40°C to +85°C	16 Thin QFN 4mm x 4mm

+ Denotes lead-free package.

Typical Operating Circuit



White LED 1x/1.5x Charge Pump for Main and Sub-Displays

ABSOLUTE MAXIMUM RATINGS

IN, OUT, ENM, ENS to GND .....-0.3V to +6.0V
SET, LED_, C1N, C2N to GND .....-0.3V to (V_{IN} + 0.3V)
C1P, C2P to GND .....-0.3V to the greater of (V_{OUT} + 1V) or (V_{IN} + 1V)
OUT Short Circuit to GND .....Continuous

Continuous Power Dissipation (T_A = +70°C)
16-Pin Thin QFN 4mm x 4mm
(derate 16.9 mW/°C above +70°C) 1349mW
Junction Temperature .....+150°C
Storage Temperature Range .....-65°C to +150°C
Lead Temperature (soldering, 10s) .....+300°C

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

ELECTRICAL CHARACTERISTICS

(V_{IN} = 3.6V, V_{GND} = 0V, ENM = ENS = IN, R_{SET} = 6.81kΩ, C_{IN} = C1 = C2 = C_{OUT} = 1µF, T_A = -40°C to +85°C, unless otherwise noted. Typical values are at T_A = +25°C.) (Note 1)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
IN Operating Voltage		2.7		5.5	V
Undervoltage-Lockout Threshold	V_{IN} falling	2.25	2.45	2.60	V
Undervoltage-Lockout Hysteresis			35		mV
OUT Overvoltage-Protection Threshold	V_{OUT} rising		5		V
No-Load Supply Current	1MHz switching in 1.5x mode		2		mA
	No switching in 1x mode,10% setting		0.5		
Shutdown Supply Current	ENM = ENS = OUT = GND		0.1	2	µA
Soft-Start Time			2		ms
SET Bias Voltage			0.6		V
SET Leakage in Shutdown	ENM = ENS = GND		0.01	1	µA
SET Current Range	T_A = 0°C to +85°C	10		130	µA
	T_A = -40°C to +85°C	30		130	
SET-to-LED_ Current Ratio ($I_{LED\_}$ / I_{SET})	100% setting		234		A/A
LED Current Accuracy	T_A = +25°C to +85°C	-8	±2	+8	%
	T_A = -40°C to +85°C	-9.5		+9.5	
LED-to-LED Current Matching (Note 2)	T_A = +25°C to +85°C	-5	±1.5	+5	%
	T_A = -40°C to +85°C	-6.5		+6.5	
Maximum LED_ Sink Current	R_{SET} = 4.53kΩ	27.4	30.0		mA
LED_ Dropout Voltage	(Note 3)		60	100	mV
LED_ 1x-to-1.5x Transition Threshold	V_{LED} falling	90	100	110	mV
LED Leakage in Shutdown	ENM = ENS = GND, $V_{LED\_}$ = 5.5V		0.01	1	µA
Maximum OUT Current	V_{IN} ≥ 3.4V, V_{OUT} = 3.9V, 100% setting	120			mA
Open-Loop OUT Resistance	1x mode (V_{IN} - V_{OUT}) / I_{OUT}		1	2.5	Ω
	1.5x mode (1.5 x V_{IN} - V_{OUT}) / I_{OUT}		4.2	10	
Switching Frequency			1		MHz
OUT Pulldown Resistance	ENM = ENS = GND		5		kΩ
ENM, ENS High Voltage	V_{IN} = 2.7V to 5.5V	1.6			V
ENM, ENS Low Voltage	V_{IN} = 2.7V to 5.5V			0.4	V
ENM, ENS Input Current	$V_{EN\_}$ = 0V or 5.5V		0.01	1	µA
Shutdown Delay	From falling edge of ENM and ENS	1.0	2	3.3	ms

ELECTRICAL CHARACTERISTICS (continued)

(V_{IN} = 3.6V, V_{GND} = 0V, ENM = ENS = IN, R_{SET} = 6.81kΩ, C_{IN} = C1 = C2 = C_{OUT} = 1µF, T_A = -40°C to +85°C, unless otherwise noted. Typical values are at T_A = +25°C.) (Note 1)

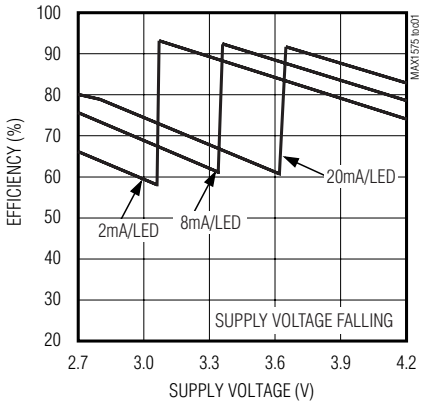
PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
t_{LO} (ENM, ENS) (Figure 1)		0.5		500	µs
t_{HI} (ENM, ENS) (Figure 1)		0.5			µs
Initial t_{HI} (ENM, ENS) (Figure 1)	Only required for first EN_ pulse	50			µs
Thermal-Shutdown Threshold			+160		°C
Thermal-Shutdown Hysteresis			20		°C

Note 1: Specifications to -40°C are guaranteed by design and not production tested.
Note 2: LED current matching is defined as: (I_{LED} - I_{AVG}) / I_{AVG}
Note 3: Dropout voltage is defined as the LED_-to-GND voltage at which current into the LED drops 10% from the LED current at $V_{LED\_}$ = 0.2V.

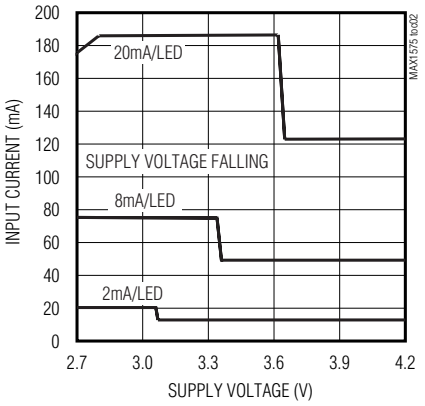
Typical Operating Characteristics

(V_{IN} = 3.6V, ENM = ENS = IN, circuit of Figure 2, T_A = +25°C, unless otherwise noted.)

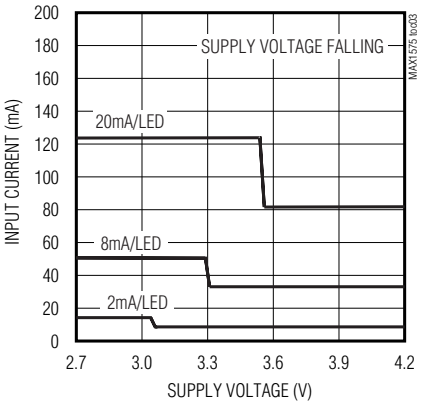
EFFICIENCY vs. SUPPLY VOLTAGE DRIVING SIX WHITE LEDs



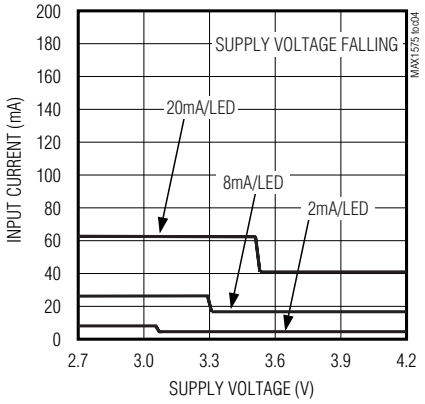
INPUT CURRENT vs. SUPPLY VOLTAGE DRIVING SIX WHITE LEDs



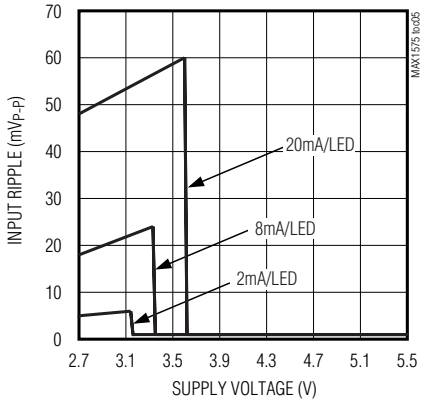
INPUT CURRENT vs. SUPPLY VOLTAGE DRIVING FOUR WHITE LEDs



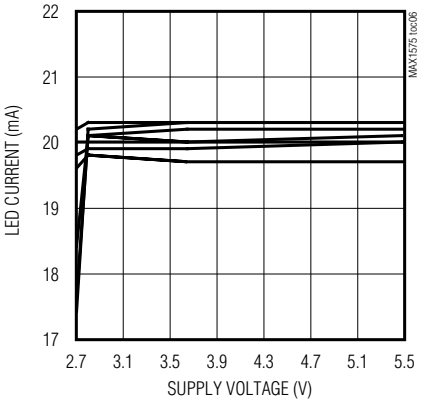
INPUT CURRENT vs. SUPPLY VOLTAGE DRIVING TWO WHITE LEDs



INPUT RIPPLE vs. SUPPLY VOLTAGE DRIVING SIX WHITE LEDs



LED CURRENT MATCHING vs. SUPPLY VOLTAGE

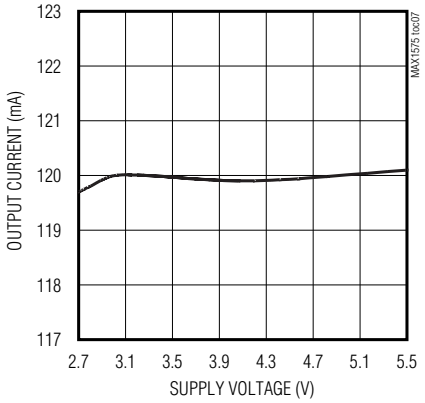


White LED 1x/1.5x Charge Pump for Main and Sub-Displays

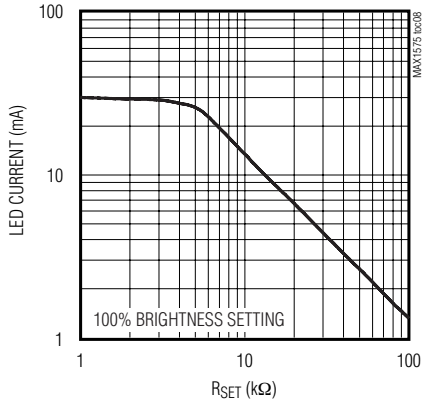
Typical Operating Characteristics (continued)

(V_{IN} = 3.6V, ENM = ENS = IN, circuit of Figure 2, T_A = +25°C, unless otherwise noted.)

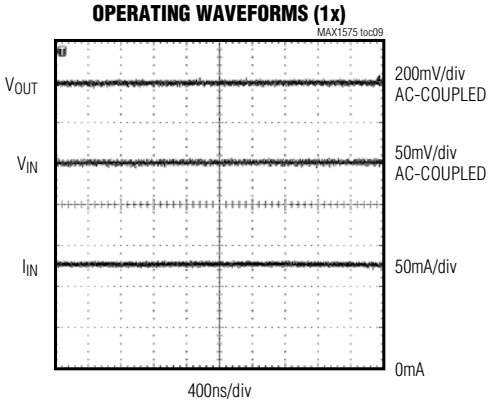
OUTPUT CURRENT vs. SUPPLY VOLTAGE DRIVING SIX LEDs AT 20mA EACH



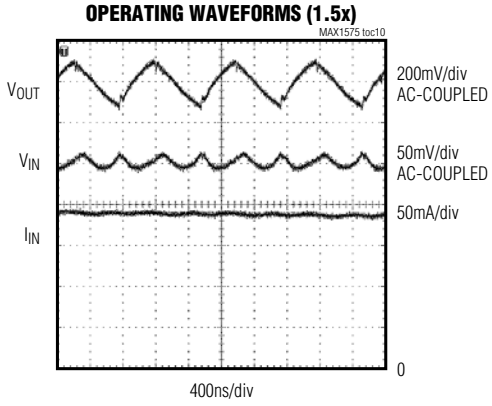
LED CURRENT vs. R_{SET}



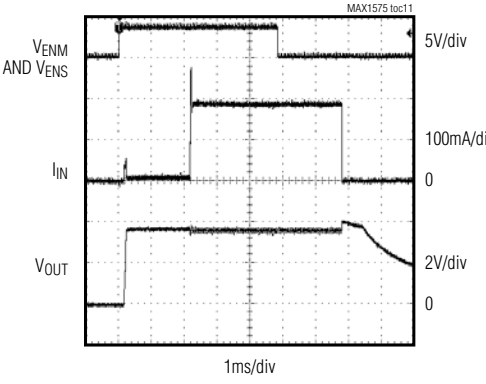
OPERATING WAVEFORMS (1x)



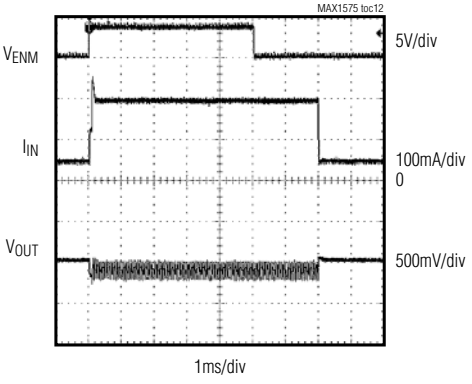
OPERATING WAVEFORMS (1.5x)



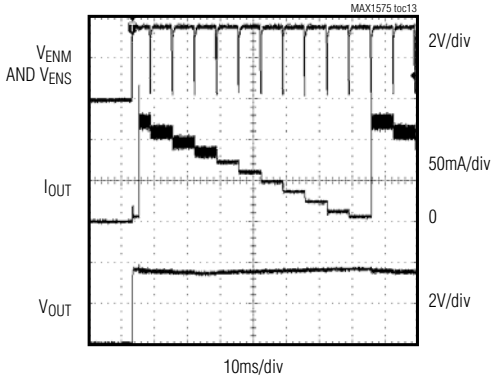
STARTUP WAVEFORMS



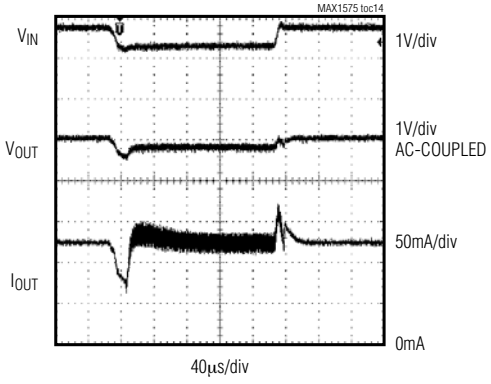
MAIN STARTUP WITH SUB-DISPLAY ON



DIMMING RESPONSE



LINE TRANSIENT 3.8V TO 3.3V TO 3.8V



Pin Description

PIN	NAME	FUNCTION
1	C2P	Transfer-Capacitor 2 Positive Connection. Connect a 1µF ceramic capacitor from C2P to C2N.
2	OUT	Output. Connect a 1µF ceramic capacitor from OUT to GND. Connect OUT to the anodes of all the LEDs. OUT is internally pulled down with 5kΩ during shutdown.
3	SET	Current-Set Input. Connect a resistor (R_{SET}) from SET to GND to set the maximum LED current. $I_{LED(MAX)} = 234 \times 0.6V / R_{SET}$. SET is internally biased to 0.6V. SET is high impedance during shutdown.
4	ENS	Enable and Dimming Control for LED5 and LED6 (Sub-Display). The first time ENS goes high (50µs min), LED5 and LED6 turn on at 100% brightness. Pulsing ENS low dims the LEDs in multiple steps. If ENS is held low for more than 2ms (typ), LED5 and LED6 turn off. When ENM and ENS are both held low for more than 2ms (typ), the IC goes into shutdown mode. See Figure 1.
5	ENM	Enable and Dimming Control for LED1–LED4 (Main Display). The first time ENM goes high (50µs min), LED1–LED4 turn on at 100% brightness. Pulsing ENM low dims the LEDs in multiple steps. If ENM is held low for more than 2ms (typ), LED1–LED4 turn off. When ENM and ENS are both held low for more than 2ms (typ), the IC goes into shutdown mode. See Figure 1.
6	LED6	Sub-Display LEDs Cathode Connection. Current flowing into LED_ is described in the ENS and SET descriptions above. The charge pump regulates the lowest-enabled LED_ voltage to 180mV. Connect LED_ to IN if the LED is not populated. LED_ is high impedance during shutdown.
7	LED5	
8	LED4	Main-Display LEDs Cathode Connection. Current flowing into LED_ is described in the ENM and SET descriptions above. The charge pump regulates the lowest-enabled LED_ voltage to 180mV. Connect LED_ to IN if the LED is not populated. LED_ is high impedance during shutdown.
9	LED3	
10	LED2	
11	LED1	
12	GND	Ground. Connect GND as close as possible to system ground and to the ground of the input bypass capacitor.
13	C1N	Transfer-Capacitor 1 Negative Connection. Connect a 1µF ceramic capacitor from C1P to C1N.
14	IN	Supply Voltage Input. Connect a 1µF ceramic capacitor from IN to GND. The input voltage range is 2.7V to 5.5V. IN is high impedance during shutdown.
15	C2N	Transfer-Capacitor 2 Negative Connection. Connect a 1µF ceramic capacitor from C2P to C2N.
16	C1P	Transfer-Capacitor 1 Positive Connection. Connect a 1µF ceramic capacitor from C1P to C1N.
—	EP	Exposed Paddle. Connect the exposed paddle to GND.

Detailed Description

The MAX1575 charge pump drives up to four white LEDs in the main display and up to two white LEDs in the sub-display with regulated constant current for uniform intensity. By utilizing adaptive 1x/1.5x charge-pump modes and very-low-dropout current regulators, it achieves high efficiency over the 1-cell lithium-battery input voltage range. 1MHz fixed-frequency switching allows for tiny external components and low input ripple.

1x to 1.5x Switchover

When V_{IN} is higher than V_{OUT}, the MAX1575 operates in 1x mode and V_{OUT} is pulled up to V_{IN}. The internal current regulators regulate the LED current. As V_{IN} drops, $V_{LED\_}$ eventually falls below the switchover threshold of 100mV and the MAX1575 starts switching in 1.5x mode. When the input voltage rises above V_{OUT} by about 50mV, the MAX1575 switches back to 1x mode.

Soft-Start

The MAX1575 includes soft-start circuitry to limit inrush current at turn-on. When starting up, the output capacitor is charged directly from the input with a ramped current source (with no charge-pump action) until the output voltage approaches the input voltage. Once this occurs, the charge pump determines if 1x or 1.5x mode is required. In the case of 1x mode, the soft-start is terminated and normal operation begins. During the soft-start time, the output current is set to 5% of the maximum set by R_{SET}. In the case of 1.5x mode, soft-start operates until the lowest of LED1–LED6 reaches regulation. If an overload condition occurs, soft-start repeats every 2ms. If the output is shorted to ground (or <1.25V), the part reverts to soft-start and the ramped current source.

White LED 1x/1.5x Charge Pump for Main and Sub-Displays

Setting the Output Current

The LED current at full (100%) brightness is set (up to 30mA) by a resistor, R_{SET}, as follows:

$$R_{SET} = \frac{0.6V \times 234}{I_{LED\_}}$$

ENM and ENS Dimming Controls

When the LEDs are enabled by driving ENM or ENS high, the LED current initially goes to $I_{LED\_}$.

Dimming for the main display is done by pulsing ENM low (500ns to 500µs pulse width). Dimming for the sub-display is done by pulsing ENS low (500ns to 500µs pulse width). Each pulse reduces the LED current by 10%, so after one pulse the LED current is 0.9 x I_{LED}. The 10th pulse reduces the current by 5% so the LED current reduces from 0.1 x $I_{LED\_}$ to 0.05 x I_{LED}. The 11th pulse sets the LED current back to $I_{LED\_}$. Figure 1 shows a timing diagram for EN_.

Because soft-start is longer than intitial t_{HI}, apply dimming pulses quickly upon startup (after initial t_{HI}) to avoid LED_ current transitioning through full brightness. If dimming control is not required, EN_ work as simple on/off controls. Drive ENM high to enable the main LEDs, or drive ENM low to turn off the main LEDs. Drive ENS high to enable the sub-LEDs, or drive ENS low to turn off the sub-LEDs. Drive both ENM and ENS low to put the IC in low-power shutdown mode.

Shutdown Mode

When both ENM and ENS are held low for 2ms or longer, the MAX1575 is shut down and put in a low-current mode. OUT is internally pulled to GND with 5kΩ during shutdown.

Overvoltage Protection

If any LED fails as an open circuit, the output voltage is limited to approximately 5V by gating on/off the charge pump. In case any LED_ is floating or grounded, the MAX1575 operates in the same overvoltage-protection mode. To avoid overvoltage-protection mode when using fewer than six LEDs, connect any unused LED_ to IN.

Thermal Shutdown

The MAX1575 includes a thermal-limit circuit that shuts down the IC at approximately +160°C. The part turns on after the IC cools by approximately 20°C.

Applications Information

Driving Fewer than Six LEDs

When driving fewer than six LEDs, connect any unused LED_ directly to IN (Figure 3). When connected in this manner, the corresponding LED driver is disabled.

Input Ripple

For LED drivers, input ripple is more important than output ripple. Input ripple depends on the source supply's impedance. Adding a lowpass filter to the input further reduces input ripple. Alternately, increasing C_{IN} to 2.2µF cuts input ripple in half with only a small increase in footprint. The 1x mode always has very low input ripple.

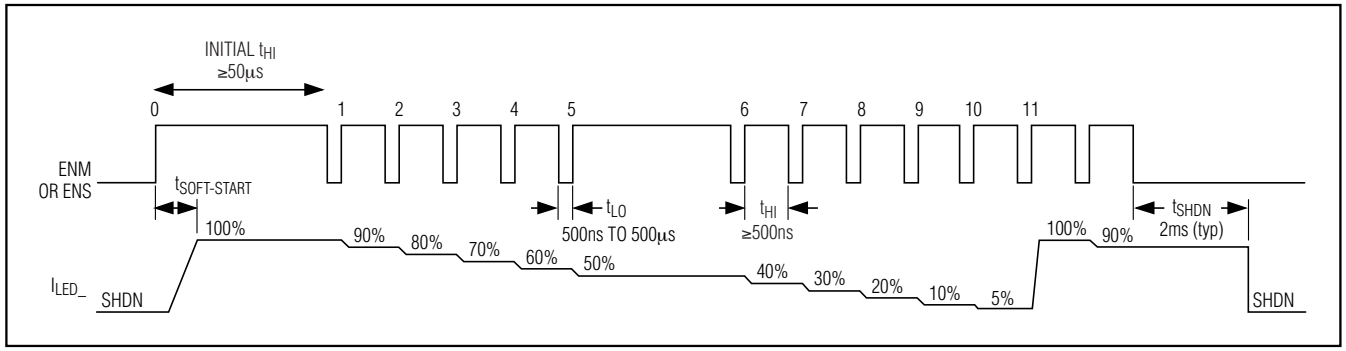


Figure 1. EN_ Timing Diagram

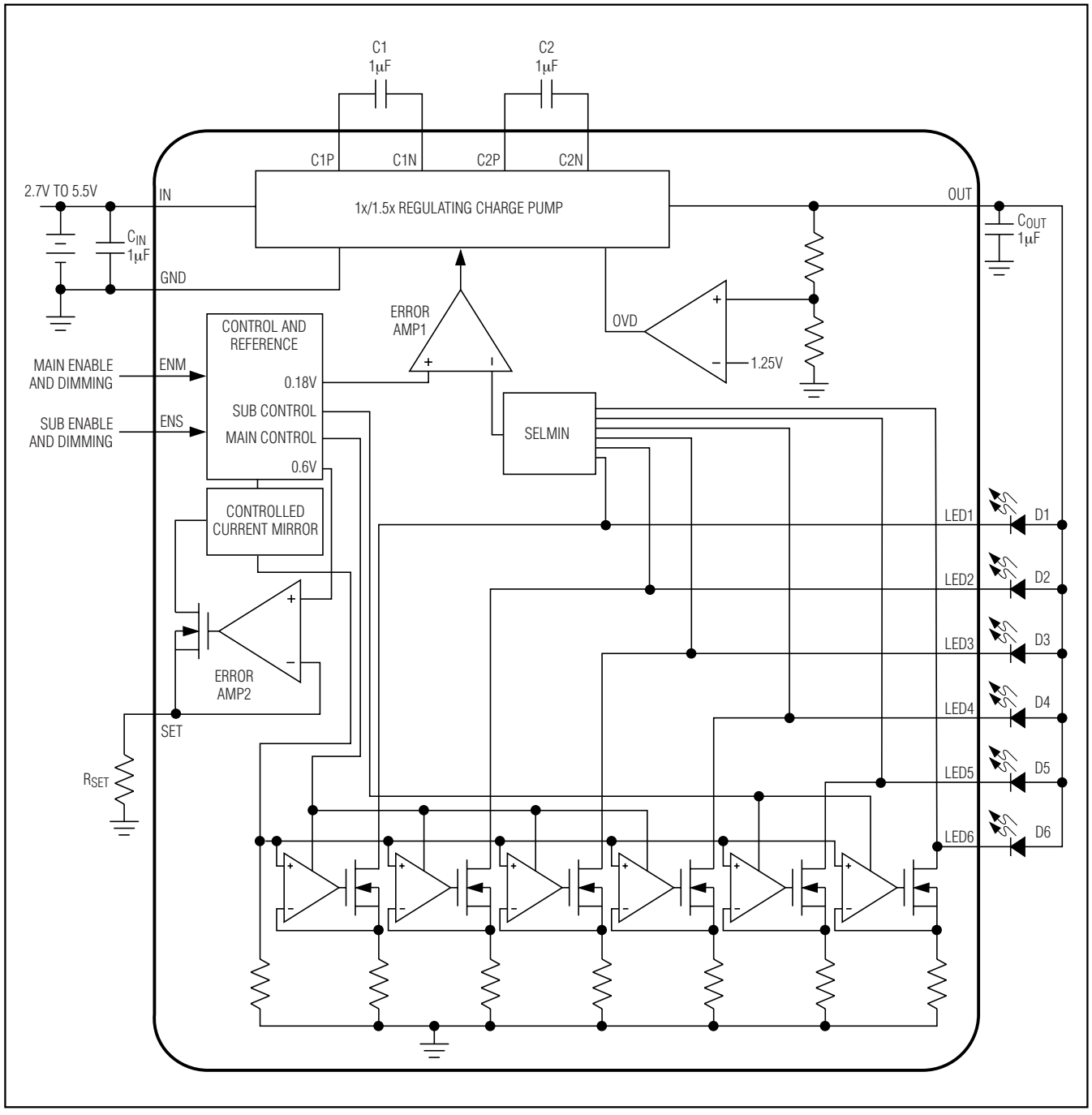


Figure 2. Functional Diagram and Typical Application Circuit

White LED 1x/1.5x Charge Pump for Main and Sub-Displays

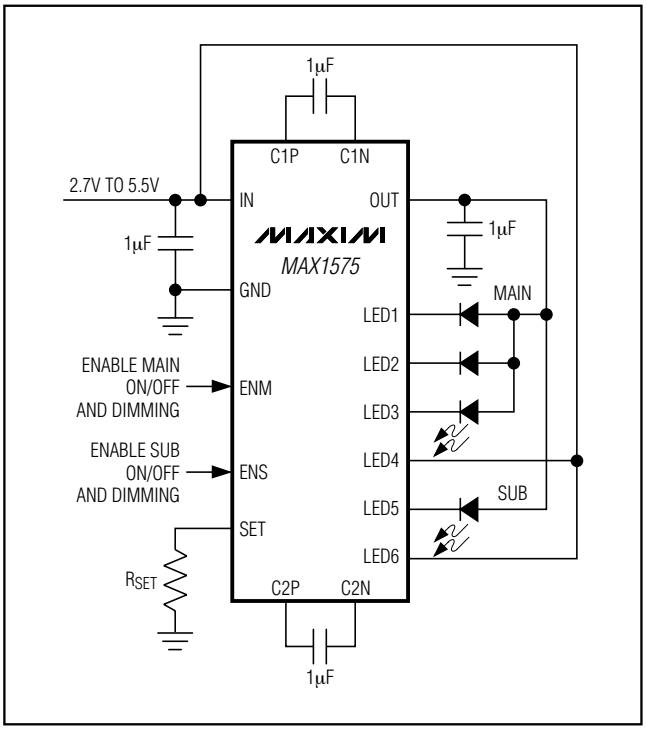


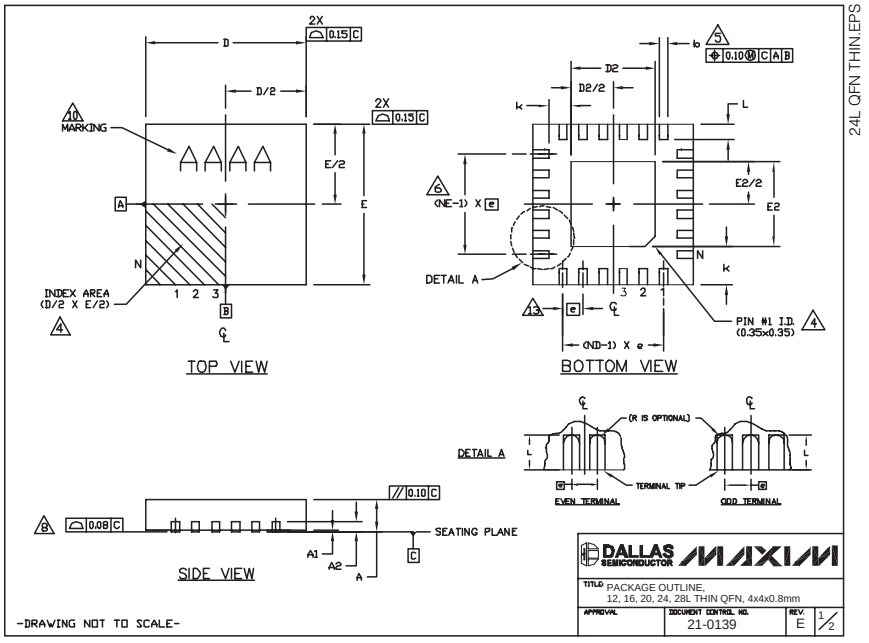
Figure 3. Driving Fewer than Six White LEDs

Table 1. Recommended Components

DESIGNATION	VALUE	MANUFACTURER	PART	DESCRIPTION
C_{IN}, C_{OUT}, C1, C2	1µF	Murata	GRM155R60J105K	1µF ±10%, 6.3V X5R ceramic capacitors (0402)
		Taiyo Yuden	JMK107BJ105KA	1µF ±10%, 6.3V X5R ceramic capacitors (0603)
		TDK	C1005X5R0J105M	1µF ±20%, 6.3V X5R ceramic capacitors (0402)
D1–D6	—	Nichia	NSCW215T	White LEDs
R_{SET}	As required	Kamaya	—	1% resistor
		Panasonic		

Package Information

(The package drawing(s) in this data sheet may not reflect the most current specifications. For the latest package outline information, go to **www.maxim-ic.com/packages**.)



COMMON DIMENSIONS

PKG	12L 4x4			16L 4x4			20L 4x4			24L 4x4			28L 4x4		
REF.	MIN.	NOM.	MAX.	MIN.	NOM.	MAX.	MIN.	NOM.	MAX.	MIN.	NOM.	MAX.	MIN.	NOM.	MAX.
A	0.70	0.75	0.80	0.70	0.75	0.80	0.70	0.75	0.80	0.70	0.75	0.80	0.70	0.75	0.80
A1	0.0	0.02	0.05	0.0	0.02	0.05	0.0	0.02	0.05	0.0	0.02	0.05	0.0	0.02	0.05
A2	0.20 REF			0.20 REF			0.20 REF			0.20 REF			0.20 REF		
b	0.25	0.30	0.35	0.25	0.30	0.35	0.20	0.25	0.30	0.18	0.23	0.30	0.15	0.20	0.25
D	3.90	4.00	4.10	3.90	4.00	4.10	3.90	4.00	4.10	3.90	4.00	4.10	3.90	4.00	4.10
E	3.90	4.00	4.10	3.90	4.00	4.10	3.90	4.00	4.10	3.90	4.00	4.10	3.90	4.00	4.10
e	0.80 BSC.			0.65 BSC.			0.50 BSC.			0.50 BSC.			0.40 BSC.		
k	0.25	-	-	0.25	-	-	0.25	-	-	0.25	-	-	0.25	-	-
L	0.45	0.55	0.65	0.45	0.55	0.65	0.45	0.55	0.65	0.30	0.40	0.50	0.30	0.40	0.50
N	12			16			20			24			28		
ND	3			4			5			6			7		
NE	3			4			5			6			7		
JEDEC Var.	WGGD			WGGC			WGGD-1			WGGD-2			WGGE		

EXPOSED PAD VARIATIONS

PKG. CODES	D2			E2			DOWN BONDS ALLOWED
	MIN.	NOM.	MAX.	MIN.	NOM.	MAX.	
T1244-3	1.95	2.10	2.25	1.95	2.10	2.25	YES
T1244-4	1.95	2.10	2.25	1.95	2.10	2.25	NO
T1644-3	1.95	2.10	2.25	1.95	2.10	2.25	YES
T1644-4	1.95	2.10	2.25	1.95	2.10	2.25	NO
T2044-2	1.95	2.10	2.25	1.95	2.10	2.25	YES
T2044-3	1.95	2.10	2.25	1.95	2.10	2.25	NO
T2444-2	1.95	2.10	2.25	1.95	2.10	2.25	YES
T2444-3	2.45	2.60	2.63	2.45	2.60	2.63	YES
T2444-4	2.45	2.60	2.63	2.45	2.60	2.63	NO
T2844-1	2.50	2.60	2.70	2.50	2.60	2.70	NO

NOTES:

1. DIMENSIONING & TOLERANCING CONFORM TO ASME Y14.5M-1994.
2. ALL DIMENSIONS ARE IN MILLIMETERS. ANGLES ARE IN DEGREES.
3. N IS THE TOTAL NUMBER OF TERMINALS.
4. THE TERMINAL #1 IDENTIFIER AND TERMINAL NUMBERING CONVENTION SHALL CONFORM TO JESD 95-1 SPP-012. DETAILS OF TERMINAL #1 IDENTIFIER ARE OPTIONAL, BUT MUST BE LOCATED WITHIN THE ZONE INDICATED. THE TERMINAL #1 IDENTIFIER MAY BE EITHER A MOLD OR MARKED FEATURE.
5. DIMENSION b APPLIES TO METALLIZED TERMINAL AND IS MEASURED BETWEEN 0.25 mm AND 0.30 mm FROM TERMINAL TIP.
6. ND AND NE REFER TO THE NUMBER OF TERMINALS ON EACH D AND E SIDE RESPECTIVELY.
7. DEPOPULATION IS POSSIBLE IN A SYMMETRICAL FASHION.
8. COPLANARITY APPLIES TO THE EXPOSED HEAT SINK SLUG AS WELL AS THE TERMINALS.
9. DRAWING CONFORMS TO JEDEC MO220, EXCEPT FOR T2444-3, T2444-4 AND T2844-1.
10. MARKING IS FOR PACKAGE ORIENTATION REFERENCE ONLY.
11. COPLANARITY SHALL NOT EXCEED 0.08mm
12. WARPAGE SHALL NOT EXCEEND 0.10mm
13. LEAD CENTERLINES TO BE AT TRUE POSITION AS DEFINED BY BASIC DIMENSION "e", ±0.05.
14. NUMBER OF LEADS SHOWN ARE FOR REFERENCE ONLY

-DRAWING NOT TO SCALE-

DALLAS SEMICONDUCTOR MAXIM
TITLE PACKAGE OUTLINE, 12, 16, 20, 24, 28L THIN QFN, 4x4x0.8mm
APPROVAL
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