NCP5602

High Efficiency Ultra Small Thinnest White LED Driver

The NCP5602 product is a dual output LED driver dedicated to the LCD display backlighting.

The built−in DC−DC converter is based on a high efficient charge pump structure with operating mode 1x and 1.5x. It provides a peak 87% efficiency together with a 0.2% LED to LED matching.

Features

- 2.7 to 5.5 V Input Voltage Range
- 87% Peak Efficiency with 1x and 1.5x Mode
- ICON Function Implemented
- Built−in Short Circuit Protection
- Provides Two Independent LED Drives
- Support I2C Protocol
- Smallest Available Package on the Market
- Tight 0.2% LED to LED Matching
- This is a Pb−Free Device

Typical Applications

- Portable Back Light
- Digital Cellular Phone Camera Photo Flash
- LCD and Key Board Simultaneously Drive

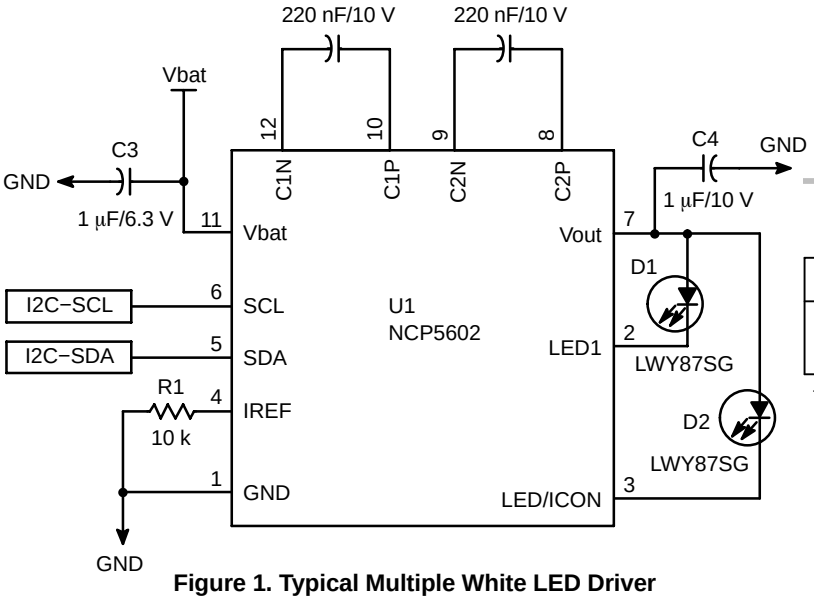
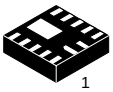


Figure 1. Typical Multiple White LED Driver

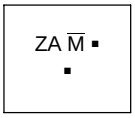
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MARKING DIAGRAM



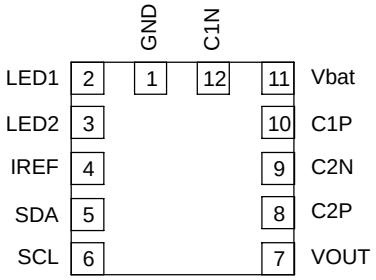
LLGA12 (2x2 mm)
MU SUFFIX
CASE 513AA



ZA = Specific Device Code
M = Date Code
▪ = Pb−Free Package

(Note: Microdot may be in either location)

PIN CONNECTIONS



(Top View)

ORDERING INFORMATION

Device	Package	Shipping†
NCP5602MUTBG	LLGA12 (Pb−Free)	3000 Tape & Reel

†For information on tape and reel specifications, including part orientation and tape sizes, please refer to our Tape and Reel Packaging Specification Brochure, BRD8011/D.

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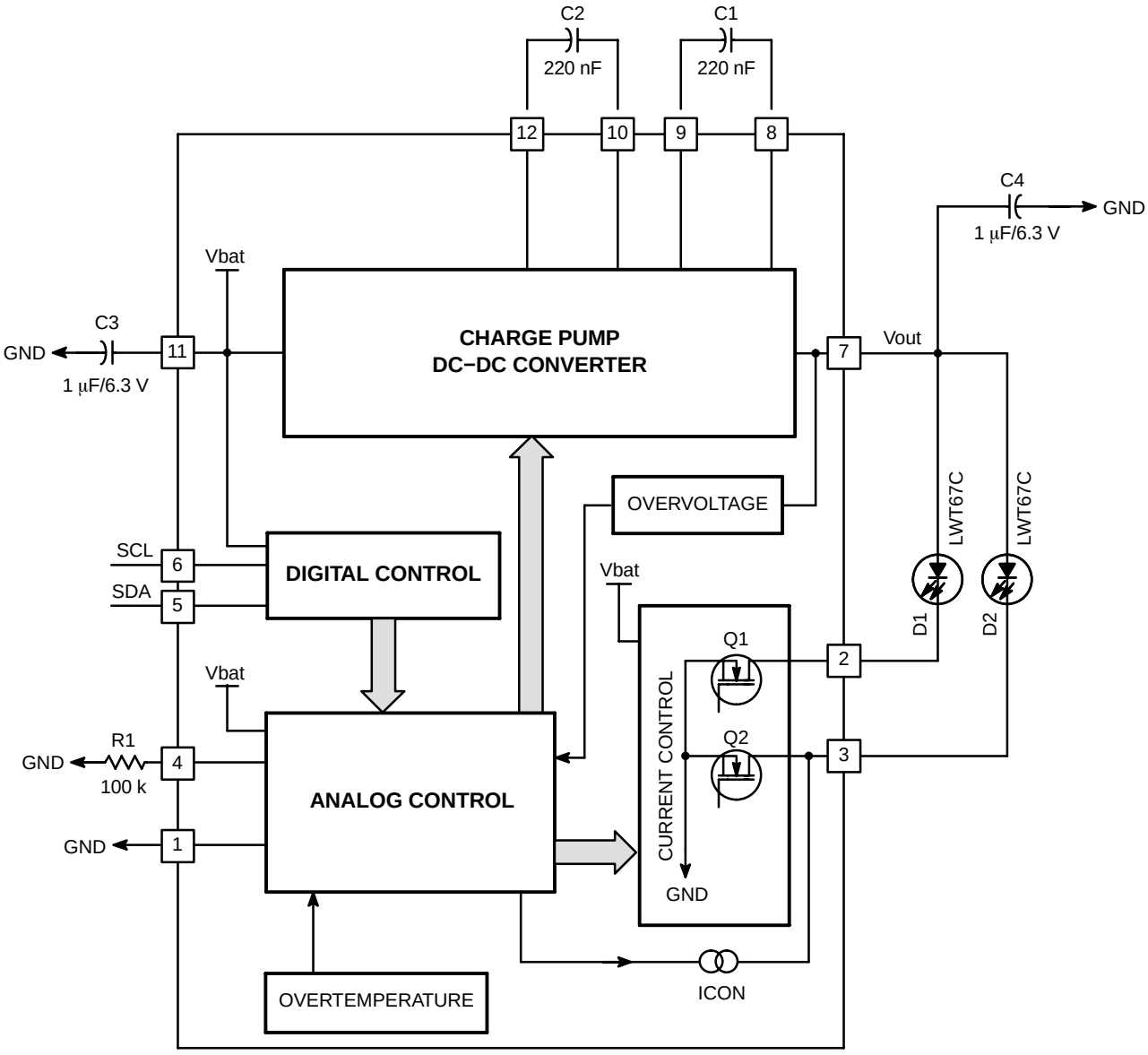


Figure 2. Simplified Block Diagram

PIN FUNCTION DESCRIPTION

Pin No.	Symbol	Function	Description
1	GND	POWER	This pin is the GROUND signal for the analog and digital blocks and must be connected to the system ground. This pin is the GROUND reference for the DC−DC converter and the output current control. The pin must be connected to the system ground, a ground plane being strongly recommended.
2	LED1	INPUT, POWER	This pin sinks to ground and monitors the current flowing into the first LED, intended to be used in backlight application. The current is limited to 30 mA maximum (see Note 2). When the ICON bit of the LED−REG register is High, the LED2 fulfills the ICON function. In this case, LED1 is deactivated.
3	LED2	INPUT, POWER	This pin sinks to ground and monitors the current flowing into the second LED, intended to be used in backlight application. The current is limited to 30 mA maximum (see Note 2). When the ICON bit of the LED−REG register is High, the LED2 fulfills the ICON function. In this case, LED1 is deactivated. The ICON current is 600 μA typical.
4	I_{REF}	INPUT, ANALOG	This pin provides the reference current, based on the internal bandgap voltage reference, to control the output current flowing in the LED. A 1% tolerance, or better, resistor shall be used to get the highest accuracy of the LED biases. An external current source can be used to bias this pin to dim the light coming out of the LED. In no case shall the voltage at pin 4 be forced either higher or lower than the 600 mV provided by the internal reference.
5	SDA	INPUT, DIGITAL	This pin carries the data provided by the I2C protocol. The content of the SDA byte is used to program the mode of operation and to set up the output current (see Table 2).
6	SCL	INPUT, DIGITAL	This pin carries the I2C clock to control the DC−DC converter and to set up the output current. The SCL clock is associated with the SDA signal.
7	VOUT	OUTPUT, POWER	This pin provides the output voltage supplied by the DC−DC converter. The Vout pin must be bypassed by 1.0 μF ceramic capacitor located as close as possible to the pin to properly bypass the output voltage to ground. The circuit shall not operate without such bypass capacitor properly connected to the Vout pin. The output voltage is internally clamped to 5.5 V maximum in the event of no load situation. On the other hand, the output current is limited to 40 mA (typical) in the event of a short circuit to ground.
8	C2P	POWER	One side of the external charge pump capacitor (C_{FLY}) is connected to this pin, associated with C2N (see Note 1).
9	C2N	POWER	One side of the external charge pump capacitor (C_{FLY}) is connected to this pin, associated with C2P (see Note 1).
10	C1P	POWER	One side of the external charge pump capacitor (C_{FLY}) is connected to this pin, associated with C1N, pin 11 (see Note 1).
11	VBAT	INPUT, POWER	Input Battery voltage to supply the analog and digital blocks. The pin must be decoupled to ground by a 1.0 μF ceramic capacitor.
12	C1N	POWER	One side of the external charge pump capacitor (C_{FLY}) is connected to this pin, associated with C1P, pin 10 (see Note 1).

1. Using low ESR ceramic capacitor is mandatory to optimize the Charge Pump efficiency.
2. Total DC−DC output current is limited to 60 mA.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Power Supply	V_{BAT}	−0.3 <V < 7.0	V
Output Power Supply	Vout	7.0	V
Digital Input Voltage Digital Input Current	SCL, SDA	−0.3 < V < V_{BAT} 1.0	V mA
Human Body Model: R = 1500 Ω, C = 100 pF (Note 3) Machine Model	ESD	2.0 200	kV V
LLGA12 Package Power Dissipation @ T_A = +85°C (Note 4) Thermal Resistance, Junction−to−Case Thermal Resistance, Junction−to−Air	 P_D $R_{\theta JC}$ $R_{\theta JA}$	 200 51 200	 mW °C/W °C/W
Operating Ambient Temperature Range	T_A	−40 to +85	°C
Operating Junction Temperature Range	T_J	−40 to +125	°C
Maximum Junction Temperature	T_{Jmax}	+150	°C
Storage Temperature Range	T_{stg}	−65 to +150	°C
Latchup Current Maximum Rating per JEDEC Standard: JESD78	−	±100	mA

Stresses exceeding Maximum Ratings may damage the device. Maximum Ratings are stress ratings only. Functional operation above the Recommended Operating Conditions is not implied. Extended exposure to stresses above the Recommended Operating Conditions may affect device reliability.

3. This device series contains ESD protection and exceeds the following tests:
   Human Body Model (HBM) ±2.0 kV per JEDEC standard: JESD22−A114.
   Machine Model (MM) ±200V per JEDEC standard: JESD22−A115.
4. The maximum package power dissipation limit must not be exceeded.
5. Moisture Sensitivity Level (MSL): 1 per IPC/JEDEC standard: J−STD−020A.

POWER SUPPLY SECTION (Typical values are referenced to T_A = +25°C, Min & Max values are referenced −40°C to +85°C ambient temperature, operating conditions 2.85 V < Vbat < 5.5 V, unless otherwise noted.)

Rating	Pin	Symbol	Min	Typ	Max	Unit
Power Supply	11	V_{bat}	2.7	−	5.5	V
Continuous DC Current in the Load @ Vf = 3.0 V, ICON = L @ 3.2 V < Vbat < 5.5 V @ 3.0 V < Vbat < 5.5 V	7	I_{out}	 60 45	 − −	 − −	mA
Output ICON Current (ICON = H) @ T_j = + 25°C, Vf = 2.8 V, Vbat = 3.6 V	7	$I_{ICONTROL}$	−	600	850	μA
Continuous Output Short Circuit Current	7	Isch	−	45	150	mA
Output Voltage Compliance (OVP)	7	Vout	4.8	−	5.7	V
DC−DC Start Time (Cout = 1.0 μF) 3.0 V < Vbat = Nominal < 5.5 V from Last ACK Bit to Full Load Operation	12	Tstart	−	150	−	μs
Output Voltage Turn Off Time from Last ACK Bit to Vout = 5%	12	Toff	−	300	−	μs
Standby Current, Vbat = 3.6 V, Iout = 0 mA, ICON = L @ SCL = SDA = L @ SCL = SDA = H (No Port Activity)	11	I_{stdb}	−	−	 6.0 12	μA
Operating Current, @ Iout = 0 mA, ICON = H, Vbat = 3.6 V	11	I_{op}	−	750	−	μA
Output LED to LED Current Matching, @ 3.0 V < Vbat < 4.2 V, I_{LED} = 10 mA, LED1 & LED2 are Identical −25°C < Ta < 85°C	2, 3	I_{MAT}	1.0	±0.2	1.0	%
Output Current Tolerance @ Vbat = 3.6 V, I_{LED} = 10 mA −25°C < Ta < 85°C	2, 3	I_{TOL}	−	±3.0	−	%
Charge Pump Operating Frequency −40°C < Ta < 85°C	−	Fpwr	−	1.0	−	MHz
Thermal Shutdown Protection	−	T_{SD}	−	160	−	°C
Thermal Shutdown Protection Hysteresis	−	T_{SDH}	−	30	−	°C
Efficiency − LED1 = LED2 = 10 mA, Vf = 3.2 V, Vbat = 3.2 V (Total = 20 mA) − LED1 = LED2 = 30 mA, Vf = 3.4 V, Vbat = 3.75 V (Total = 60 mA)	 − −	E_{PWR}	 − −	 87 84	 − −	%

ANALOG SECTION (Typical values are referenced to T_A = +25°C, Min & Max values are referenced −40°C to +85°C ambient temperature, operating conditions 2.85 V < Vbat < 5.5 V, unless otherwise noted.)

Rating	Pin	Symbol	Min	Typ	Max	Unit
Reference Current @ Vref = 600 mV (Note 7)	4	I_{REF}	1.0	−	60	μA
Reference Voltage (Note 7)	4	V_{REF}	−3%	600	+3%	mV
Reference Current (IREF) Current Ratio (see Table 2)	−	I_{LEDR}	−	16	−	−

6. The overall output current tolerance depends upon the accuracy of the external resistor. Using 1% or better resistor is recommended.
7. The external circuit must not force the I_{REF} pin voltage either higher or lower than the 600 mV specified. The limits represent the min/max values one can force to run the normal operation.

DIGITAL PARAMETERS SECTION (Typical values are referenced to T_A = +25°C, Min & Max values are referenced −40°C to +85°C ambient temperature, operating conditions 2.85 V < Vbat < 5.5 V, unless otherwise noted.) Note: Digital inputs undershoot < − 0.30 V to ground, Digital inputs overshoot < 0.30 V to V_{BAT}.

Rating	Pin	Symbol	Min	Typ	Max	Unit
InputI2C Clock Frequency (Note 8)	6	F_{SCK}	−	−	400	kHz
Positive Going Input High Voltage Threshold, SCL, SDA Signals	5, 6	V_{IH}	1.3	−	V_{BAT}	V
Negative Going Input High Voltage Threshold, SCL, SDA Signals	5, 6	V_{IL}	0	−	0.4	V

8. Parameter not tested in production, guaranteed by design.

APPLICATION INFORMATION

DC−DC Operation

The converter is based on a charge pump technique to generate a DC voltage capable to supply the White LED load. The system regulates the current flowing into each LED by means of internal current mirrors associated with the white diodes. Consequently, the output voltage will be equal to the Vf of the LED, plus the drop voltage (ranging from 200 mV to 400 mV, depending upon the output current) developed across the internal NMOS mirror. Typically, assuming a standard white LED forward biased at 10 mA, the output voltage will be 3.8 V.

The built−in OVP circuit continuously monitor each output and stops the converter when the voltage is above 5.0 V. The converter resumes to normal operation when the voltage drops below 5.0 V (no latchup mechanism). Consequently, the chip can operate with no load during any test procedures.

Load Current Calculation

The load current is derived from the 600 mV reference voltage provided by the internal Bandgap associated to the external resistor connected across I_{REF} pin and Ground (see Figure 3). In any case, no voltage shall be forced at I_{REF} pin, either downward or upward.

The reference current is multiplied by the constant k = 250 to yield the output load current. Since the reference voltage is based on a temperature compensated Bandgap, a tight tolerance resistor will provide a very accurate load current. The resistor is calculated from the Ohm's law ($R_{bias} = Vref/I_{REF}$) and a more practical equation can be arranged to define the resistor value for a given output current:

$$R_{bias} = (Vref * k)/Iout$$
$$R_{bias} = (0.6 * 250)/Iout \quad \text{(eq. 1)}$$

$$R_{bias} = 150/Iout \quad \text{(eq. 2)}$$

Consequently, the resistor value will range between R_{bias} = 150/30 mA = 5000 Ω and R_{bias} = 150/0.5 mA = 300 kΩ. Obviously, the tolerance of such a resistor must be 1% or better, with a 100 ppm thermal coefficient, to get the expected overall tolerance.

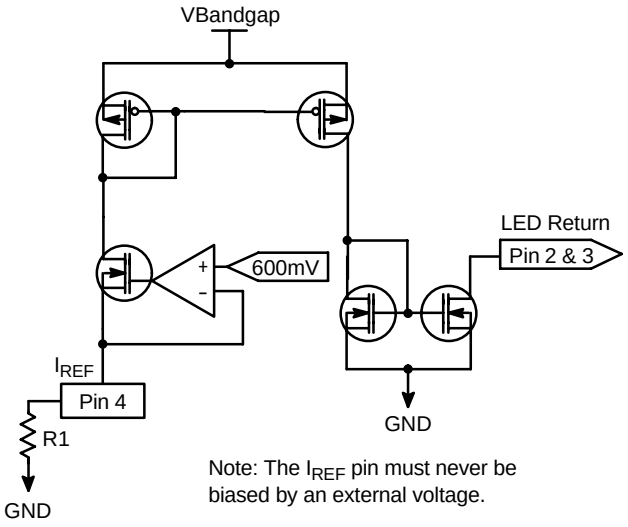


Figure 3. Basic Reference Current Source

Load Connection

The NCP5602 chip is capable to drive the two LED simultaneously, as depicted in Figure 1, but the load can be arranged to accommodate one or two LED if necessary in the application (see Figure 4). In this case, the two current mirrors can be connected in parallel to drive a single power full LED, thus yielding 60 mA current capability in a single LED.

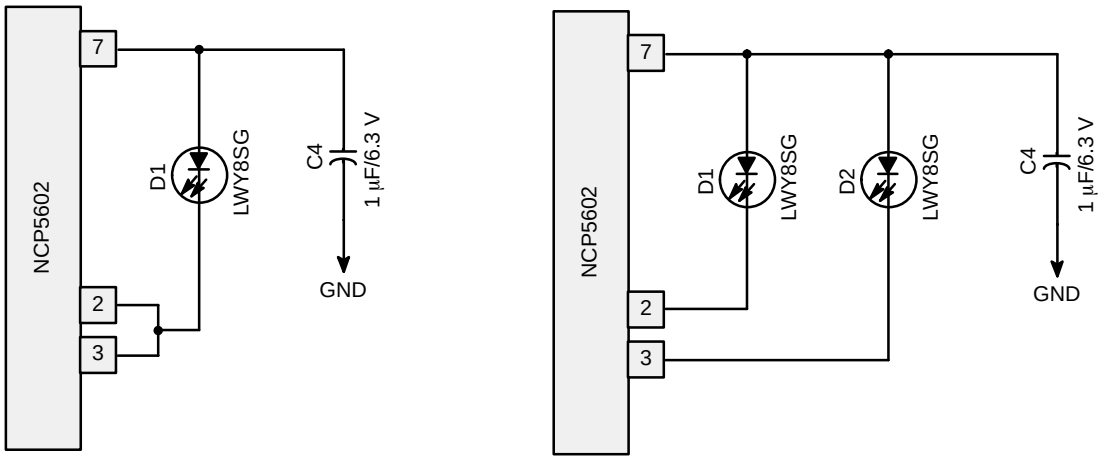


Figure 4. Typical Single and Double LED Connections

Finally, an external network can be connected across Vout and ground , but the current through such network will not be regulated by the NCP5602 chip (see Figure 5). On top of that, the total current out of the Vout pin shall be limited to 60 mA.

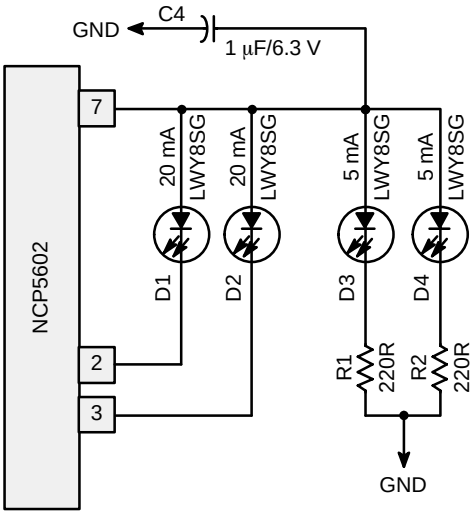


Figure 5. Extra Load Connected to Vout

I2C Protocol

The standard I2C protocol is used to transfer the data from the MCU to the NCP5602. Leaving aside the Acknowledge bit, the NCP5602 does not return data back to the MCU.

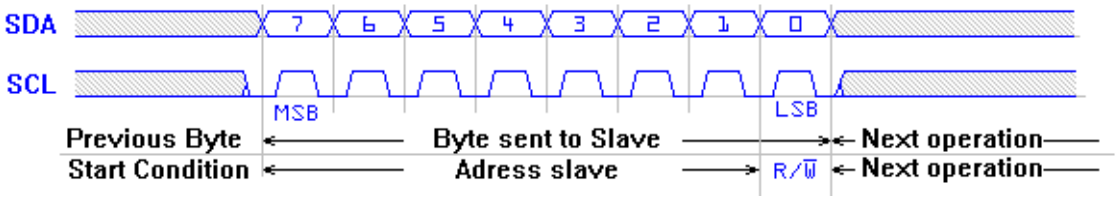


Figure 6. Basic I2C Timings

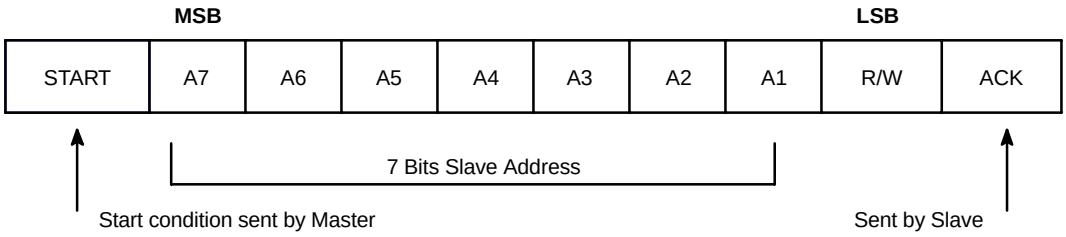


Figure 7. Peripheral Address Identification

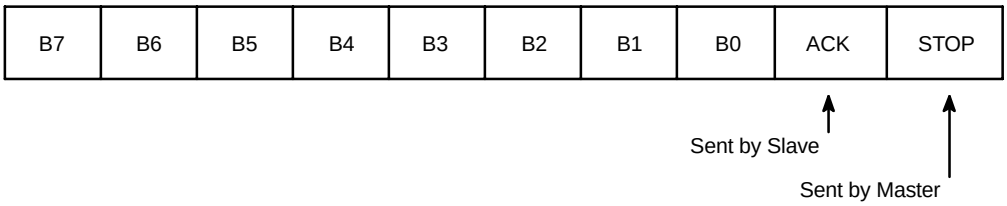


Figure 8. Basic DATA Transfer from MCU to Peripheral

The physical address of the NCP5602 is 1001 111X, the X being the Read/Write identifier as defined by the I2C specification. Since the NCP5602 does not return data, the first byte of the I2C frame shall be 1001 1110 ($9E) as depicted in Table 2.

Table 1. NCP5602 Physical I2C Address

B7	B6	B5	B4	B3	B2	B1	B0
1	0	0	1	1	1	1	0

To set up a new output current value, a full frame shall be sent by the MCU. The frame contains three consecutive bytes and shall fulfill the I2C specifications:

First byte : I2C address →$9E
Second byte : internal register address →$01
Third byte : output current value →$00 to $1E
(0 mA to 30 mA, Assuming Rext = 10 kΩ)

The waveforms given in Figure 9 illustrate a typical output current update.

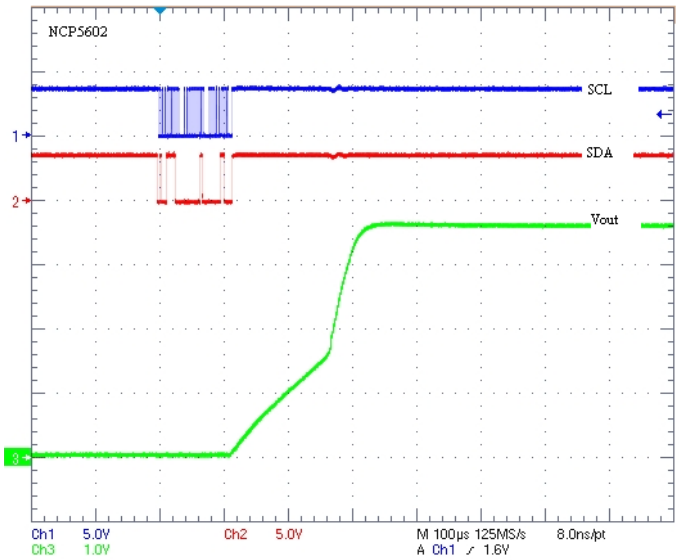


Figure 9. Typical NCP5602 I2C Startup Sequence

Dimming

The built−in I2C interface provides a simple way to accurately control the output current flowing in the two LED. Such dimming is active under the NORMAL mode only and the LED2 current cannot be adjusted when the ICON mode is active.

The internal register LED−REG[0..7] is set up by the content of the SDA byte sent by the external MCU as depicted in Table 2. For typical application, the 60 µA reference current forced by the external resistor is multiply by 16 to get a 1.0 mA/step in the output LED. The waveforms given Figure 10 illustrate a normal programming sequence.

Table 2. LED−REG[0..7] Internal Register Bits Assignment

B7	B6	B5	B4	B3	B2	B1	B0
RFU	RFU	ICON	IREF*16*16	IREF*16*8	IREF*16*4	IREF*16*2	IREF*16

[B7,B6] = RFU:bits reserved for future use
B5 = ICON:control the NORMAL/ICON mode of operation:
ICON = Low → Normal MODE takes place, the two LED are activated and the current can be adjusted from 0 mA to 30 mA maximum per LED.
ICON = High → ICON mode takes place, LED#1 is deactivated, the current to LED#2 being setup to 450 µA. It is not possible to adjust this current.
[B4..B0]= Output LED current. The content of these bits is latched to the current reference on the 8th SCK clock pulse.

The DC−DC converter is switched OFF and the two LED are disconnected when LED−REG=$00.

When the ICON mode is activated, the DC−DC converter is switched OFF, LED#1 is deactivated from the VOUT and 450 μA are forced into LED#2. The waveforms, given Figure 11, illustrate the programming sequence to activate the ICON.

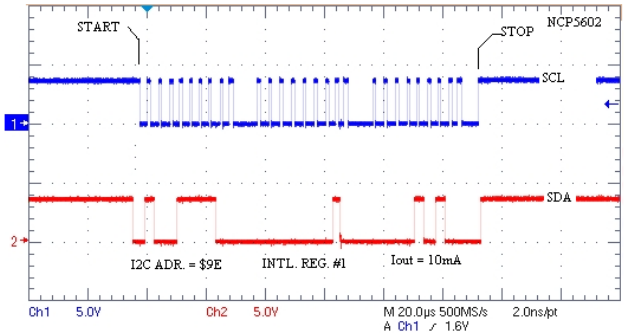


Figure 10. Output Current I2C Programming Sequence

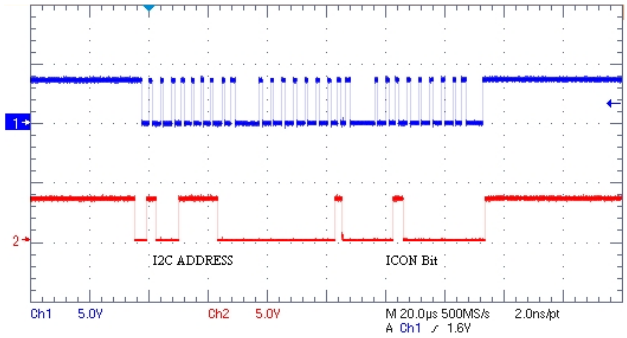


Figure 11. ICON Programming Sequence

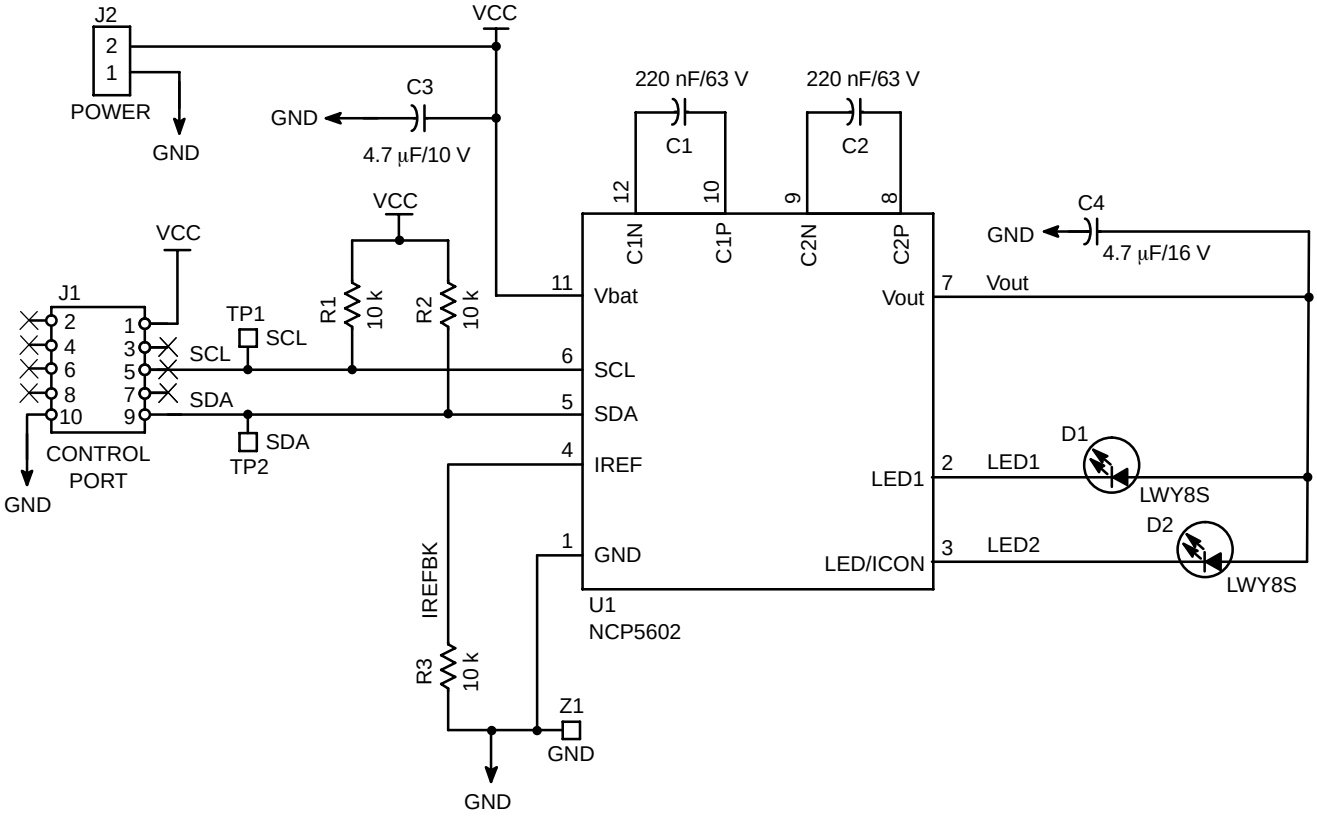


Figure 12. Demo Board Schematic Diagram

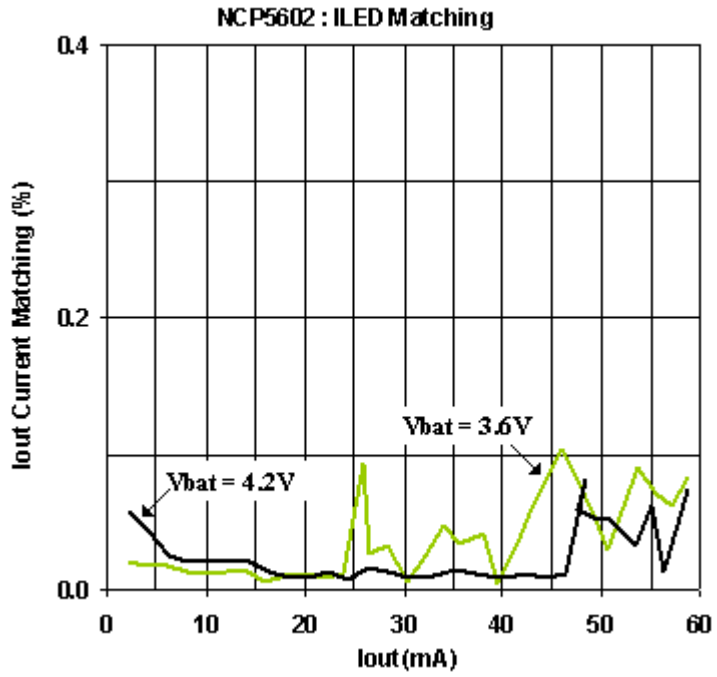


Figure 13. LED Current Matching

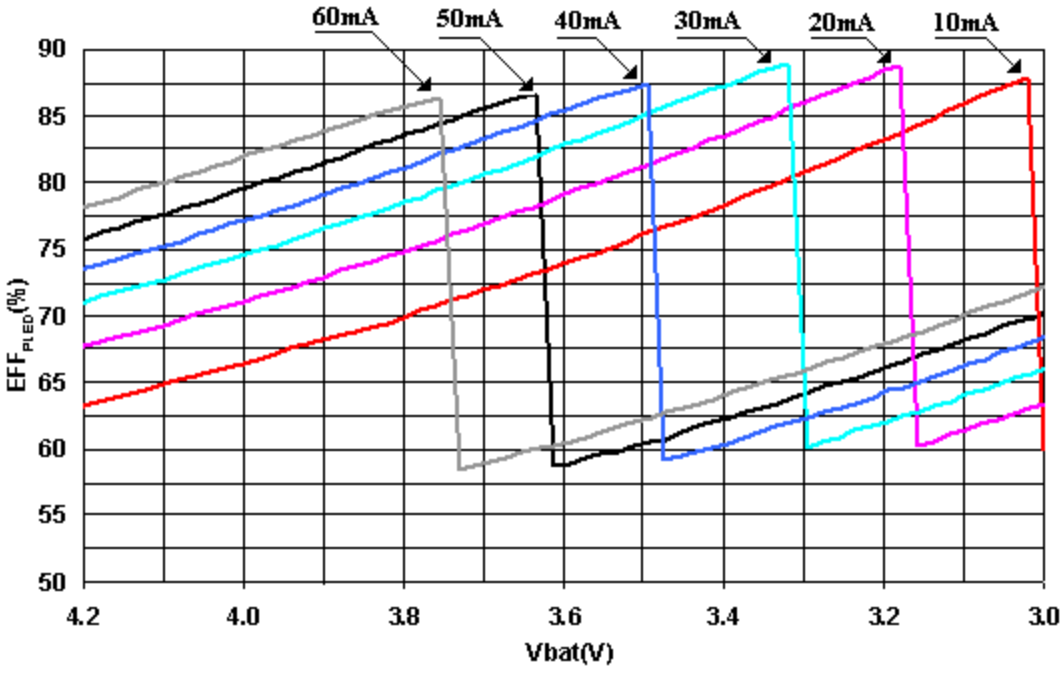


Figure 14. Efficiency as a Function of V_F, V_{bat}

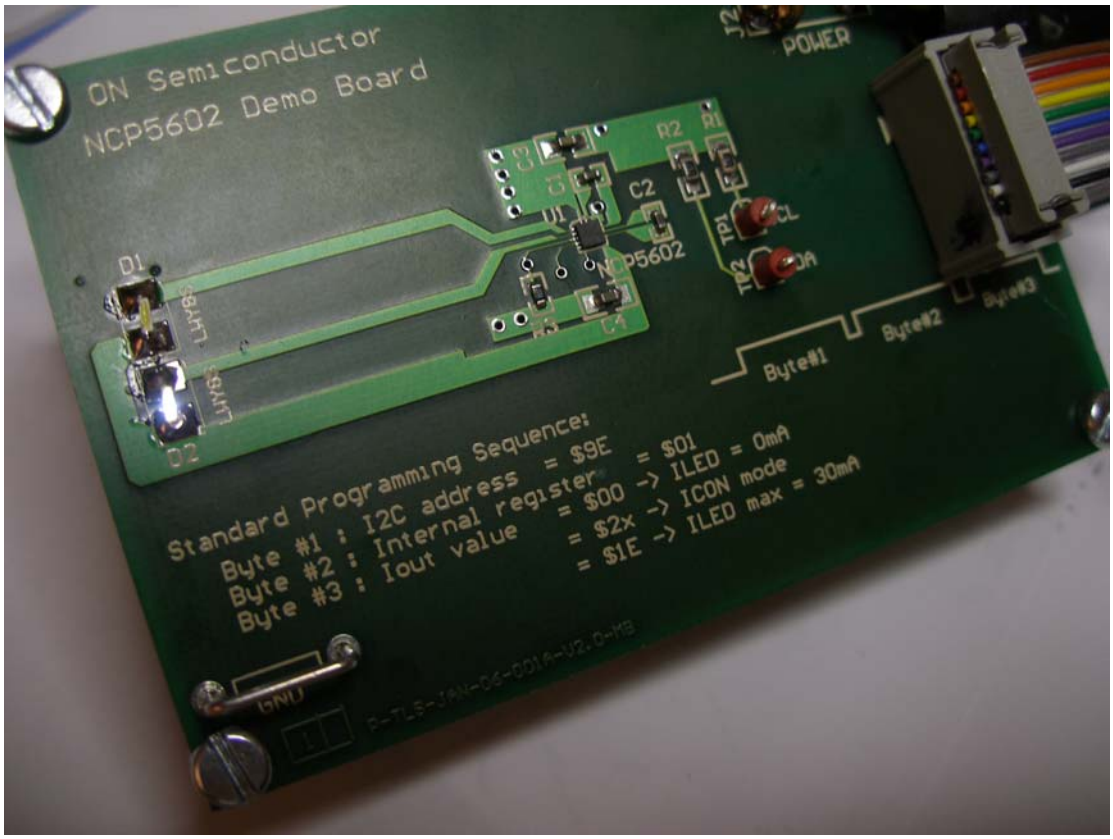
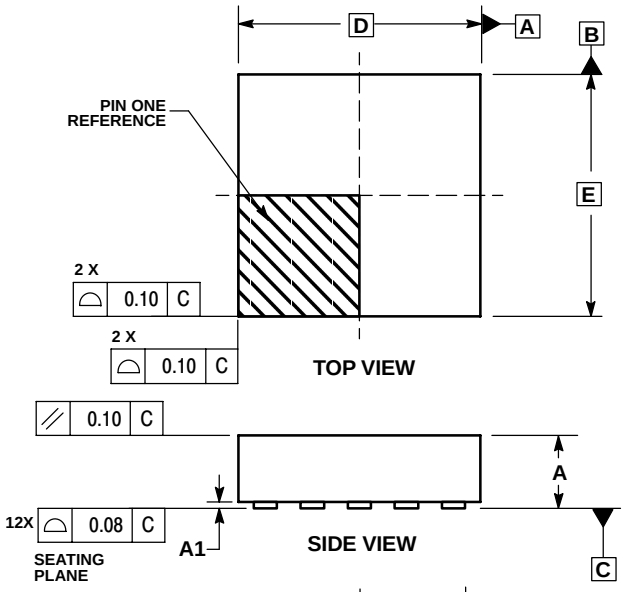
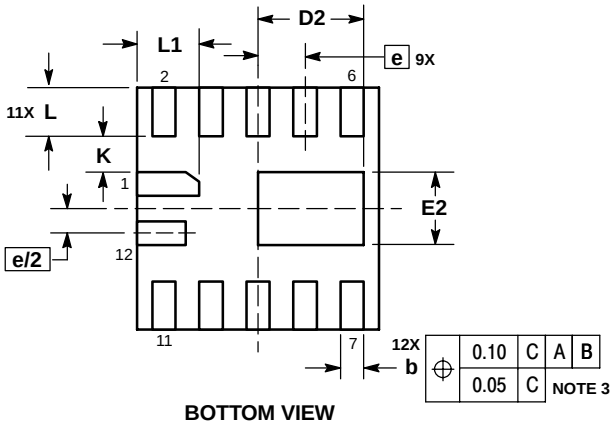


Figure 15. NCP5602 Demo Board

PACKAGE DIMENSIONS

LLGA12
MU SUFFIX
CASE 513AA−01
ISSUE O

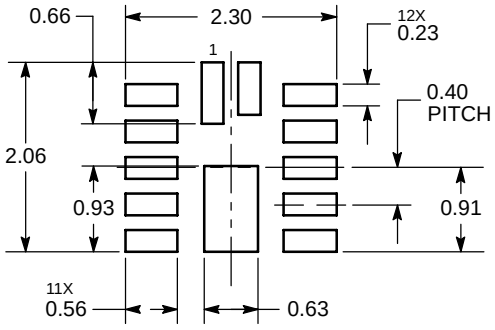




NOTES:
1. DIMENSIONING AND TOLERANCING PER ASME Y14.5M, 1994 .
2. CONTROLLING DIMENSION: MILLIMETERS.
3. DIMENSION b APPLIES TO PLATED TERMINAL AND IS MEASURED BETWEEN 0.15 AND 0.20 MM FROM TERMINAL.
4. COPLANARITY APPLIES TO THE EXPOSED PAD AS WELL AS THE TERMINALS.

	MILLIMETERS	
DIM	MIN	MAX
A	0.50	0.60
A1	0.00	0.05
b	0.15	0.25
D	2.00 BSC	
D2	0.80	1.00
E	2.00 BSC	
E2	0.55	0.65
e	0.40 BSC	
K	0.25	−−−
L	0.30	0.50
L1	0.40	0.60

SOLDERING FOOTPRINT*



DIMENSIONS: MILLIMETERS

*For additional information on our Pb−Free strategy and soldering details, please download the ON Semiconductor Soldering and Mounting Techniques Reference Manual, SOLDERRM/D.

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