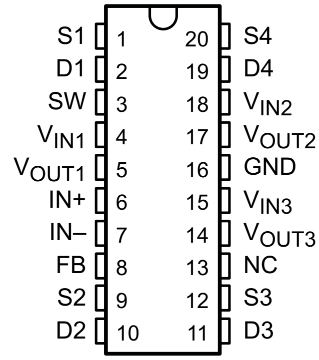
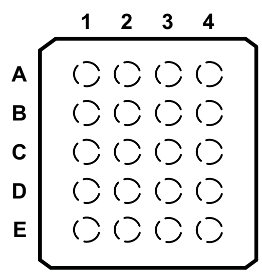
- **Integrated FETs with Low R_{DS-ON} . . . 6 Ω Max**
- **Current-Controlled Output Drives That Are Proportional to Battery Voltage to Save Power**
- **Integrated Power-Supply Switches for Power Savings During OFF State . . . 1 μA Max**
- **Up to 89% Efficiency**
- **Applications: LCD Display for Cell Phones, PDAs, Palmtops, etc.**

PW PACKAGE
(TOP VIEW)



NC – No internal connection

GQN PACKAGE
(TOP VIEW)



terminal assignments

	1	2	3	4
A	D1	S1	S4	D4
B	V_{IN1}	V_{OUT2}	SW	V_{IN2}
C	IN+	V_{OUT1}	V_{IN3}	GND
D	FB	NC	IN–	V_{OUT3}
E	D2	S2	D3	S3

NC – No internal connection

TERMINAL	DESCRIPTION
D1, D2, D3, D4	Drain of FETs 1, 2, 3, and 4, respectively
S1, S2, S3, S4	Source of FETs 1, 2, 3, and 4, respectively
V_{IN1}, V_{IN2}, V_{IN3}	Input of switches 1, 2, and 3, respectively
V_{OUT1}, V_{OUT2}, V_{OUT3}	Output of switches 1, 2, and 3, respectively
SW	Operates switches 1, 2, and 3 in unison Low input = switches are closed High input or Open = switches are open
IN+	Noninverting input to current-control amplifier
IN–	Inverting input to current-control amplifier
FB	Provides feedback connection to IN– of current-control amplifier
GND	Device ground

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TEXAS INSTRUMENTS
POST OFFICE BOX 655303 • DALLAS, TEXAS 75265

SLDS147C – JUNE 2002 – REVISED NOVEMBER 2002

description/ordering information

The TLED2043 is a four-channel, white LED driver used for backlighting color LCD displays in portable equipment. The device consists of four FET outputs, each of which is used essentially as a current sink to bias a single LED. The gates of the FETs are controlled collectively by a current-control amplifier that automatically monitors the battery voltage. If the battery voltage drops when compared to an externally set reference voltage, the current-control amplifier proportionately lowers all four FETs' output drives to conserve battery power. Additionally, the TLED2043 has internal switches that are programmed to disconnect the power supply and supporting circuitry to the device when LED operation is not needed, offering significant power savings during periods of inactivity.

Offering smaller board space, lower $R_{DS\text{-}ON}$, and lower overall cost, the TLED2043 has clear advantages over the use of discrete devices in implementing a white-LED driver solution. Compared to the use of charge pumps and dc-dc converters in similar applications, the TLED2043 again can offer the advantages of smaller board space and lower solution cost because no costly inductors and/or capacitors are required. In addition, it avoids the switching-noise and power-loss issues associated with such devices.

Characterized for operation from –40°C to 85°C, the TLED2043 is offered in 20-pin TSSOP (PW) and MicroStar Jr. BGA (GQN) packages for maximum space savings.

ORDERING INFORMATION

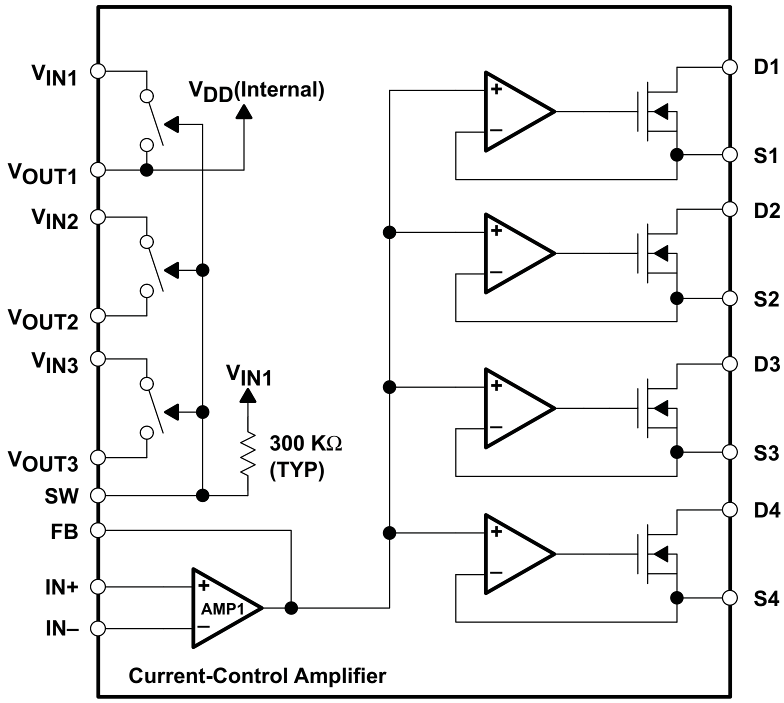
T_A	PACKAGE†		ORDERABLE PART NUMBER	TOP-SIDE MARKING
–40°C to 85°C	TSSOP (PW)	Tube of 70	TLED2043IPW	2043I
		Reel of 2000	TLED2043IPWR	
	VFBGA (GQN)	Reel of 1000	TLED2043IGQNR	2043I

† Package drawings, standard packing quantities, thermal data, symbolization, and PCB design guidelines are available at www.ti.com/sc/package.

FUNCTION TABLE

SW INPUT	SWITCH 1, 2, 3 STATUS
H	All OFF
L	All ON
Open	All OFF

functional block diagram



absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

Switch input voltage: V_{IN1}, V_{IN2}, V_{IN3} (see Note 1)		7 V
Switch output current: I_{OUT1}, I_{OUT2}, I_{OUT3}		15 mA
Amplifier input voltage, V_I		V_{DD}
Output FET drain-source voltage, V_{DS}		7 V
Output FET drain current, I_D		50 mA
Package thermal impedance, θ_{JA} (see Notes 2 and 3):	GQN package	78°C/W
	PW package	83°C/W
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds		260°C
Storage temperature range, T_{stg}		–65°C to 150°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 under “recommended operating conditions” is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

NOTES:
1. All voltage values are with respect to the network ground terminal.
2. Maximum power dissipation is a function of T_J(max), θ_{JA}, and T_A. The maximum allowable power dissipation at any allowable ambient temperature is $P_D = (T_J(max) - T_A)/\theta_{JA}$. Operating at the absolute maximum T_J of 150°C can affect reliability.
3. The package thermal impedance is calculated in accordance with JESD 51-7.

recommended operating conditions

		MIN	MAX	UNIT
V_{IN1}	Switch input voltage	2.7	5.5	V
V_{IN2}		0	5.5	
V_{IN3}		0	5.5	
V_{SW}	Input voltage for SW pin	0	5.5	V
I_{OUT1}	Switch output current		3	mA
I_{OUT2}			3	
I_{OUT3}			3	
V_{DS}	FET output drain-source voltage		5.5	V
I_D	FET output drain current		50	mA
T_A	Operating free-air temperature	–40	85	°C

electrical characteristics, T_A = 25°C (unless otherwise noted)

supply voltage switch section

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{OUT1}	Switch output voltage	V_{IN1} = 3.6 V, I_{OUT} = 3 mA	V_{IN}–0.1			V
V_{OUT2}		V_{IN1} = 3.6 V, I_{OUT} = 3 mA	V_{IN}–0.1			
V_{OUT3}		V_{IN1} = 3.6 V, I_{OUT} = 3 mA	V_{IN}–0.1			
V_{SW}	High input voltage range for SW OFF	V_{IN1} = 2.7 V to 5.5 V (see Note 4)	V_{DD} × 0.7			V
	Low input voltage range for SW ON	V_{IN1} = 2.7 V to 5.5 V (see Note 4)			V_{DD} × 0.3	
I_L	Low input current for SW	V_{IN1} = 3.6 V, V_{SW} = 0 V		20	100	µA
I_{DD}	Input current (see Figure 1)	ON state (V_{SW} = 0 V)			1	mA
		OFF state (V_{SW} = OPEN)			1	µA

NOTE 4: $V_{DD} = V_{OUT1}$

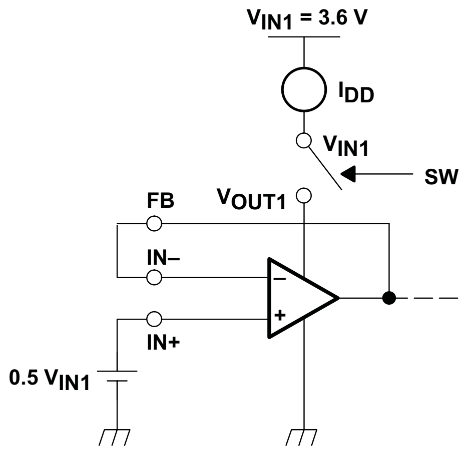
amplifier (AMP1) section, V_{IN1} = 3.6 V

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
V_{IO}	Input offset voltage	V_{IN1} = 2.7 V to 5.5 V, V_{IC} = 0.5 × V_{IN} or 100 mV (see Figure 2)	T_A = 25°C		0.3	4	mV
			T_A = Full range			5	
I_{IO}	Input offset current				8		pA
I_{IB}	Input bias current				45		pA
V_{ICR}	Common-mode input voltage	V_{IN1} = 2.7 V to 5.5 V (see Figure 3)		0		V_{DD}–1.5	V
A_{VD}	Open-loop voltage gain			70			dB
B_1	Unity-gain bandwidth				630		kHz
V_{OH}	Output voltage (FB)	R_L ≥ 100 kΩ (see Figure 4)		V_{DD}–1.5			V
V_{OL}	Output voltage (FB)	R_L ≥ 100 kΩ (see Figure 5)				0.1	V

constant-current circuit section, AMP + FET

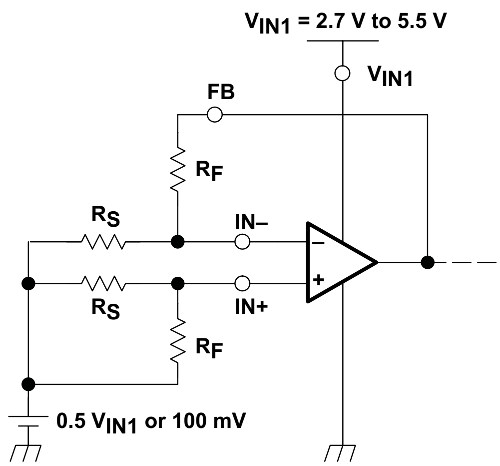
PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$I_{D(OFF)}$	Drain off-state current	V_{IN1} = 3.6 V, SW: OFF (V_{SW} = V_{DD} or OPEN), V_{DS} = 5.5 V		25	250	nA
r_{on}	Drain-source ON resistance	V_{IN1} = 2.7 V, IN+ = 0.1 V, I_D = 20 mA (see Figure 6)			6	Ω
V_S	Source voltage	V_{IN1} = 2.7 V to 5.5 V, FB = 200 mV, V_D = 0.5 V, R_L = 10 Ω (see Figure 7)	194	199	204	mV

PARAMETER MEASUREMENT INFORMATION



NOTE: V_{SW} = 0 V or open, all other pins open

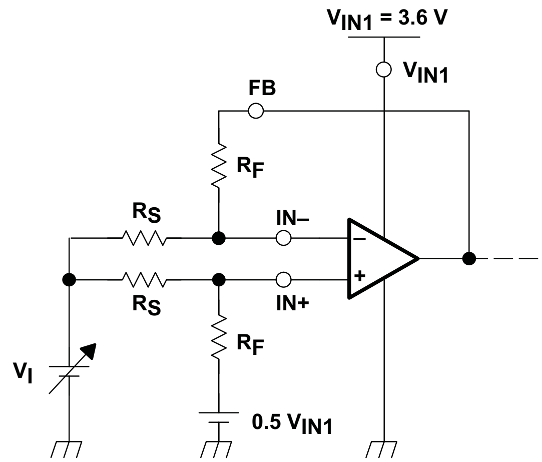
Figure 1. I_{DD} (ON State)



NOTE: SW = 0 V, all other pins open

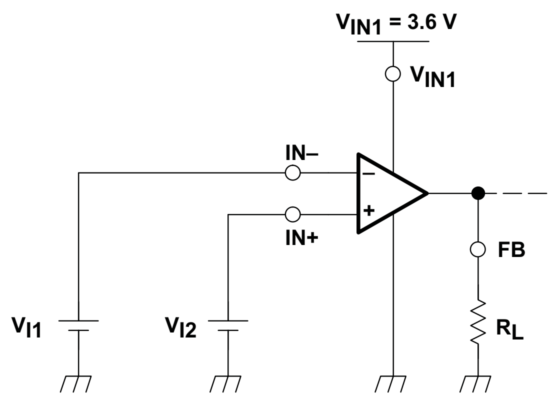
Figure 2. V_{IO}

PARAMETER MEASUREMENT INFORMATION



NOTE: SW = 0 V, all other pins open

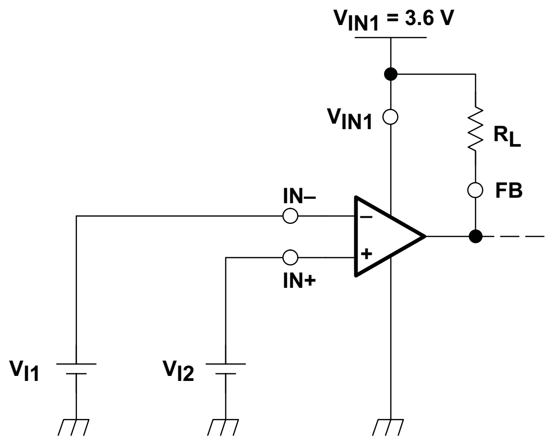
Figure 3. V_{ICR}



NOTE: SW = 0 V, all other pins open

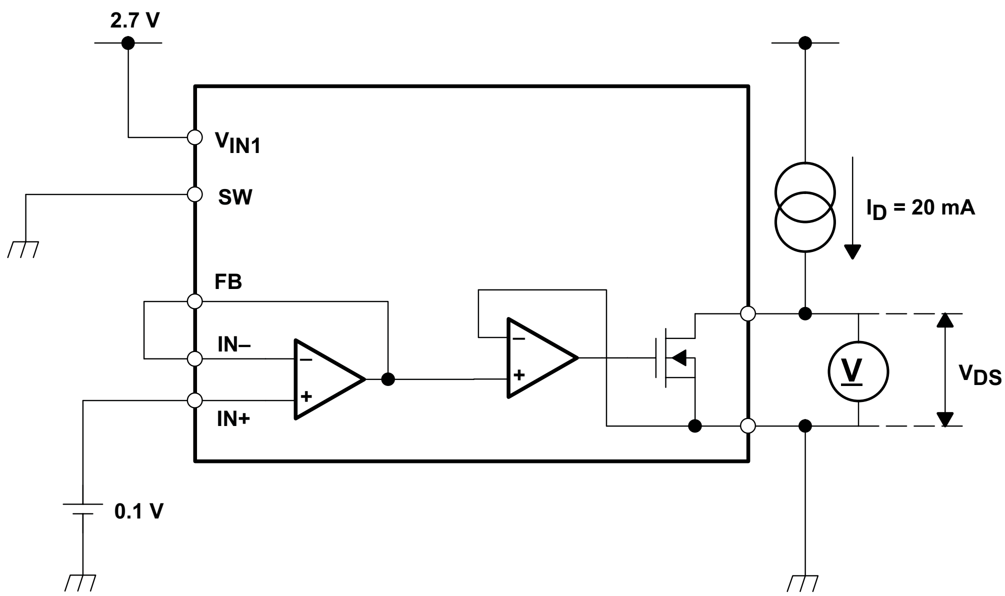
Figure 4. V_{OH}

PARAMETER MEASUREMENT INFORMATION



NOTE: SW = 0 V, all other pins open

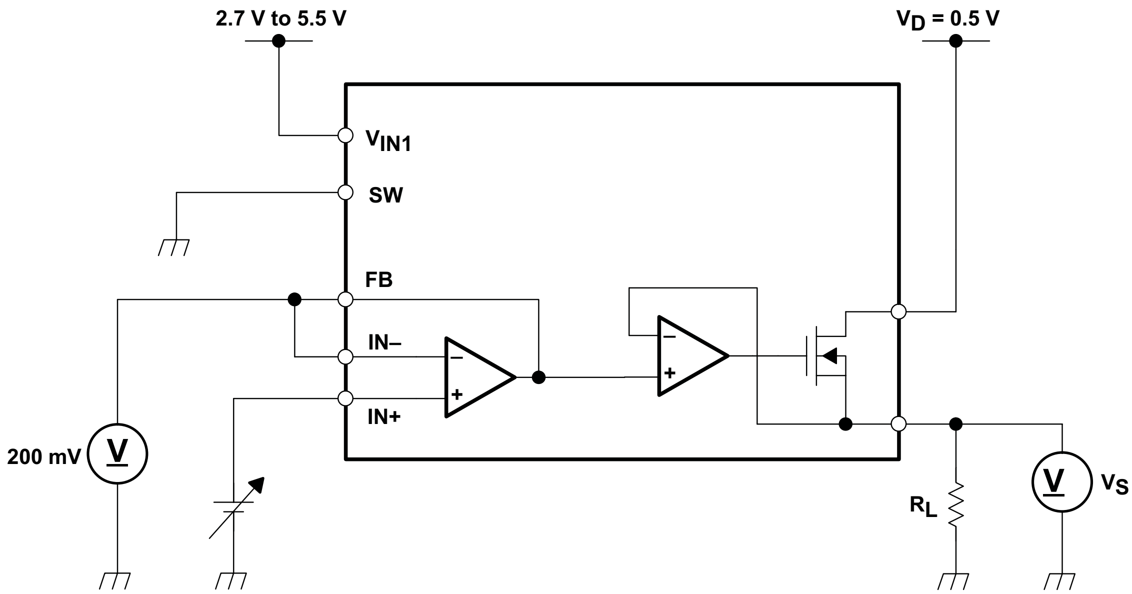
Figure 5. V_{OL}



NOTE: V_{IN1} = 2.7 V, SW = 0 V, IN+ = 0.1 V, all other pins open
$r_{on} = V_{DS}/I_D$

Figure 6. r_{on}

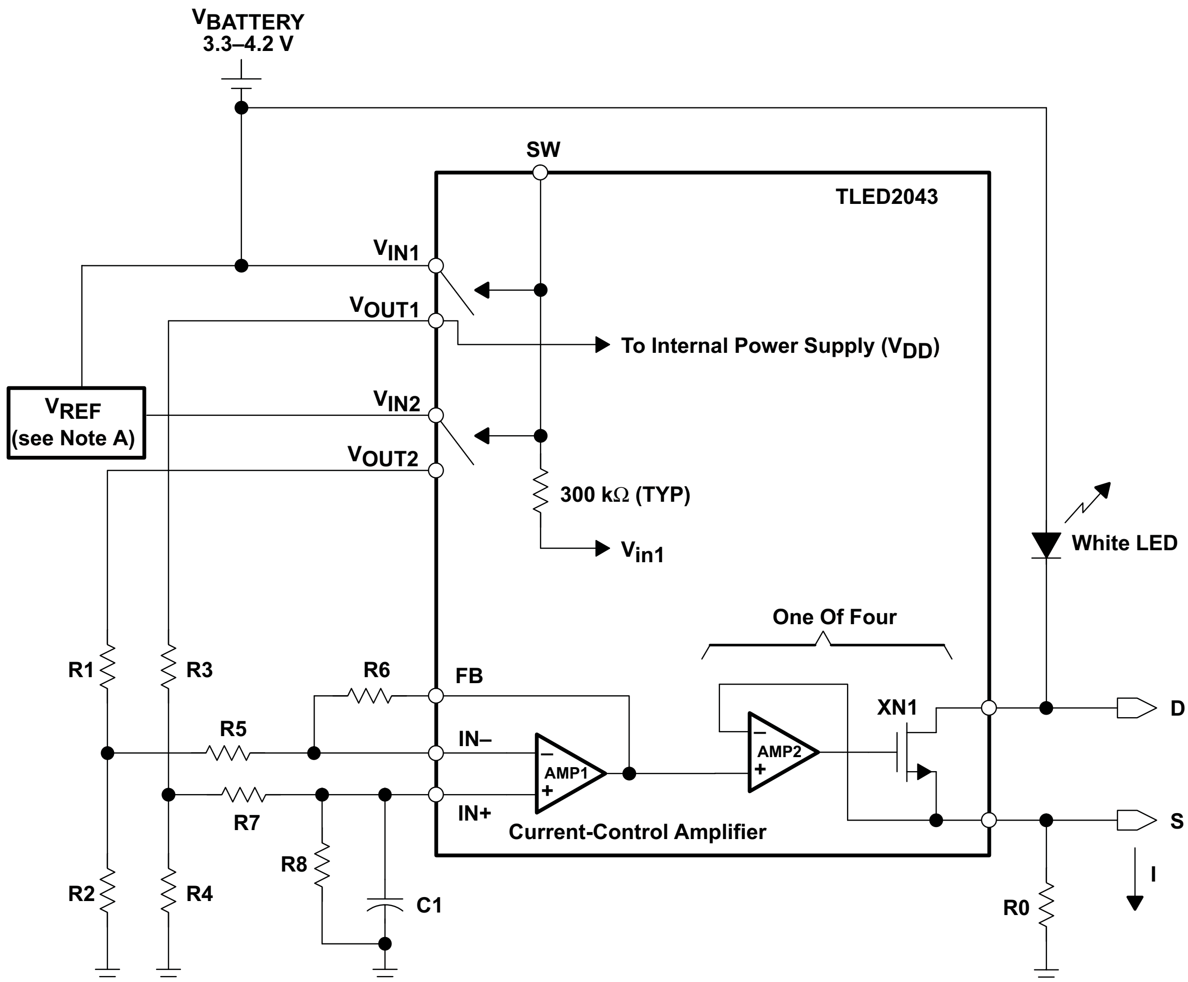
PARAMETER MEASUREMENT INFORMATION



NOTE: V_{IN1} = 2.7 V to 5.5 V, FB = 200 mV, V_D = 0.5 V, R_L = 10 Ω

Figure 7. V_S

TYPICAL CHARACTERISTICS



R0 = 0.01 kΩ
R1 = 20 kΩ
R2 = 1.6 kΩ
R3 = 20 kΩ
R4 = 2.2 kΩ
R5 = 6.8 kΩ
R6 = 20 kΩ
R7 = 100 kΩ
R8 = 100 kΩ
C1 = 1 µF
V_{REF} = 2.8 V

NOTE A: V_{REF} and resistor values should be chosen for proper control of LED current, which is adjusted by the current-control amplifier to be directly proportional to the difference between $V_{BATTERY}$ and V_{REF}. A stable V_{REF} can be achieved through a low-power voltage reference (such as the REF29xx), a shunt regulator (such as the TLV431A), or a low-power LDO (such as the TPS770xx or TPS769xx families).

Figure 8. Typical Application Circuit

TYPICAL CHARACTERISTICS

DEVICE OPERATION/APPLICATION HINTS

Refer to the functional block diagram and typical application circuit (see Figure 8)

White LEDs commonly are used to produce the backlight for small color LCDs found in portable electronics, such as cell phones and PDAs. Because the LED's brightness and chromaticity are dependent on the LED's bias current, precise control of this current is necessary for proper illumination of the LCD. The TLED2043 is, essentially, four voltage-controlled current sinks that are regulated in unison, with each current sink setting the bias current for one white LED. The basic circuitry and operation of the TLED2043 can be divided into three main operating blocks described below.

output FETs

The TLED2043 has four n-channel MOSFETs to drive four external LEDs. The FETs have a specified maximum r_{on} of 6 Ω, while delivering 20 mA of load current. To determine the biasing current for each LED, the gate of each FET is driven by a buffer whose output is controlled by the current-control amplifier.

current control amplifier

The output of the Current Control Amplifier simultaneously drives four unity-gain amplifiers connected to the gates of the output FETs. To determine the drain current of each FET (the LED current), the noninverting input (IN+) of this amplifier typically is coupled to the battery voltage via Switch 1, while the inverting input (IN–) typically is coupled to a fixed reference voltage that remains constant as battery voltage changes. Therefore, the output of the Current Control Amplifier and the corresponding LED currents are proportional to the difference between the battery and reference voltages. As battery voltage drops with use, so does the LED current, allowing for lower power consumption to conserve battery power.

switch 1, 2, 3

The TLED2042 has three switches that are opened/closed in unison via an active-low switch-enable (SW) pin; the switches are closed with a low input applied and opened with a high input. Each switch has a maximum loss of 0.1 V across it; thus, the output of each switch is specified to be (V_{IN} – 0.1 V) < V_{OUT} < V_{IN}.

During periods of inactivity when the LEDs are not needed, significant power savings can be achieved (from a maximum of 1 mA to 1 μA) by opening the switches. The purpose of each switch is described below:

- Switch 1: used to remove power to the TLED2043 when the LEDs are not needed.
- Switch 2 (or 3): used to remove power to the series voltage reference (V_{REF} in the typical application Circuit). Without this switch, V_{REF} current flows continuously (through R1 and R2), even when power is removed from the TLED2043. (Note that, if a shunt reference like the TLV431 is used, current still flows through the reference, even if Switch 2 is open).
- Switch 3: Though not used in the typical application circuit here, this switch can be used to connect various external circuitries to the current-control amplifier. One example is to connect an external voltage to either input of the current-control amplifier to implement an analog LED brightness control (see next section).

TYPICAL CHARACTERISTICS

efficiency

Laboratory measurements and calculations have shown that the application circuit in Figure 8 typically has the following efficiency:

- Battery Voltage = 3.6 V: **η = 78.8%** (I_{LED} = 12.2 mA)
- Battery Voltage = 3.3 V: **η = 89%** (I_{LED} = 7.8 mA)
- Battery Voltage = 3.1 V: **η = 80.4%** (I_{LED} = 4.5 mA)

NOTE: Efficiency, as mentioned previously, refers to the efficiency of the **overall solution** and is defined simply as:

$$\eta = P_{LED}/P_{BATTERY}$$

where $P_{BATTERY}$ is the total power delivered by the battery to the entire circuit.

Thus, the efficiency indicates how effectively the TLED2043 delivers power to the LEDs. As such, LED selection can have a significant impact on calculated efficiency. For instance, two different brands of LEDs may have different values of V_F for the same value of I_F. According to the equation above, the LED with the larger V_F will dissipate more power ($P_{LED} = V_F \times I_F$) and thus will achieve higher efficiency. This result simply states how much power is dissipated in the LED, not how well that particular LED converts the electrical power into light–this, of course, solely depends on the LED construction and characteristics.

It should be pointed out that although a lower calculated efficiency is achieved using the LED with the lower V_F (for the same I_F), the benefit of the lower V_F is that there is now more headroom for LED operation as battery voltage drops.

LED brightness control

The brightness of an LED is proportional to its bias current. Since the current control amplifier determines the LED current by sensing the difference between its two inputs, changing the voltage at either IN– or IN+ (or both) affects LED current and brightness. There are several methods to achieve this.

1. **Variable V_{REF}:** use an adjustable shunt regulator (e.g., TL431/TLV431) and a variable resistor to change voltage applied to IN– of the current-control amplifier.
   - V_{REF} ↑, brightness ↓
2. **External Analog Voltage, V_{BRIGHT}:** applied to either IN– or IN+ of the current-control amplifier.
   - IN–: V_{BRIGHT} ↑ , brightness ↓
   - IN+: V_{BRIGHT} ↑ , brightness ↑

   NOTE: If using this method, V_{BRIGHT} should be coupled resistively to the Current Control Amplifier via Switch 3, allowing it to be disconnected from the amplifier when the switches are opened. Doing so prevents wasted current flow from V_{BRIGHT} to ground when no power is applied to the TLED2043.
3. **Variable Resistors:** use a variable resistor anywhere along the signal path of IN– or IN+ (R1–R8); this allows for adjustment of the voltage at IN– or IN+ (or both).

TYPICAL CHARACTERISTICS

example of a “digital” brightness control circuit

When using equipment such as cell phones, often it is desirable to adjust the brightness of the LCD display. While variable resistors offer an easy means of adjusting the LED brightness as described above, they are not economical if a digital potentiometer is required. Figure 9 shows a relatively simple and cost-effective means of achieving “digital” control of the LED brightness using standard resistors and signal switches.

Using a simple dual signal switch such as the SN74LVC2G66, resistors R2A and R2B can be individually paralleled to R2 to change the voltage divider being fed by V_{REF}. Doing so lowers the voltage applied to IN– of the current-control amplifier, resulting in increased LED current and brightness.

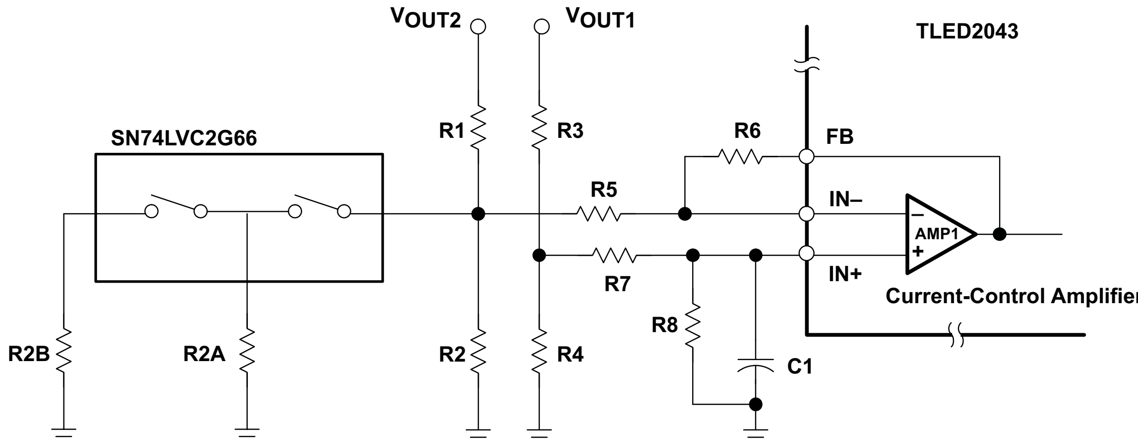


Figure 9. Example of a “Digital” Brightness Control

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish	MSL Peak Temp (3)
TLED2043IGQNR	OBSOLETE	VFBGA	GQN	20		TBD	Call TI	Call TI
TLED2043IPW	OBSOLETE	TSSOP	PW	20		TBD	Call TI	Call TI
TLED2043IPWR	OBSOLETE	TSSOP	PW	20		TBD	Call TI	Call TI

(1) The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
PREVIEW: Device has been announced but is not in production. Samples may or may not be available.
OBSOLETE: TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS) or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
TBD: The Pb-Free/Green conversion plan has not been defined.
Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.
Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

(3) MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

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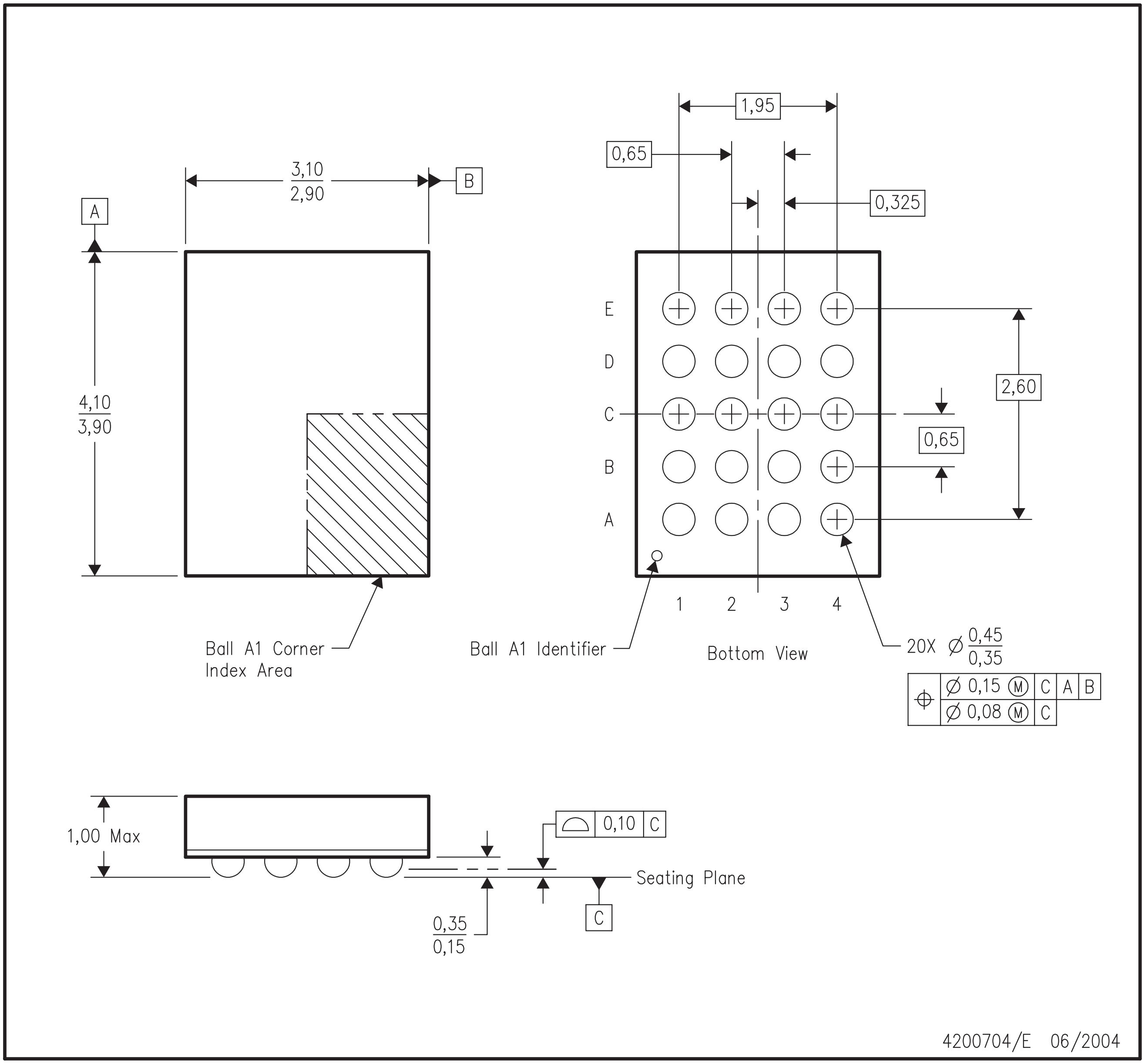
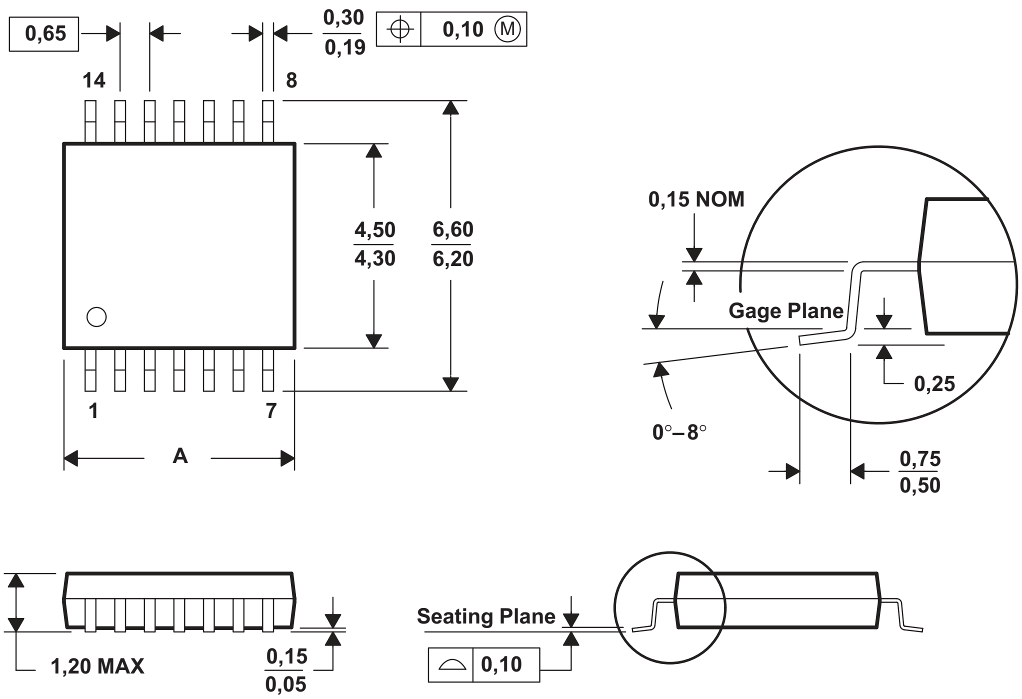
GQN (R-PBGA-N20) PLASTIC BALL GRID ARRAY



NOTES:
- A. All linear dimensions are in millimeters.
- B. This drawing is subject to change without notice.
- C. Falls within JEDEC MO-225 variation BC.
- D. This package is tin-lead (SnPb). Refer to the 20 ZQN package (drawing 4204492) for lead-free.

PW (R-PDSO-G)** **PLASTIC SMALL-OUTLINE PACKAGE**

14 PINS SHOWN



PINS ** / DIM	8	14	16	20	24	28
A MAX	3,10	5,10	5,10	6,60	7,90	9,80
A MIN	2,90	4,90	4,90	6,40	7,70	9,60

4040064/F 01/97

NOTES: A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion not to exceed 0,15.
D. Falls within JEDEC MO-153

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