

LTC3219 User's Guide

by Marty Merchant

INTRODUCTION

The LTC[®]3219 is a 250mA LED driver which illuminates 9 Universal LEDs (ULEDs). The ULEDs are considered universal because they may be individually turned on or off, set in general purpose output (GPO) mode, set to blink at a selected on-time and period, or gradate on and off at a selected gradation rate. This device also has an external enable (ENU) pin that may be used to blink, gradate, or turn on/off the LEDs without using the I²C bus. This may be useful if the microprocessor is in sleep or standby mode. If used properly, these features may save valuable memory space, programming time, and reduce I²C traffic.

I²C Control

The LTC3219 has 12 data registers, each with its own sub-address as shown in Table 2. The data is loaded into the registers when the device receives a Stop bit. This device is written using the standard I²C protocol. A 7-bit slave

address and Write bit is followed by the 8-bit sub-address byte and an 8-bit data byte.

The LTC3219 is a slave I²C device that only can receive data.

DATA BYTES

REG0 (Tables 3 and 4) is used to set the charge pump to Auto, Force 1x, Force 1.5x, or Force 2x modes. It is also used to prepare for a Quick Write, or set the gradation UP bit. REG1 through REG9 set the intensity and mode for the nine individual ULEDs (Table 5). REG10 is used to select ULED1 to ULED8 for ENU control, as shown in Table 6. REG11 is separated into three portions as illustrated in Table 7. D0 is used to select ULED9 for ENU control. D1 and D2 are used to control the gradation time, while D3 and D4 are used to select the blinking on-time and period.

LT, LT, LTC and LTM are registered trademarks of Linear Technology Corporation. All other trademarks are the property of their respective owners.

Table 1. Features of LTC3219

FEATURE	BENEFITS
9 Separate 28mA Current Sources	9 Individually Controlled LEDs
Blink Mode	Blinks One of Four Blinking Patterns
GPO Mode	I ² C Controlled Open Drain Drivers
Gradation	Gradually Turns On and Off LEDs
External Enable	Controls LEDs with Single Input
Auto Switching Charge Pump	Automatically Switches to 1x, 1.5x, or 2x Modes for Better Efficiency
Forced Charge Pump Mode	Can Be Programmed to Remain in 1x, 1.5x or 2x Mode

Application Note 111

Table 2. Sub-Address Byte

MSB							LSB	Register
7	6	5	4	3	2	1	0	
X	X	X	X	0	0	0	0	REG0
X	X	X	X	0	0	0	1	REG1
X	X	X	X	0	0	1	0	REG2
X	X	X	X	0	0	1	1	REG3
X	X	X	X	0	1	0	0	REG4
X	X	X	X	0	1	0	1	REG5
X	X	X	X	0	1	1	0	REG6
X	X	X	X	0	1	1	1	REG7
X	X	X	X	1	0	0	0	REG8
X	X	X	X	1	0	0	1	REG9
X	X	X	X	1	0	1	0	REG10
X	X	X	X	1	0	1	1	REG11

X = Don't Care

Table 3. REG0, Command Byte

MSB							LSB
D7	D6	D5	D4	D3	D2	D1	D0
Reserved	Reserved	Reserved	Reserved	Force2x	Force1p5	Quickwrite	UP

Table 4. Command Byte Bit Functions

UP	0	Gradation Counts Down
	1	Gradation Counts Up
Quickwrite	0	Normal Write to Each Register
	1	Quick Write, REG1 Data is Written to All 12 Universal Registers
Force1p5	1	Forces Charge Pump Into 1.5x Mode
	0	Enables Mode Logic to Control Mode Changes Based On Dropout Signal
Force2x	1	Forces Charge Pump Into 2x Mode
	0	Enables Mode Logic to Control Mode Changes Based On Dropout Signal
Force1x		D2 (Force1p5x) = 1 D3 (Force2x) = 1 } Forces Charge Pump Into 1x Mode
Reserved	X	

Table 5. REG1 to REG9, Universal LED

BLINK/GRADATION/DROPOUT ENABLED			LED CURRENT DATA					
	MSB		LSB					
Bits	D7	D6	D5	D4	D3	D2	D1	D0
Normal	0	0	D5	D4	D3	D2	D1	D0
Blink Enabled	0	1	D5	D4	D3	D2	D1	D0
Gradation Enabled	1	0	D5	D4	D3	D2	D1	D0
GPO Mode	1	1	D5	D4	D3	D2	D1	D0

Table 6. REG10, Lower ENU Control Bits

MSB							LSB
D7	D6	D5	D4	D3	D2	D1	D0
ULED8	ULED7	ULED6	ULED5	ULED4	ULED3	ULED2	ULED1

Table 7. REG11, Gradation, Blink Times, Upper ENU Control Bits

BLINK TIMES AND PERIOD				GRADATION TIMES			UPPER ENU CONTROL BIT
D4	D3	Blink	Period	D2	D1	Gradation	D0
0	0	0.625s	1.25s	0	0	Disabled	ULED9
0	1	0.156s	1.25s	0	1	0.24s	
1	0	0.625s	2.5s	1	0	0.48s	
1	1	0.156s	2.5s	1	1	0.96s	

Application Note 111

DEVICE SET UP AND OPERATION

Although the Power on Reset clears all the data registers, it is good practice to write zeros to all the data registers to make sure all data registers are reset after V_{BAT} is powered up. DV_{CC} may be used to reset the registers by holding DV_{CC} low until V_{BAT} completes power. The Quick Write feature may also be used to clear the ULED registers simultaneously with fewer I²C writes.

To set one or more ULED(s) using the I²C bus, write the intensity setting to the desired ULED registers followed by a Stop bit. The following example illustrates how to set ULED1 and ULED2 to 5mA. Since the full-scale current is 28mA, use the following formula to determine the number of steps needed to acquire 5mA.

$$\text{Steps} = I_{LED} \cdot \text{StepsFullScale}/I_{FullScale}$$

$$5\text{mA} \cdot 63\text{Steps}/28\text{mA} = 11.25 \text{ Steps}$$

The number of steps is rounded to 11 and converted to the hexadecimal value 0BH. Setting the ULED register to 0BH will set the ULED to approximately 5mA.

Example 1: Setting ULED1 and ULED2 to 5mA

S 36H 01H 0BH 'Set ULED1 to 5mA, No Stop bit'

S 36H 02H 0BH P 'Set ULED2 to 5mA, Stop bit loads data'

In Example 1, the "S" designates the Start Bit and 36H designates the 7-bit slave address plus the Write bit to form the 8-bit hexadecimal byte of 36. The second hexadecimal bytes, 01 and 02, are the sub-address bytes. The third hexadecimal byte is the register data byte. The "P" designates the Stop bit. The Stop bit was set after the last write to load the ULED1 and ULED2 registers and set the LEDs simultaneously. A Stop bit may be used after each I²C write except where specified when gradating. All of the following examples will use the same format used in Example 1.

The GPO mode may be used as an open drain output to drive some other device. This is accomplished by allowing the ULED pin to be driven to 0V without causing the

charge pump to change modes (drop-out). For low speed applications, the GPO current setting should be set greater than the maximum current needed, however setting the current greater than 10 times the maximum current may increase the quiescent current by more than 10%.

Example 2: Set ULED1 and ULED2 to 1mA in GPO mode

S 36H 01H C2H 'Set ULED1 to 1mA in GPO mode'

S 36H 02H C2H P 'Set ULED2 to GPO mode, Stop bit loads data'

Blinking LEDs may be used to indicate voicemail messages, missed calls, low battery, or other messages. The LTC3219 has a blinking feature that allows the user to choose between one of four different blinking rates. This feature reduces processor time and I²C traffic. To set a ULED to blink:

- 1) Set the blinking rate in REG11.
- 2) Set the ULED register with the desired intensity and the blinking bit set, followed by a Stop bit.

The blink rate may be changed at any time by changing the blink times and period bits in register 11.

Example 3: Setting ULED1 and ULED2 to blink at 5mA with a 2.5s period and a 0.625s on-time:

S 36H 0BH 10H 'Set blinking time to 0.625s on, 2.5s period'

S 36H 01H 4BH 'Set ULED1 to blink at 5mA'

S 36H 02H 4BH P 'Set ULED2 to blink, Stop bit loads all data'

It is sometimes desirable to gradually turn on and off LEDs or displays. Normally it uses a lot of I²C bus time to gradually turn on and off LEDs smoothly. The LTC3219 has a gradation feature that allows the user to smoothly turn on and off LEDs with little I²C interaction. Gradation may be controlled with the I²C bus or by the ENU pin only when the I²C bus is not controlling the device. To gradate

a ULED from the off to on state via the I²C bus, the following procedure must be followed in order to achieve the proper results.

- 1) Clear the Up bit in REG0 followed by a Stop bit.
- 2) Set the gradation time in REG11 without a Stop bit.
- 3) Set the ULED register with the Gradation bit set and without a Stop bit.
- 4) Set the Up bit in REG0 followed by a Stop bit.

The Stop bit loads the registers and starts the gradation process. Never have the ULED Gradation bit set without the Gradation Timer enabled. This is an invalid state and may cause undesirable results.

Example 4: Start gradating ULED1 and ULED2 from 0mA to 5mA at 0.48s ramp time:

```
S 36H 00H 00H P 'Clear Up bit to prepare
                  gradation ramp'
S 36H 0BH 04H   'Set Gradation time, no Stop bit'
S 36H 01H 8BH   'Set ULED1 to gradate to 5mA,
                  no Stop bit'
S 36H 02H 8BH   'Set ULED2 to gradate to 5mA,
                  no Stop bit'
S 36H 00H 01H P 'Set Up bit, Stop bit starts
                  gradation'
```

Prior to disabling the gradation timer in register 11 or gradating up any other ULEDs, the gradation bits in the ULED register must be cleared. This is accomplished by writing an intensity value with the gradation bit cleared.

Example 5: Disabling gradation timer with ULED1 and ULED2 at 5mA

```
S 36H 01H 0BH   'Set ULED1 to 5mA with
                  gradation bit low'
S 36H 02H 0BH   'Set ULED2 to 5mA with
                  gradation bit low'
S 36H 0BH 00H P 'Disable gradation, Stop bit
                  loads all data'
```

The ULEDs may be set to gradate off from an on state. To do this:

- 1) Clear the Up bit in REG0.
- 2) Set the ULED with the current intensity and the Gradation bit set without a Stop bit.
- 3) Enable the Gradation Timer followed by a Stop bit.
- 4) Set the ULED intensity to 0 with the Gradation bit set.

Step 4 must be completed before the gradation ramp completes or the ULEDs will flicker at a low intensity. If all ULEDs and charge pump are off, then the part will go into shutdown.

Example 6: Start gradating ULED1 and ULED2 from 5mA to 0mA

NOTE: These steps must be completed within the gradation time.

```
S 36H 00H 00H P 'Clear Up bit'
S 36H 01H 8BH   'Set ULED1 with gradation bits,
                  no Stop bit'
S 36H 02H 8BH   'Set ULED2 with gradation bits,
                  no Stop bit'
S 36H 0BH 04H P 'Set gradation timer, Stop bit
                  starts gradation'
S 36H 01H 80H   'Set ULED1 & ULED2 registers
                  to 0 with gradation bit set'
S 36H 02H 80H P 'Stop bit loads data'
```

The ULED gradation bit must be cleared before the gradation timer in register 11 is disabled.

It may be desired to continuously gradate a ULED up and down. This may be achieved by first initiating the gradation as in Example 4 or Example 6, then change the ULED intensity and Up bit accordingly. To gradate down after gradating up as illustrated in example 4:

- 1) Clear the Up bit followed by a Stop bit. This starts the ULEDs gradating down.
- 2) Clear the ULED registers with the gradation bit set.

Example 7: Continue gradating down after gradating up as illustrated in Example 4

S 36H 00H 00H P 'Clear Up bit, Stop bit starts gradation ramp down'

S 36H 01H 80H 'Set ULED1 register to 0 with gradation bit set'

S 36H 02H 80H P 'Set ULED2 to 0, Stop bit loads data'

To gradate back up again:

1) Set the ULED intensity with the gradation bit set and without a Stop bit.

2) Set the Up bit in REG0 followed by a Stop bit.

This starts the ULEDs gradating up.

Example 8: Continue gradating ULED1 and ULED2 back up to 5mA after gradating down

S 36H 01H 8BH 'Set ULED1 to gradate to 5mA, no Stop bit'

S 36H 02H 8BH 'Set ULED2 to gradate to 5mA, no Stop bit'

S 36H 00H 01H P 'Set Up bit, Stop bit starts gradation'

There may be times when all the ULEDs need to be changed to the same value simultaneously. The LTC3219 has a "Quick Write" feature that allows all the ULED registers to be loaded at the same time. This is done by setting the Quick Write bit in REG0 and then writing the desired value in REG1.

Example 9: Clearing all ULED registers using the Quick Write feature

S 36H 00H 02H 'Set the Quick Write bit'

S 36H 01H 00H P 'Clear all ULEDs with Stop bit'

S 36H 00H 00H P 'Clear Quick Write bit'

This feature may also be used to start all the ULEDs blinking or gradating. To gradate all ULEDs up using the Quick Write feature:

1) Set the Quick Write bit and clear the Up bit in REG0 followed by a Stop bit.

2) Set REG1 gradation bit to the desired intensity without a Stop bit.

3) Set the gradation time in REG11 without a Stop bit.

4) Clear the Quick Write bit and set the Up bit in REG0 followed by a Stop bit.

The Stop bit starts the gradation ramp.

Example 10: Start gradating all ULEDs up from 0mA to 5mA using the Quick Write feature

S 36H 00H 02H P 'Set the Quick Write bit, Clear the Up bit'

S 36H 01H 8BH 'Set ULEDs to gradate to 5mA, no Stop bit'

S 36H 0BH 04H 'Set the gradation time, no Stop bit'

S 36H 00H 01H P 'Clear Quick Write bit, Set Up bit, Gradation starts'

The Quick Write feature is especially useful when gradating down all ULEDs simultaneously. This feature may reduce the number of I²C writes from twenty times to five times. To gradate all ULEDs down using the Quick Write feature:

1) Set the Quick Write bit and clear the Up bit in REG0.

2) Set REG1 gradation bit with the present intensity setting without a Stop bit. This sets up all ULEDs to gradate down.

3) Set the gradation time in REG11 followed by a Stop bit. This starts all ULEDs gradating down.

4) Set REG1 gradation bit with 0mA intensity. This allows the part to go into shutdown when gradation is completed.

5) Clear the Quick Write bit in REG0.

This prepares the part for other operations.

Example 11: Start gradating all ULEDs down from 5mA to 0mA using the Quick Write feature

S 36H 00H 02H	'Set the Quick Write bit, Clear the Up bit'
S 36H 01H 8BH	'Set ULEDs to gradate from 5mA, no Stop bit'
S 36H 0BH 04H P	'Set gradation time, Stop bit starts gradation'
S 36H 01H 80H P	'Set all ULED registers to 0 with gradation bit set'
S 36H 00H 00H P	'Clear Quick Write bit'

ENU Control

Many battery devices go into a standby or sleep mode when not in use. It may be necessary to alert the user of events while keeping the microprocessor in standby mode. The ENU pin on the LTC3219 allows the user to set ULEDs in normal, GPO, blinking, or gradation modes without the use of the I²C bus. The ENU pin is intended to be used when I²C control is not preferred, however the I²C may be used to drive other ULEDs as long as the gradation timer remains disabled. To control a ULED via the ENU pin in normal, GPO, or blinking modes:

- 1) Set the ENU pin to the desired state, high if LEDs are on or low if LEDs are off.
- 2) Set the ENU control bits and set the blinking time, if required, in REG10 and/or REG11.
- 3) Set the ULED intensity with the desired control bits followed by a Stop bit.

Example 12: Setting ULED1 and ULED2 to blink at 0.625s on for a period of 2.5s with ENU control

Set ENU pin to 0V	'Starting with ULEDs off'
S 36H 0AH 03H	'Set ULED1 & ULED2 for ENU control'
S 36H 0BH 10H	'Set blinking time to 0.625s on, 2.5s period'

S 36H 01H 4BH	'Set ULED1 to blink at 5mA'
S 36H 02H 4BH P	'Set ULED2 to blink, Stop bit loads data'

Set ENU pin to DV_{CC} to initiate ULED1 and ULED2 blinking.

The ENU pin may also be used to control gradation, however it is important that all other ULEDs remain off and that the charge pump remains in auto mode (not forced to any mode) to allow the part to go into shutdown and to operate properly. This mode may be initiated with the ULEDs in the on or off states, but care must be taken not to turn on any other LEDs or change the charge pump from auto mode once gradation with ENU control is set. To gradate on with the ENU pin:

- 1) Make sure all ULEDs are off, the charge pump is in auto mode, and the ENU pin is set to 0V. The Quick Write feature may be used to clear all ULEDs quickly.
- 2) Select the desired ULEDs for ENU control in REG10 and/or REG11.
- 3) Set the gradation time followed by a Stop bit.
- 4) Set the ULEDs intensity with the gradation bit set followed by a Stop bit.

The ULEDs are now set to gradate using ENU control. Set the ENU pin to DV_{CC} to gradate up and to 0V to gradate down.

Example 13: Gradate ULED1 and ULED2 to 5mA using ENU control at 0.48s

Set ENU pin to 0V	'Start with ULEDs off'
S 36H 00H 02H P	'Set the Quick Write bit'
S 36H 01H 00H P	'Clear all ULEDs'
S 36H 00H 00H	'Clear command register, charge pump=Auto'
S 36H 0AH 03H	'Set ULED1 and ULED2 for ENU control'
S 36H 0BH 04H P	'Set gradation time for 0.48s'

Application Note 111

S 36H 01H 8BH 'Set ULED1 to gradate to 5mA'

S 36H 02H 8BH P 'Set ULED2 to gradate to 5mA'

Set ENU pin to DV_{CC} to gradate up and to 0V to gradate down.

Before any other ULEDs are turned on, the ENU with gradation must be disabled. To do this:

- 1) Set the ENU pin in the desired state to have ULEDs on or off.
- 2) Clear the ENU control bits without a Stop bit.
- 3) Clear the gradation timer bits without a Stop bit.
- 4) Set the ULED registers to the desired intensity and the gradation bit low followed by a Stop bit after the last write.

Example 14: Disabling ENU and gradation control while ULED1 and ULED2 are set to 5mA

Set ENU pin High 'Gradate ULEDs to on state'

S 36H 0AH 00H 'Relinquish ENU control'

S 36H 0BH 00H 'Disable gradation timer, no Stop bit'

S 36H 01H 0BH 'Clear ULED1 gradation bit, set to 5mA, no Stop bit'

S 36H 02H 0BH P 'Stop bit loads data simultaneously'

Gradation with ENU may also be initiated with the ULEDs to be controlled in the on state. To do this, the gradation ramp must first be ramped up and the ENU pin must be high. To set ULEDs to gradate with ENU control from the on state:

- 1) Make sure all ULEDs that are not going to be ENU controlled are off, the charge pump is in auto mode, and the ENU pin is set to DV_{CC} .

- 2) Set the ULEDs to be controlled to the desired value with the gradation bit clear.

- 3) Set the gradation timer and the ENU control bits in REG11 and/or REG10 followed by a Stop bit.

- 4) Wait for the gradation ramp to finish.

- 5) Set the ULED registers with the desired intensity and the gradation bit set.

The ULEDs will now gradate down and up under ENU control.

Example 15: Gradating ULED1 and ULED2 from 5mA with ENU control

Set ENU pin to DV_{CC} 'Start ENU control from ON state'

Turn off all ULEDs that are not going to be under ENU control

S 36H 00H 00H 'Clear Command Register, Charge pump=Auto'

S 36H 01H 0BH 'Set ULED1 to 5mA'

S 36H 02H 0BH P 'Set ULED2 to 5mA'

S 36H 0AH 03H 'Set ULEDs 1 and 2 for ENU control'

S 36H 0BH 04H P 'Set gradation ramp up at 0.48s'

Wait for gradation ramp to finish before setting ULED gradation bits.

S 36H 01H 8BH 'Set ULED gradation bit and intensity'

S 36H 02H 8BH P 'Stop bit enables gradation with ENU control'