7 CHANNEL WHITE LED DRIVER
1x/1.5x Charge Pump Display Backlight Solution

A8470

Description

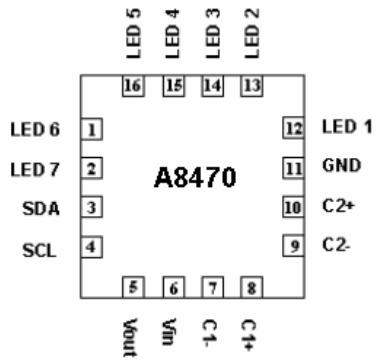
The A8470 is a complete backlight display solution that is designed to independently control LEDs for main and auxiliary displays as well as the keypad. An I^2C serial interface allows simple way to adjust each current individually in order to provide ultimate flexibility in driving LEDs. The data is loaded into internal registers upon power up and stored while in shutdown. When the chip is enabled the stored values set the LED currents. Extra low 31uA LSB allows trickle current through the LEDs for non-reflecting LCD displays.

The A8470 automatically detects 1x or 1.5x operation for optimal efficiency over full load range.

Features

- Separate Control for 4 main, 2 sub, and keypad LEDs
- Built-in Current 6-bit DAC for Precise Current Setting
- Input Voltage Range: 2.7V to 5.5V
- I^2C Serial Interface
- Data is stored in shutdown
- 1x and 1.5x mode Operating with Automatic Switchover
- Very Low Dropout Current Sources: 200mV typ
- Ultra Low 31uA current (LSB)
- Low-noise Constant Frequency Operation
- 2MHz Constant Switching Frequency reduces external components
- Power-Saving Shutdown mode of 1uA
- Built-in Over-Temperature Protection
- Soft-start to Reduce Inrush Current
- Small 16-pin 3x3mm QFN Package

Pin Assignment



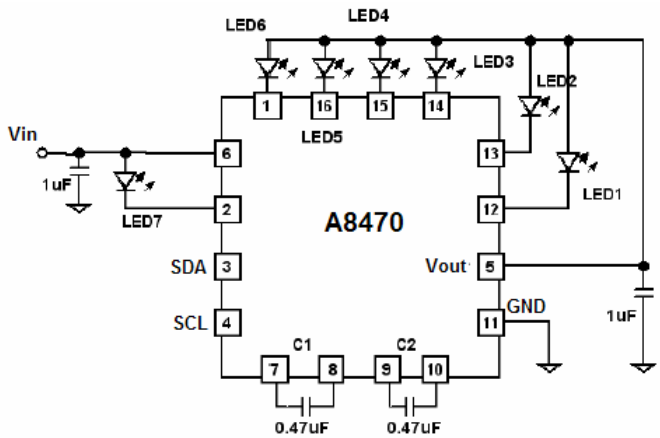
Top View

Package: 3mm x 3mm QFN-16

Application

- Portable Devices, Mobile Phone, DSC, DVR, Smart Phone
- White LED Backlight Application
- PDA, PMP

Typical Application



Ordering Information

PN	A8470Q16

Pin Description

Pin #	Pin Name	Description
1	LED6	Current Sink for LED
2	LED7	Current Sink for LED
3	SDA	Data Input for I^2C Interface
4	SCL	Clock Input for I^2C Interface
5	V_{OUT}	Output Pin
6	V_{IN}	Power Input
7	C1-	Negative Terminal of 0.47uF Ceramic Capacitor C1
8	C1+	Positive Terminal of 0.47uF Ceramic Capacitor C1
9	C2-	Negative3 Terminal of 0.47uF Ceramic Capacitor C2
10	C2+	Positive Terminal of 0.47uF Ceramic Capacitor C2
11	GND	Ground Pin
12	LED1	Current Sink for LED
13	LED2	Current Sink for LED
14	LED3	Current Sink for LED
15	LED4	Current Sink for LED
16	LED5	Current Sink for LED

Absolute Maximum Ratings (Those values beyond which the life of a device may be impaired)

V_{IN}, SDA, SCL, LEDx, V_{OUT}	-0.3V ~ 6.0V
Junction Temperature Range (note 1)	-40°C ~ +125°C
Power Dissipation	Internally Limited (note2)
Storage Temperature Range	-65°C ~ +150°C
Lead Temperature (Soldering, 10s)	+300°C
Operating Temperature Range	-40°C ~ +85°C

Note 1: T_J is calculated from the ambient temperature T_A and power dissipation P_D according to the following formula: $T_J=T_A + (P_D) \times (250^oC/W)$

Note 2: Dropout is defined when LED current goes 5% below nominal value as Vin is lowered.

Electrical Characteristics

V_{IN}=3.4V, T_A=25°C, Unless otherwise specified.

Parameter	Conditions	Min	Typ	Max	Unit
Operating Input Voltage Range		2.7		5.5	V
V_{OUT} Regulation Voltage (1.5x Mode)	VIN=3.4V, Status=11000000 Control=00000000 MAIN=SUB=AUX=00000000	4.0	4.2	4.4	V
Operating Input Current (4 main LEDs operating at 1mA each, all other LEDs off, in 1x mode)	Vin=4.0V, V_{LED}=3.3V Status=11000000 Control=00011110 MAIN=SUB=AUX=00001000		260		uA
Operating Input Current (Charge pump in 1.5x mode with all LEDs at 1mA each)	Vin=3.0V, V_{LED}=3.3V Status=11000000 Control=11111110 MAIN=SUB=AUX=00001000		5.0		mA
Standby Mode Quiescent Current	Vin=4.0V, Status=10000000 Control=00000000 MAIN=SUB=AUX=00000000		200		uA
Maximum Output Current (note3)	Vin=3.4V, V_{LED}=3.3V V_{OUT}=V_{LED} + Dropout	180			mA
LED Current Accuracy	I_{LED}=20mA	-10		10	%
LED Current Matching	MAIN, I_{LED}=20mA	-3		3	%
	SUB, I_{LED}=20mA	-3		3	%
Current DAC Resolution			64		Seps
Current for DAC=000000	1x mode only		0		mA
Current for DAC=000001		5	31	100	uA
Current DAC LSB DAC=00010	MAIN and SUB LEDs		1		mA
	AUX LEDs		2		mA
LED Dropout Voltage (note2)	I_{LED}=20mA for MAIN and SUB LEDs I_{LED}=40mA for AUX LEDs		0.2		V
Maximum LED Current	After 63 counts MAIN and SUB LEDs		31.5		mA
	After 63 counts AUX LED		63		mA
Switching Frequency		1.6	2	2.4	MHz
Equivalent Resistance, 1x mode	Vin=4.0V, I_{VOUT}=100mA		4	5	Ohm
Equivalent Resistance, 1.5x mode	Vin=3.4V		7	10	Ohm

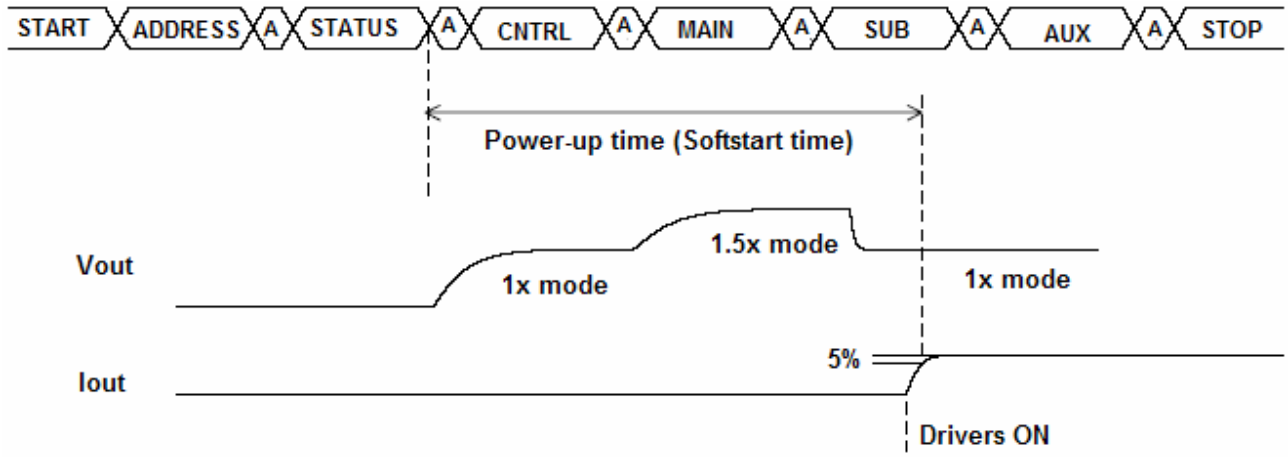
Parameter	Conditions	Min	Typ	Max	Unit
Maximum Control Clock Frequency		0.4			MHz
Power-Up Time from Shutdown (Note 4)	Vin=3.4V Initial State: Status=00000000 Final State: Status=11000000 Control=11111110 MAIN=00001000 SUB=AUX=00000000		2		ms
Soft Start Interval (within 1x mode) (Note 5)	Vin=4.0V Initial State: Status=11000000 Control=11111110 MAIN=SUB=AUX=11111100 Final State: Status=11000000 Control=11111110 MAIN=SUB=AUX=11111100		5	10	us
Soft Start Interval (Transition 1x to 1.5x) at max current (Note 6)	Vin=3.4V, V_{LED}=3.3V Initial State: Status=11000000 Control=11111110 MAIN=SUB=AUX=11111100 Final State: Status=11000000 Control=11111111 MAIN=SUB =11111100 AUX=00000000		100		us
Shutdown Supply Current	V_{EN}<0.4V (shutdown) V_{SUPPLY}=4.2V, 25°C		0.01	2	uA
	V_{EN}<0.4V (shutdown) V_{SUPPLY}=4.2V, 85°C			5	uA
Short LED Threshold			V_{OUT} -5V	V_{OUT} -1V	
Thermal Shutdown Die Temperature	Regulator Turns Off	125	150	175	°C
Thermal Shutdown Hysteresis	Regulator Turns On again @150°C		20		°C
SDA, SCL Low Timeout	If both SDA and SCL are Low for 50ms, Part goes into shutdown mode set Status=00000000	50			ms
SDA, SCL Input Logic Low Voltage	Regulator Shutdown			0.4	V
SDL, SCA Input Logic High Voltage	Regulator Enabled	1.6			V

Note 2: Dropout is defined when LED current goes 5% below nominal value as Vin is lowered.

Note 3: The maximum output current is a derived spec Iout max= (Vin*1.5-V_{LED}-Vdropout)/(max Req 1.5x mode)

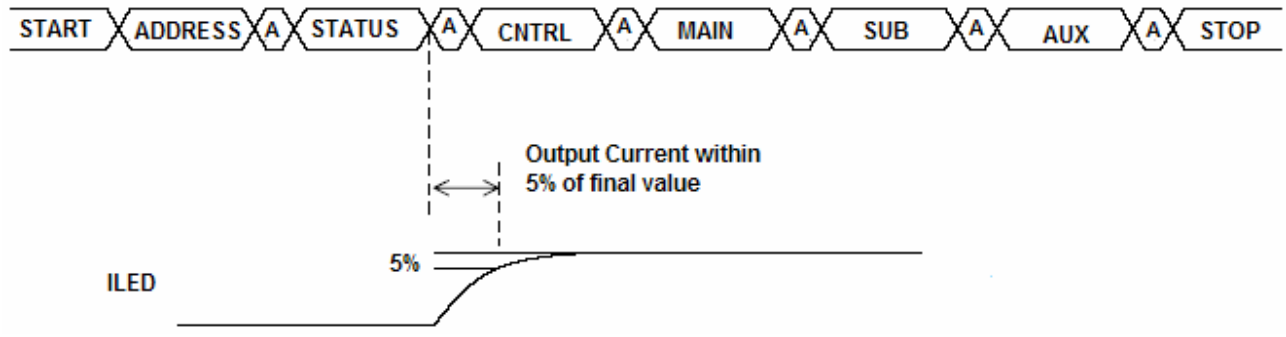
Note 4:

I^2C data input



Note 5: Soft Start Interval Within 1X mode

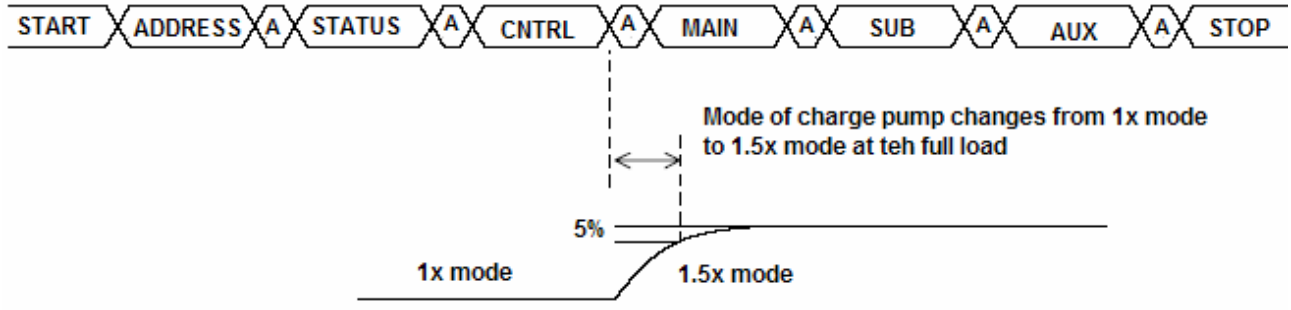
I^2C data input (Final State)



The softstart interval within 2x mode: After mode changing from Standby to Active, the time from the raising edge of " STATUS" acknowledge bit to the point where the ILED is within 5% of its final value at full load. This softstart is tested within Vin=4.0V to ensure 1x mode.

Note 6: Soft Start Interval Within 1.5X mode

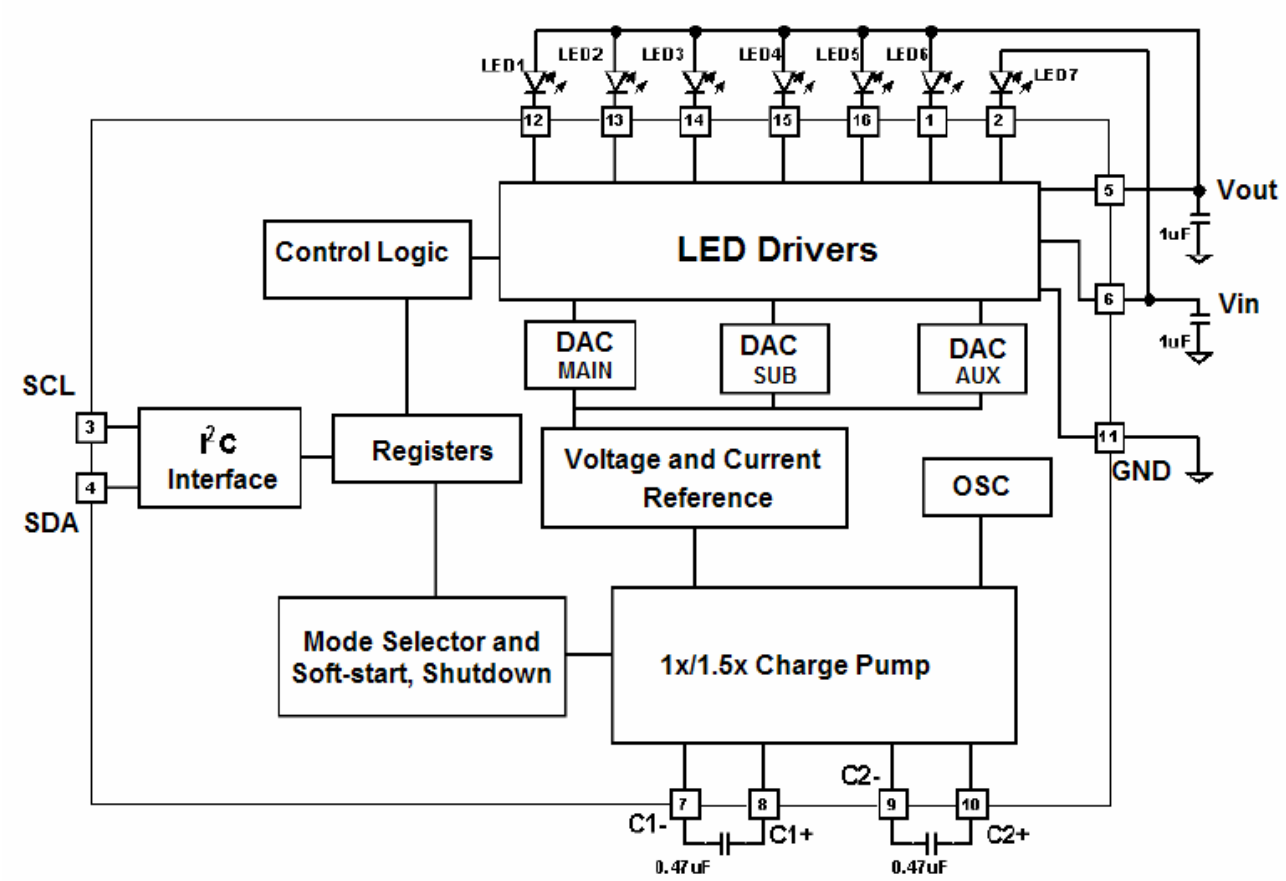
I^2C data input (Final State)



This softstart interval within 1x to 1.5x mode: After mode changing from 1x mode to 1.5x mode, the time from the raising edge of "CNTRL" acknowledge bit to the point where V_{OUT} is within 5% of its final value at full load.

This is measurement to know the boosting time of charge pump at the full load current. In this case, it is easier to measure V_{OUT} than I_{OUT}. This softstart is tested with Vin=3.4V to force a mode transition.

Block Diagram



The A8470 is a high efficiency charge pump white LEDs driver for portable applications. It can drive 7 LEDs for 4 main, 2 sub and a single auxiliary keypad LEDs. With I^2C serial interface, each LED can be turned on/off independently so any combination of LEDs is available. The drive current setting of the LEDs is classified as 3 groups, main, sub and aux. Three 6-bit DAC are included to provide precise current level setting. The drive current is set simultaneously the whole group. The brightness integrity is assured in this control method and good current match among channels.

The A8470 is a fractional charge pump and can multiply the input voltage by 1 and 1.5 times. The charge pump switches at a high fixed frequency of 2MHz and allows for the reduced external components.

The internal-mode-selection-circuit automatically switches the mode between 1x and 1.5x based on the input voltage, output voltage and load current.

This mode switching maximizes the efficiency over the full load range. When the battery voltage is high enough, the A8470 operates in 1x mode to provide maximum efficiency. If the battery voltage is too low to sustain the LED current, a 1.5x mode is automatically enabled. As the battery discharges and the voltage decays, the A8470 automatically switches between mode to maintain a constant current to drive LEDs throughout the battery life.

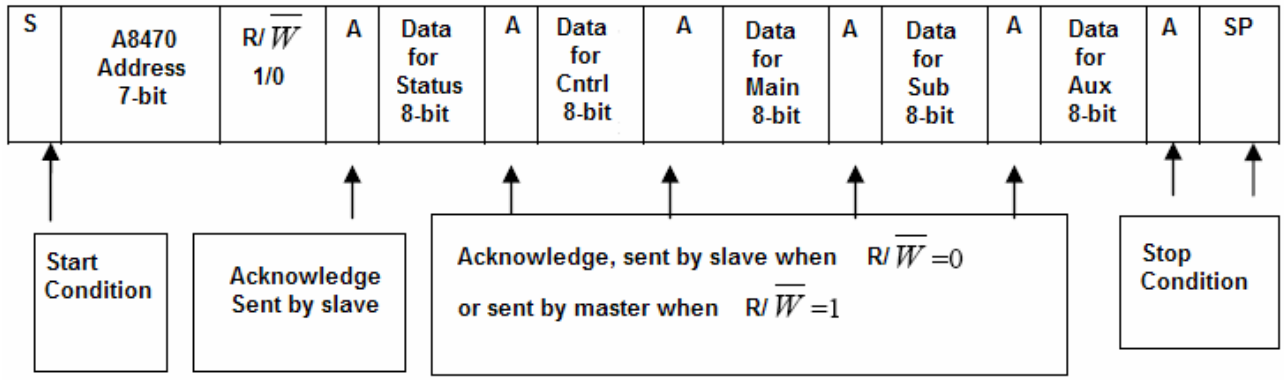
The I^2C interface allows a simple way to adjust each channel current individually in order to provide ultimate flexibility in driving LED. The A8470 has five data registers which can be programmed serially via the I^2C interface.

The STATUS register is used to enable/disable the part as well as for fault mode readback. The CNTRL register contains information regarding the state of each of the 7 individual LEDs. The final three registers contain information regarding the current level for the MAIN, SUB and AUX channels.

I²C Specifications

This protocol defines any device that sends data to the bus as a transmitter and any device that reads the data as a receiver. The device that controls the data transfer is known as master and the other as the slave. The master will always initiate a data transfer and will provide the serial clock for synchronization.

I²C Data Format



The A8470 has five data registers which can be programmed serially via the I²C interface. The STATUS register is used to enable/disable the part as well as for fault mode readback. The CNTRK register contains information regarding the state of each of the 7 individual LEDs. The final three registers contain information regarding the current level for the MAIN, SUB and AUX channels.

Fault Conditions

1. **Under Voltage Lockout**
2. **Over Temperature Detection**
3. **Over Voltage Protection**

Upon entering UVLO and Over Temperature fault modes, the A8470 get into shutdown mode and all registers reset to default values. If enter Over Voltage fault mode, the LED drivers will turn off but the register contents should remain unchanged with the exception of the fault mode readback bits of the status register.

The WZ and WP bits of the status register should also remain unchanged. The microprocessor needs not to reset the A8470 if it goes into fault mode. The chip should continuously monitor it's fault indicators and when the fault condition si no longer present, then can resume normal operation.

Registers

	B7	B6	B5	B4	B3	B2	B1	B0
STATUS	WZ	WP	FLT	OVP	OVT	UVL	CPS	FCP
CNTRL	LED7	LED6	LED5	LED4	LED3	LED2	LED1	CPM
MAIN	D5	D4	D3	D2	D1	D0	dc	dc
SUB	D5	D4	D3	D2	D1	D0	dc	dc
AUX	D5	D4	D3	D2	D1	D0	dc	dc

1. STATUS Register

	B7	B6	B5	B4	B3	B2	B1	B0
STATUS	WZ	WP	FLT	OVP	OVT	UVL	CPS	FCP

In the STATUS register, B7 and B6 are used to enable/disable the A8470. The following table defines the states for bits WZ and WP. These bits are used to put the A8470 into shutdown, standby or active mode.

WZ	WP	State	Iq	LED drivers
0	0	Shutdown and reset registers to 00000000	0 uA	Off
0	1	Shutdown - keep register contents	0 uA	Off
1	0	Standby – keep register contents – bandgap and other analog circuits active, V_{IN} shorted to V_{OUT} through internal switch	200 uA	Off
1	1	Active	Active Iq	Off

Bits B5, B4, B3, B2 and B1 are for read back only. Bit B5 is held high whenever any kind of fault condition exists on the A8470. Bits B4, B3 and B2 indicat3e the specific fault condition, over-voltage (B4=1), over-temp (B3=1) or under voltage lockout (B2=1). B1 communicates the stats of the charge pump, (B1=1 for 1.5x mode or B1=0 for 1x mode).

B0 of the STATUS register is used to select between automatic charge pump mode selection and forced charge pump mode selection. If B0 is low,l then the charge pump mode (1x or 1.5x) is automatically selected. If B0 is high, then the charge pump is forced into either 1x mode or 1.5x mode depending upon B0 of the CNTRL register.

2. MAIN, SUB and AUX registers

	B7	B6	B5	B4	B3	B2	B1	B0
MAIN	D5	D4	D3	D2	D1	D0	dc	dc
SUB	D5	D4	D3	D2	D1	D0	dc	dc
AUX	D5	D4	D3	D2	D1	D0	dc	dc

	Main	Sub	Aux		Main	Sub	Aux
000000	0	0	0	**100000**	16.0	16.0	32.0
000001	0.031	0.031	0.031	**100001**	16.5	16.5	33.0
000010	1.0	1.0	2.0	**100010**	17.0	17.0	34.0
000011	1.5	1.5	3.0	**100011**	17.5	17.5	35.0
000100	2.0	2.0	4.0	**100100**	18.0	18.0	36.0
000101	2.5	2.5	5.0	**100101**	18.5	18.5	37.0
000110	3.0	3.0	6.0	**100110**	19.0	19.0	38.0
000111	3.5	3.5	7.0	**100111**	19.5	19.5	39.0
001000	4.0	4.0	8.0	**101000**	20.0	20.0	40.0
001001	4.5	4.5	9.0	**101001**	20.5	20.5	41.0
001010	5.0	5.0	10.0	**101010**	21.0	21.0	42.0
001011	5.5	5.5	11.0	**101011**	21.5	21.5	43.0
001100	6.0	6.0	12.0	**101100**	22.0	22.0	44.0
001101	6.5	6.5	13.0	**101101**	22.5	22.5	45.0
001110	7.0	7.0	14.0	**101110**	23.0	23.0	46.0
001111	7.5	7.5	15.0	**101111**	23.5	23.5	47.0
010000	8.0	8.0	16.0	**110000**	24.0	24.0	48.0
010001	8.5	8.5	17.0	**110001**	24.5	24.5	49.0
010010	9.0	9.0	18.0	**110010**	25.0	25.0	50.0
010011	9.5	9.5	19.0	**110011**	25.5	25.5	51.0
010100	10.0	10.0	20.0	**110100**	26.0	26.0	52.0
010101	10.5	10.5	21.0	**110101**	26.5	26.5	53.0
010110	11.0	11.0	22.0	**110110**	27.0	27.0	54.0
010111	11.5	11.5	23.0	**110111**	27.5	27.5	55.0
011000	12.0	12.0	24.0	**111000**	28.0	28.0	56.0
011001	12.5	12.5	25.0	**111001**	28.5	28.5	57.0
011010	13.0	13.0	26.0	**111010**	29.0	29.0	58.0
011011	13.5	13.5	27.0	**111011**	29.5	29.5	59.0
011100	14.0	14.0	28.0	**111100**	30.0	30.0	60.0
011101	14.5	14.5	29.0	**111101**	30.5	30.5	61.0
011110	15.0	15.0	30.0	**111110**	31.0	31.0	62.0
011111	15.5	15.5	31.0	**111111**	31.5	31.5	63.0

In the MAIN, SUB and AUX registers bits B7, B6, B5, B4, B3 and B2 represent the DAC codes D5-D0 used to set the LED current in the MAIN, SUB and AUX channel.
Bits B1 and B0 are don't care.
The above table lists the DAC codes and the corresponding current for each channel in mA.

3. CNTRL Register

	B7	B6	B5	B4	B3	B2	B1	B0
CNTRL	LED7	LED6	LED5	LED4	LED3	LED2	LED1	CPM

In the CNTRL register B1, B2, B3 and B4 are used to control the four MAIN LEDs, bits B5 and B6 are used for two SUB LEDs and B7 is used for the AUX LED. To enable an individual LED the corresponding bit is active high.

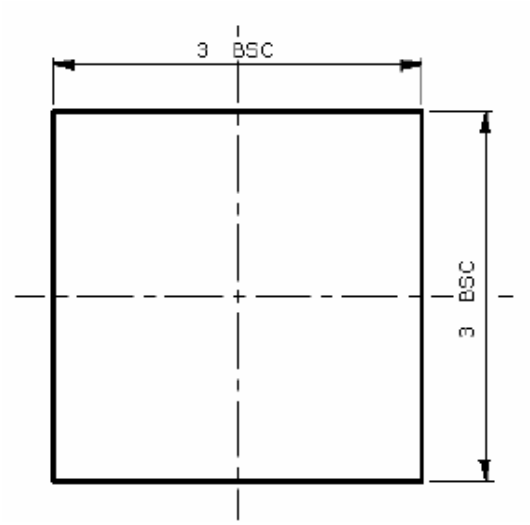
When B0 of the STATUS register is high, B0 of the CNTRL register is used to force the charge pump into 1x mode (CNTRL B0=low) or 1.5x mode (CNTRL B0=high). When B0 of the STATUS register is low then CNTRL B0 is ignored.

Addressing and Writing Data to the A8470

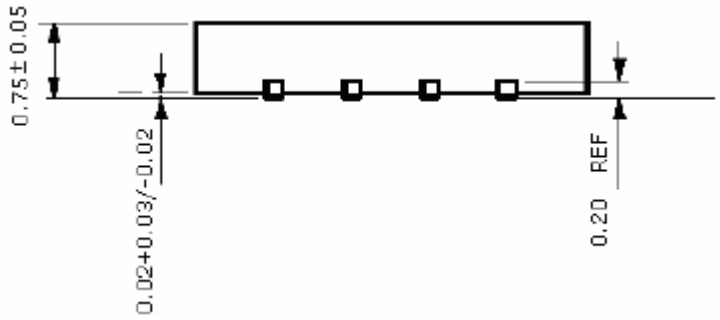
To write data to the A8470 the following data cycle must be obeyed:
[Slave Address with write bit] [Data for STATUS] [Data for CNTRL] [Data for MAIN] [Data for SUB] [Data for AUX] Six bytes are communicated each data cycle.

Package Information

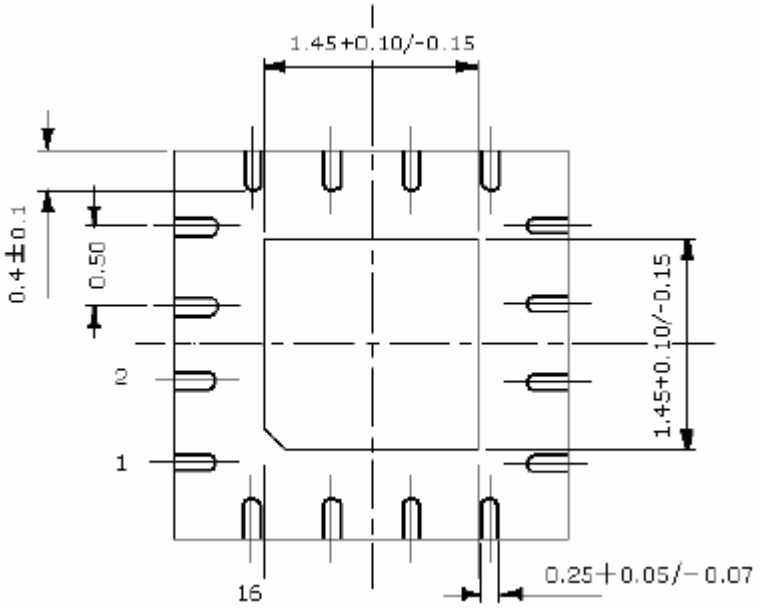
Dimension in 16Pin 3x3mm QFN (Unit: mm)



Top View



Side View



Bottom View

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