

1X/1.5X Fractional Charge Pump for White LED Driver with 32step Dimming Control.

The KAC3304DU is low noise constant frequency charge pump DC/DC converter specially designed to drive up to four white LEDs on 32step dimming control. Dual (1x/1.5x) Modes and low dropout voltage of LED driver maximize efficiency for the white LED application over full Li-ion battery input range. Various kinds of protection circuits protect your system from every undesirable output condition.

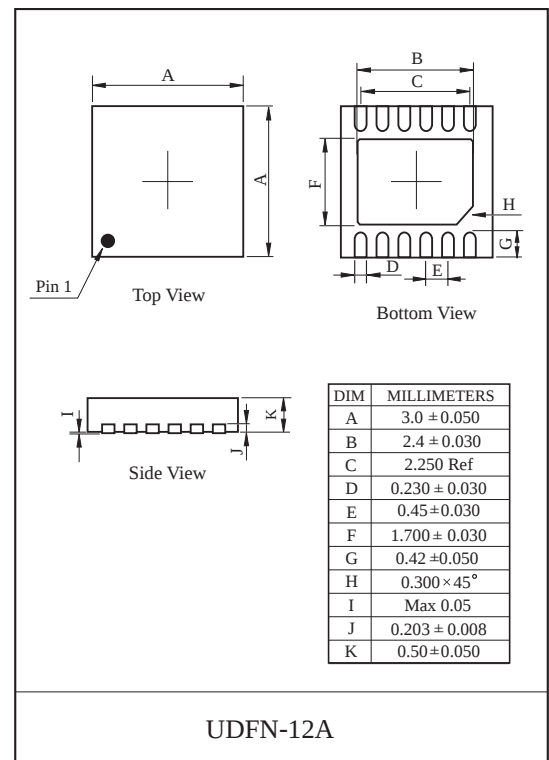
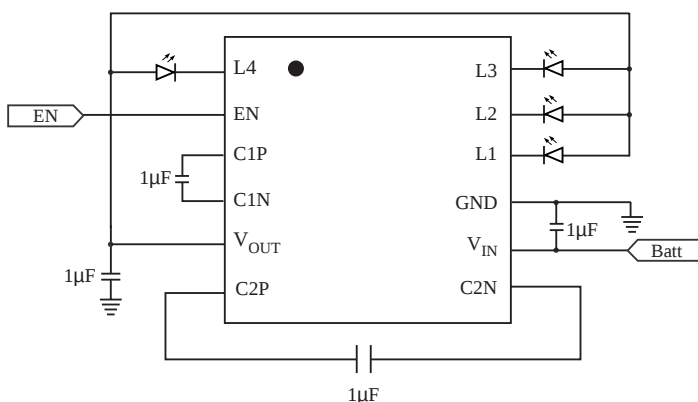
Features

- 1x/1.5x dual charge pump modes with auto detection.
- Excellent Power Efficiency. (more than 92% of P_{MAX})
- LED current matching of $\pm 2\%$. (Typ.)
- Power-down current below $1\mu A$. (max.)
- Drives up to 4 LED's on 32step dimming control.
- Up to 22mA/LED current capability. [$V_{IN} > 3.1V$]
- Up to 15mA/LED current capability. [$V_{IN} > 2.7V$]
- Strong to ESD. [MM:>200V, HBM:>2000V]
- Low input ripple and EMI.
- Fast serial dimming control.
- 2.7V to 5.5V input voltage range.
- Output over-voltage protection.
- Thermal shutdown protection.
- Output over-current protection.
- Soft start limits Inrush current.
- Automatic soft-start protects IC from output short.
- 1MHz switching frequency.
- Small UDFN-12A Package [$3 \times 3mm^2$, $t=0.5mm$]

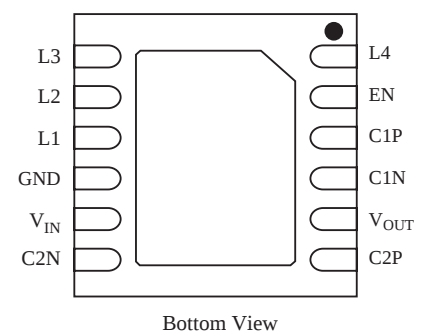
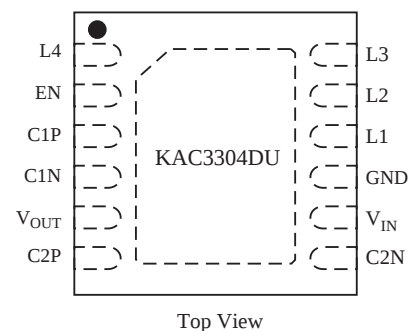
Applications

- Cellular phones, Smart Phones, PDA, Digital Cameras, Camcorders.
- MP3 player and other handheld devices with color displays

Typical operating Circuit

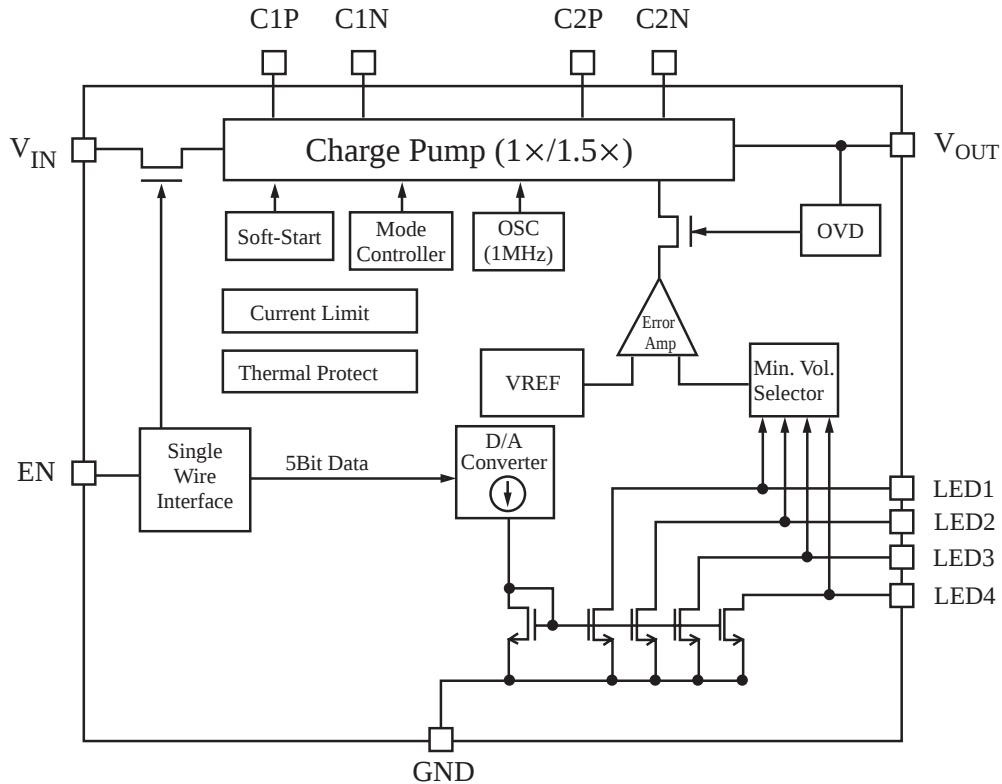


Pin Configuration



KAC3304DU

Block Diagram



Pin Descriptions

Pin	Name	Function
1	L4	Sinking current input for LED4
2	EN	Chip enable input. (Shutdown to Low state)
3	C1P	Positive terminal of switched capacitor 1
4	C1N	Negative terminal of switched capacitor 1
5	V _{OUT}	Charge pump output
6	C2P	Positive terminal of switched capacitor 2
7	C2N	Negative terminal of switched capacitor 2
8	V _{IN}	Power supply voltage Input
9	GND	Ground
10	L1	Sinking current input for LED1
11	L2	Sinking current input for LED2
12	L3	Sinking current input for LED3

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Absolute Maximum Ratings

Characteristics	Symbol	Rating	Units
Input Supply Voltage	V_{IN}	-0.3 to +6.0	V
Input Pin	DIM, EN	-0.3 to ($V_{IN}+0.2$)	V
Maximum Power Dissipation. (@ $T_a=25^{\circ}\text{C}$)	P_D	1.6	W
Thermal Resistance[QFN-16]	θ_{JA}	78.12	$^{\circ}\text{C}/\text{W}$
Operating Ambient	T_a	-40 to + 85	$^{\circ}\text{C}$
Junction Temperature Range	T_j	-40 to + 150	$^{\circ}\text{C}$
Storage Temperature Range	T_{stg}	-55 to + 150	$^{\circ}\text{C}$
Lead Temperature	T_{LEAD}	265	$^{\circ}\text{C}$

Electrical Characteristics ($T_a=-40$ to 85°C , $2.7\text{V} < V_{IN} < 5.5\text{V}$, $C_1=C_2=1.0\mu\text{F}$. unless otherwise noted.) (note 1)

Parameter	Symbol	Conditions	Min	Typ	Max	Units
Input Supply Voltage	V_{IN}	-	2.7	-	5.5	V
Maximum LED sink current	I_{LED}	$V_{IN}>2.7\text{V}$	-	15	-	mA
		$V_{IN}>3.1\text{V}$	-	22	-	mA
Quiescent current	I_Q	No output load	-	1.0	3.0	mA
Power-down Current	I_{PD}	$V_{EN}=\text{Low}$	-	0.1	1	μA
I_{LED} Accuracy	I_{LED_ACC}	$V_{IN}=4.2\text{V}$, @ $I_{LED}=22\text{mA}$	-	± 3	-	%
I_{LED} Matching between any other I_{LED}	I_{LED_MAT}	$V_{IN}=4.2\text{V}$, @ $I_{LED}=22\text{mA}$	-	± 2	-	%
LED regulation Voltage	V_{LED}	-	75	120	-	mV
Oscillator Frequency	F_{OSC}	$2.5\text{V} < V_{IN} < 5.5\text{V}$	0.7	1	1.3	MHz
Maximum Output Current	I_{OUT}	$V_{IN}>3.1\text{V}$, $V_{OUT}\leq 3.8\text{V}$	80	-	-	mA
		$V_{IN}>2.7\text{V}$, $V_{OUT}\leq 3.5\text{V}$	60	-	-	mA
Input Current Limit	I_{LIMIT}	Short Condition in V_{OUT} Without Softstart. (Note 2)	-	280	600	mA
Thermal Shutdown Threshold	T_{SD}	40°C Hysteresis	-	150	-	$^{\circ}\text{C}$
Over-Voltage Protect	V_{OVP}	-	-	5.5	6.0	V
Hysteresis of V_{OVP}	V_{HTY_OVP}	-	-	0.4	-	V
Enable Logic High	V_{EN_H}	-	1.6	-	-	V
Enable Logic Low	V_{EN_L}	-	-	-	0.4	V

Note 1) Specifications to -40°C are guaranteed by design and not production tested.

Note 2) This is occurred when Pin of LED is shorted to GND, or there are ohmic short V_{OUT} to GND

Application Information

• Output Regulation

KAC3304DU maintains constant LED brightness even at very low battery voltage. For example, at 2.7V of the battery voltage KAC3304DU can maintain constant LED bright above 20mA. For better efficiency KAC3304DU will be kept in 1x mode unless lowest voltage of the LED1~LED4 goes under the 75mV. Constant switching frequency & optimized duty make low input and output ripple at the 1.5x mode. Of course, KAC3304DU has almost no output ripple at the 1x mode.

• Shutdown (Enable=Low)

When voltage of the ENABLE pin goes under 0.4V over then 2ms, KAC3304DU enter the shutdown mode where input current go to zero and there are no current between output capacitors and transfer capacitor.

• Soft-Start

KAC3304DU has its original soft-start function to limit inrush current at turn on. KAC3304DU charges transfer capacitors and output capacitor with a constant input current until output voltage goes to the value of $(1.4 \times V_{IN})$. If output voltage reached the value of $(1.4 \times V_{IN})$ or over-voltage protection circuit is activated, LED current start to flow. But input current remains to zero until output voltage goes down to usual output operating voltage from the discharge of LED current. At the every turn on the ENABLE and output voltage less than 25% of the input voltage, soft-start sequence is introduced for the safety.

• Short protection (various short mode)

- 1) Short V_{OUT} pin to GND pin: If output is shorted to ground, output current is limited by the soft-start which is repeated until V_{OUT} remains under 25% of V_{IN} .
- 2) Short LED pin to GND pin: If this occurs at the soft-start-mode or shutdown state, KAC3304DU stays at soft-start-mode. Else this is done during operating, the output current is limited by the current-limit-circuitry.
- 3) Short V_{OUT} pin to LED pin(shorted LED) : There are no change but shorted LED doesn't work.

• Open protection

If more than one LED is opened, output voltage is limited by over-voltage-protect circuitry. But, other LEDs work continuously without change of the brightness.

• Current limit

There could be variable short mode in the backlight system. For example, V_{OUT} pin to GND or LED pin to GND or short of LEDs, etc. In these case, large current could be flow at the output pin. KAC3304DU are protected by the "thermal shutdown" circuitry, but external elements might be damaged without "current limit" circuitry. Current limit "circuitry set you to ease to design safely.

• Over-voltage protection

When a LED pin shorted to the ground or LED is opened itself, voltage of the LED terminal could be almost 0V without any concerning to the other conditions. In this case, output voltage might be raised over IC's maximum ratings. And, then IC may be destroyed KAC3304DU maintains "over voltage protection" circuitry for the prohibiting output voltage over the maximum ratings.

• Thermal shutdown

KAC3304DU includes a thermal shutdown circuit which makes IC shutdown at 150 °C(typ.) and recover after IC cools by approximately 40 °C.

- **Input Ripple**

For driving LED Current IC's in mobile system, input ripple is more important than output ripple, because there are many other components which have input supply terminal from battery instead of the output terminal. KAC3304DU has very excellent input ripple characteristics. You can get better input ripple characteristics, by minimizing resistance from battery to the V_{IN} pin.

- **Unused LED**

When driving fewer than 4 LEDs, connect any unused LED pin to V_{IN} . This makes the corresponding LED driver disable, then there is no current consumption through unused LED pin, so KAC3304DU maintains its efficiency.

- **Flash or Large Current Drive**

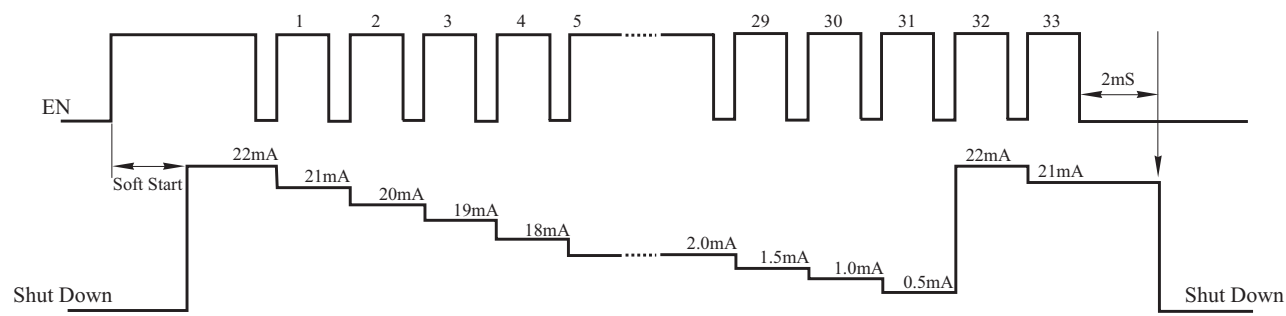
KAC3304DU can be used Flash Driver when shorting pins of 4 LEDs as circuits. Be careful that R_{SET} should be set not for the I_{LED} but for the I_{FLASH} ($=I_{LED} \times 4$).

- **LED Current Control & Dimming**

KAC3304DU don't need external R_{SET} terminal for the LED Current control. You can easily set LED current up to 32step with FSC(Fast Serial Control) through Enable terminal.

KAC3304DU

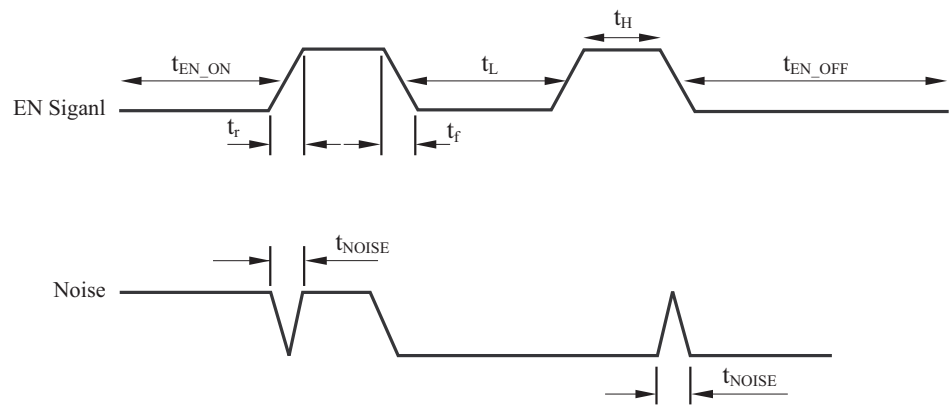
FSC(Fast Serial Control)



LED Current Level

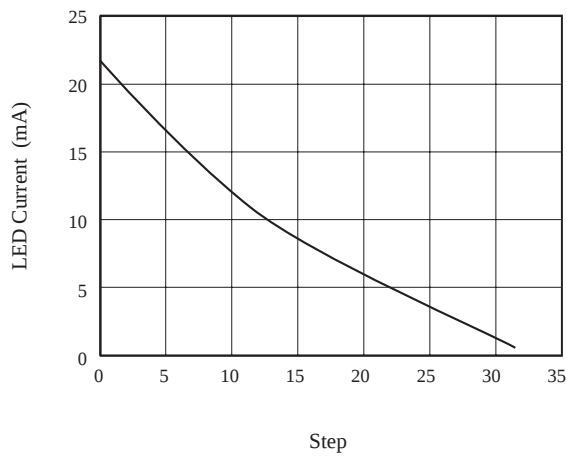
Parameter	Symbol	Min	Typ	Max	Units
Digital input voltage	V_{IL}	-	-	0.4	V
	V_{IH}	1.6	-	-	V
Digital input Current	I_{EN}	-0.2	-	0.2	μA
Start Time	t_{EN_ON}	300	-	-	μS
Stop Time	t_{EN_OFF}	2.5	-	-	mS
EN High Time	t_H	7	-	-	μS
EN Low Time	t_L	6	-	1000	μS
Rising Time	t_r	-	-	100	nS
Falling Time	t_f	-	-	100	nS
Filtered Noise Width	t_{noise}	-	-	0.1	μS

Step	Current[mA]	Step	Current[mA]
0	22	16	8.0
1	21	17	7.5
2	20	18	7.0
3	19	19	6.5
4	18	20	6.0
5	17	21	5.5
6	16	22	5.0
7	15	23	4.5
8	14	24	4.0
9	13	25	3.5
10	12	26	3.0
11	11	27	2.5
12	10	28	2.0
13	9.5	29	1.5
14	9.0	30	1.0
15	8.5	31	0.5

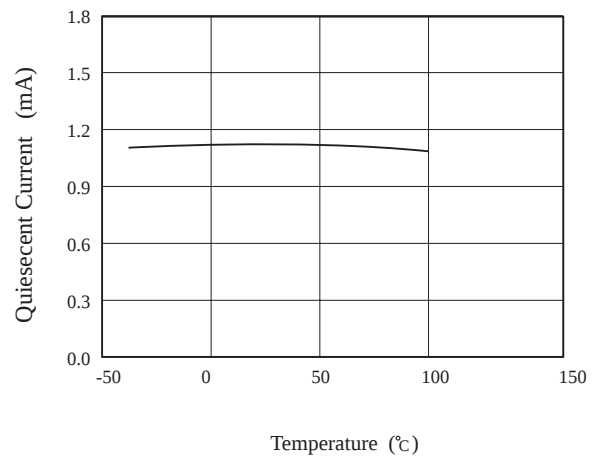


KAC3304DU

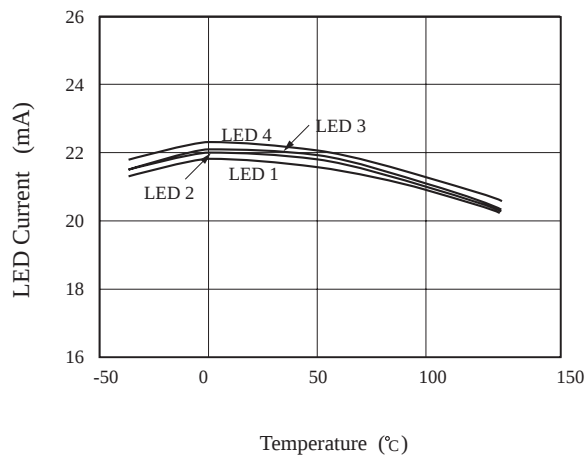
LED Current vs. Dimming Step



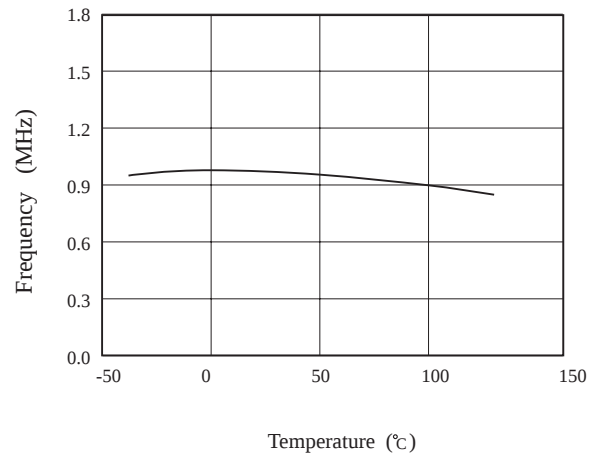
Quiescent Current vs Temp



LED Current vs Temp



Freg vs Temp



V_{OUT} vs Temp

