High Efficiency 1.5X Fractional Charge Pumps For White LED Applications

■ General Description

The LN2113 and LN2114 are low noise, constant frequency charge pump DC/DC converters that use fractional (1.5X) conversion to increase efficiency in white LED applications. The devices can be used to produce current levels up to 20mA for each output from a 2.7V to 5.5V input. A low external parts count (two 1μF flying capacitors and two small bypass capacitors at VIN and OUT) makes the LN2113/LN2114 ideally suited for small battery-powered applications. Simple Serial Interface is used to enable, disable, and set the LED drive current for 32-level logarithmic scale LED brightness control.

LN2113/LN2114 devices have a thermal management system for protection in the event of a short-circuit condition on any of the output pins. Built-in soft-start circuitry prevents excessive inrush current during start-up. A high switching frequency enables the use of small external capacitors. A low-current shutdown feature disconnects the load from VIN and reduces quiescent current to less than 1μA. The LN2113 provides four LED current source outputs, and the LN2114 provides six. The LN2114 is available in the 16-pin quad QFN package, and the LN2113 is available in the 12-pin TSOPJW package.

■ Features

- LN2113: four outputs
- LN2114: six outputs
- 20mA full-scale current
- 32-position logarithmic scale with digital control
- Low noise constant frequency operation
- 33% less input current than doubler charge pump
- High accuracy brightness matching
- Vin range: 2.7v to 5.5v
- I_Q <1μa in shutdown
- 16-pin QFN, 12-pin TSOPJW package
- Simple serial interface
- Automatic soft start
- Small application circuit
- No inductors
- Regulated output current
- 600KHz switching frequency

■ Applications

- LCD backlighting
- MP3/MP4 player
- PDA、Notebook
- Digital camera
- Programmable current source

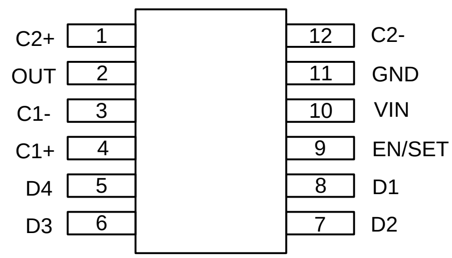
■ Package

- TSOPJW-12 (LN2113)
- QFN4×4-16 (LN2114)

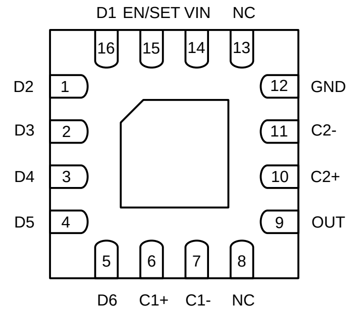
■ Ordering Information

Package	Part Number	Function
QFN4×4-16	LN2114-20-6	Six diode outputs, 20mA full scale.
TSOPJW-12	LN2113-20-4	Four diode outputs, 20mA full scale.

■ Pin Configuration



LN2113(TSOPJW-12)

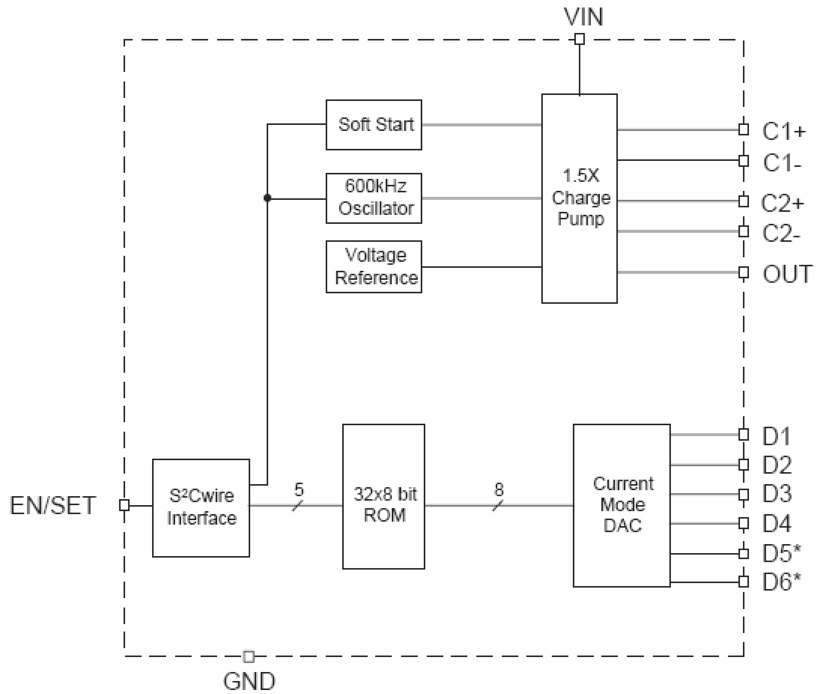


LN2114(QFN4*4-16)

■ Pin Assignment

Pin		symbol	Function
QFN4×4-16	TSOP JW-12		
1	7	D2	Current source output
2	6	D3	Current source output
3	5	D4	Current source output
4	N/A	D5	Current source output (2114 option only)
5	N/A	D6	Current source output (2114 option only)
6	4	C1+	Flying capacitor 1+ terminal
7	3	C1-	Flying capacitor 1- terminal
8	N/A	NC	No connect
9	2	OUT	Charge pump output requires 1MF bypass capacitor to ground
10	1	C2+	Flying capacitor 2+ terminal
11	12	C2-	Flying capacitor 2-terminal
12	11	GND	Ground
13	N/A	NC	No connect
14	10	VIN	Input power supply .requires 1μF bypass capacitor to ground
15	9	EN/SET	Control pin using S^2C wire serial interface
16	8	D1	Current source output 1.Required reference current source.Do not leave pin floating.
EP			Exposed paddle(bottom);connect to GND directly beneath package

■ Function Block Diagram



■ Absolute Maximum Ratings

TA = 25°C, unless otherwise noted

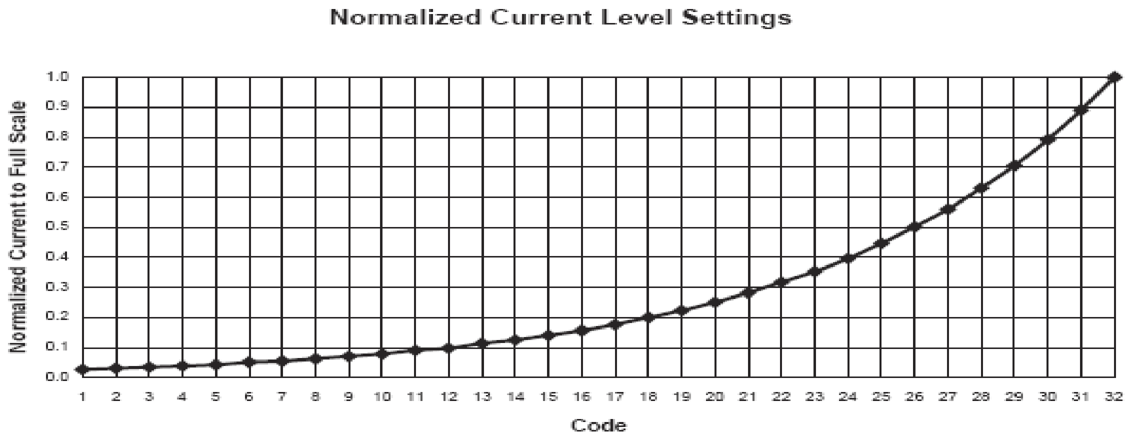
Symbol	Description	Value	Units
V_{IN}	Input voltage	-0.3 to 6	V
V_{OUT}	Charge pump output	-0.3 to 6	V
$V_{EN/SET}$	EN/SET to GND voltage	-0.3 to 6	V
$V_{EN/SET(MAX)}$	Maximum EN/SET to input voltage	0.3	V
I_{OUT}	Maximum DC output current(sum of I_{OUT} and D currents)	150	mA
θ_{JA}	Thermal Resistance	37	℃/W
T_J	Operating junction temperature range	-40 to 150	℃

Electrical Characteristics

TA = -40°C~85°C, VIN =3.5v unless otherwise noted.

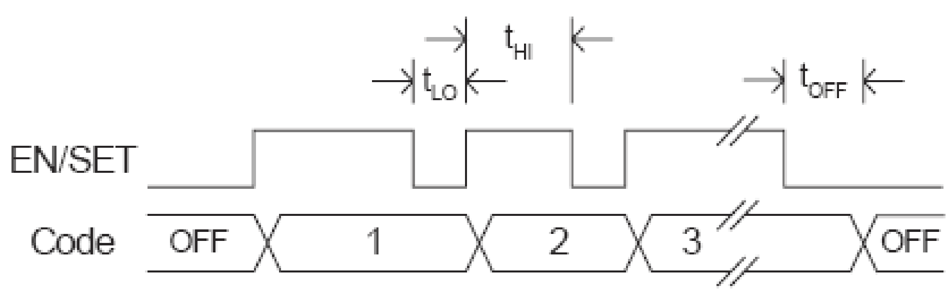
Symbol	Description	Conditions		Min	Typ	Max	Units
Input Power Supply							
V_{IN}	Operating range			2.7		5.5	V
I_{CC}	Operating current	Active,no load currrent			1	2	mA
I_{SHCN}	Shutdown current	EN=0				1	μA
I_{DX}	Output current	2113: 3.0≤V_{IN}≤5.5 2114：3.2≤V_{IN}≤5.5	TA=25℃,All Outputs max current	18	20	22	mA
$\triangle I_D/\triangle V_{IN}$	Output current line regulation	3.0≤V_{IN}≤5.5		-2		2	%/v
$I_{D\text{-}MATCH}$	Current matching between any two outputs	V_{D1}:Dn=3.6,V_{IN}=3.3v			0.3		%
η	efficiency	V_{IN}=3.5,$I_{OUT(total)}$=40mA			93		%
Charge Pump							
t_{SS}	Soft-start time				400		μs
F_{CLK}	Clock frequency			300	600	900	KHZ
EN/SET							
$V_{EN(L)}$	Enable threshold low	V_{IN}=2.7 to 5.5V				0.5	V
$V_{EN(H)}$	Enable threshold high	V_{IN}=2.7 to 5.5V		1.4			V
t_{LO}	EN/SET low time			0.3		75	μs
t_{Ht}	Minimum EN/SET high Time				50		ns
t_{OFF}	EN/SET off timeout				300	500	μs
I_L	EN/SET Input Leakage	V_{IN}= 5.5V		-1		1	μA

Current Levels



Code	20mA max	Code	20mA max
1	0.549	17	3.529
2	0.627	18	4.000
3	0.706	19	4.471
4	0.784	20	5.020
5	0.863	21	5.647
6	1.020	22	6.353
7	1.098	23	7.059
8	1.255	24	7.922
9	1.412	25	8.941
10	1.569	26	10.039
11	1.804	27	11.216
12	1.961	28	12.627
13	2.275	29	14.118
14	2.510	30	15.843
15	2.824	31	17.804
16	3.137	32	20.000

EN/SET Timing



■ Functional Description

The LN2113/LN2114 is a high efficiency 1.5X fractional charge pump device intended for white LED backlight applications. The fractional charge pump consists of a linear regulator followed by a 1.5X charge pump. The LN2113/LN2114 requires only four external components: two 1μF ceramic capacitors for the charge pump flying capacitors (C1 and C2), one 1μF ceramic capacitor for CIN, and one 0.33μF to 1μF ceramic capacitor for COUT. The charge pump output is converted into four or six constant current outputs (D1 to D4 or D6) to drive four or six individual LEDs with a maximum of 20mA each.

EN/SET Serial Interface: The current source output magnitude is controlled by the EN/SET serial data interface. The interface records rising edges of the EN/SET pin and decodes them into 32 individual current level settings each 1dB apart (see Current Level Settings table). Code 32 is full scale, and Code 1 is full scale attenuated by 31dB. The modulo 32 interface wraps states back to state 1 after the 32nd clock. With each EN/SET pulse, the output current increases by 1dB. To decrease the output current by 1dB, 31 EN/SET clock pulses are required. The counter can be clocked at speeds up to 1MHz, so intermediate states are not visible. The first rising edge of EN/SET enables the IC and initially sets the output LED current to -31dB, the lowest setting equal to 525μA. Once the final clock cycle is input for the desired brightness level, the EN/SET pin is held high to maintain the device output current at the programmed level. The device is disabled 500μs after the EN/SET pin transitions to a logic low state.

The EN/SET timing is designed to accommodate a wide range of data rates. After the first rising edge of EN/SET, the charge pump is enabled and reaches full capacity after the soft-start time (TSS). During the soft-start time, multiple clock pulses may be entered on the EN/SET pin to set the final output current level with a single burst of clocks. Alternatively, the EN/SET clock pulses may be entered one at a time to gradually increase the LED brightness over any desired time period. A constant current is sourced as long as EN/SET remains in a logic high state. The current source outputs are switched off after EN/SET has remained in a low state for at least the t_{OFF} timeout period.

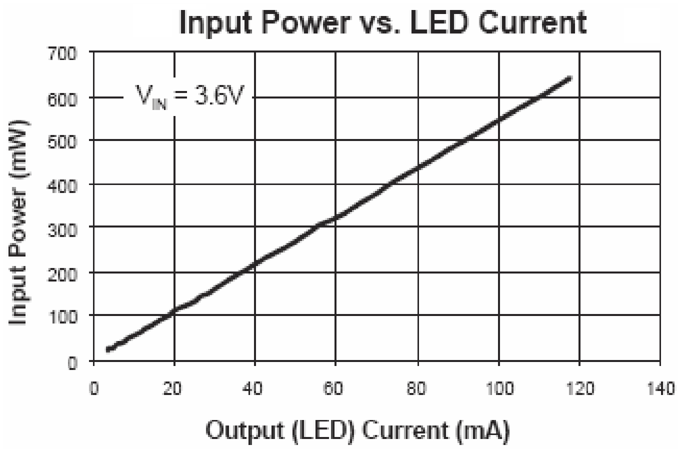
LED Selection : LN2113/LN2114 devices are designed to drive white LEDs with forward voltages of less than 4.2V. Since the D1:D6 output current sources are matched with negligible voltage dependence; the LED brightness will be matched regardless of their forward voltage matching.

Charge Pump Efficiency: The LN2113/LN2114 is a fractional charge pump. The efficiency (η) can be simply defined as a linear voltage regulator with an effective output voltage that is equal to one and a half times the input voltage. Efficiency (η) for an ideal 1.5X charge pump can typically be expressed as the output power divided by the input power. In addition, with an ideal 1.5X charge pump, the output current may be expressed as 2/3 of the input current. The expression to define the ideal efficiency (η) can be written as:

$$\eta = \frac{P_{OUT}}{P_{IN}} = \frac{V_{OUT} \times I_{OUT}}{V_{IN} \times I_{IN}} = \frac{V_{OUT} \times I_{OUT}}{V_{IN} \times 1.5 I_{OUT}} = \frac{V_{OUT}}{1.5 V_{IN}} \quad \text{or} \quad \eta(\%) = 100\left(\frac{V_{OUT}}{1.5 V_{IN}}\right)$$

For a charge pump with an output of 5 volts and a nominal input of 3.5 volts, the theoretical efficiency is 95%. Due to internal switching losses and IC quiescent current consumption, the actual efficiency can be measured at 93%. These figures are in close agreement for output load conditions from 1mA to 100mA. Efficiency will decrease as load current drops below 0.05mA or when the level of V_{IN} approaches V_{OUT}.

Power Efficiency and Device Evaluation: The charge pump efficiency discussion of the previous section only accounts for efficiency of the charge pump section itself. Due to the unique circuit architecture and design of the LN2113/LN2114, it is very difficult to measure efficiency in terms of a percent value comparing input power over output power. Since the LN2113/LN2114 outputs are pure constant current sources, it is difficult to measure the output voltage for a given output (D1 to D6) to derive an output power measurement. For any given application, white LED forward voltage levels can differ, yet the output drive current will be maintained as a constant. This makes quantifying output power a difficult task when taken in the context of comparing to other white LED driver circuit topologies. A better way to quantify total device efficiency is to observe the total input power to the device for a given LED current drive level. The best white LED driver for a given application should be based on trade-offs of size, external components count, reliability, operating range, and total energy usage...not just "% efficiency."

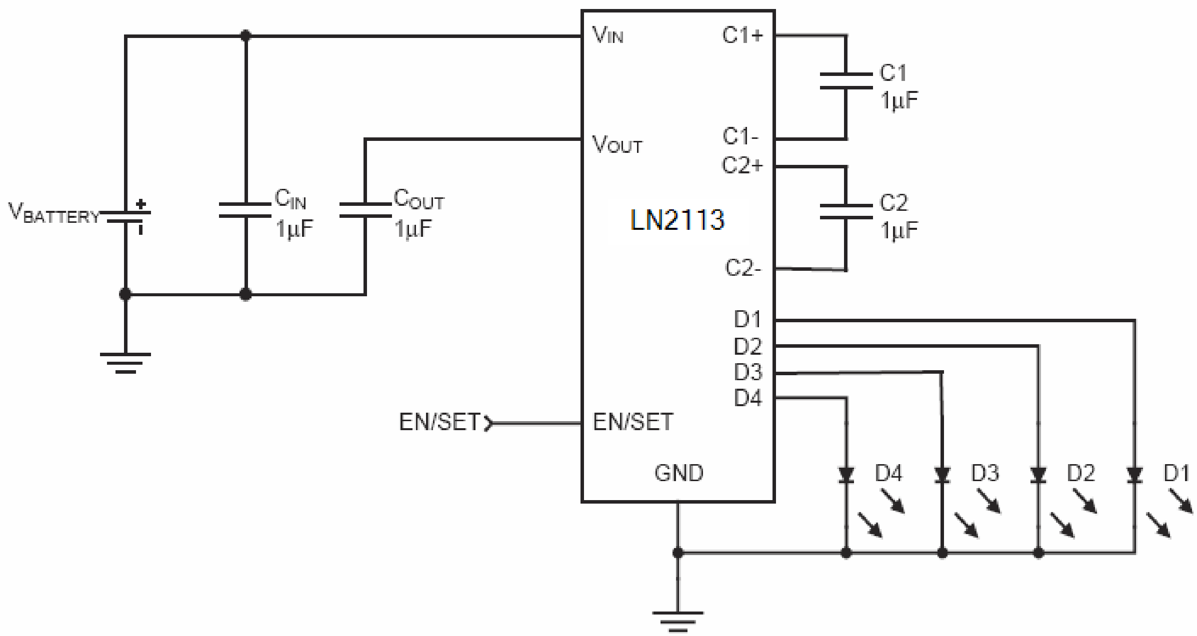


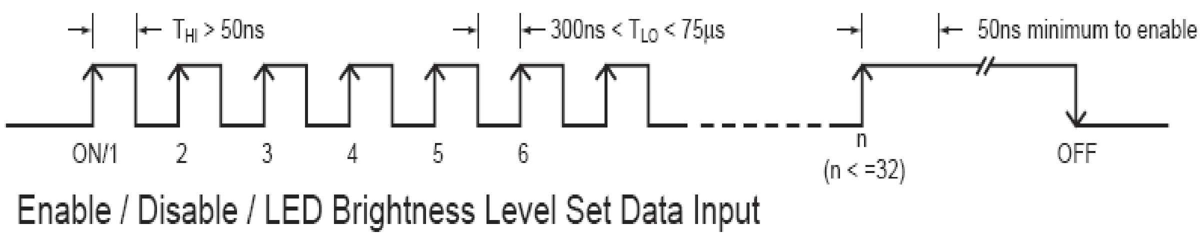
Capacitor Selection: Careful selection of the four external capacitors CIN, C1, C2, and COUT is important because they will affect turn-on time, output ripple, and transient performance. Optimum performance will be obtained when low equivalent series resistance (ESR) ceramic capacitors are used. In general, low ESR may be defined as less than 100mΩ. A value of 1μF for all four capacitors is a good starting point when choosing capacitors. If the LED current sources are only programmed for minimal current levels, then the capacitor size may be decreased. Ceramic composition capacitors are highly recommended over all other types of capacitors for use with the LN2113/LN2114 products. Ceramic capacitors offer many advantages over their tantalum and aluminum electrolytic counterparts. A ceramic capacitor typically has very low ESR, is lowest cost, has a smaller PCB footprint, and is non-polarized. Low ESR ceramic capacitors help maximizes charge pump transient response. Since ceramic capacitors are non-polarized, they are not prone to incorrect connection damage.

Thermal Protection: The LN2113/LN2114 has a thermal protection circuit that will shut down the charge pump and current outputs if the die temperature rises above the thermal limit. However, thermal resistance of the QFN package is so low that if, in the case of the LN2114, all six outputs are shorted to ground at maximum 20mA output level, the die temperature will not rise sufficiently to trip the thermal protection. The thermal protection will only trip if COUT is shorted to ground and the ambient temperature is high.

■ Application Circuits

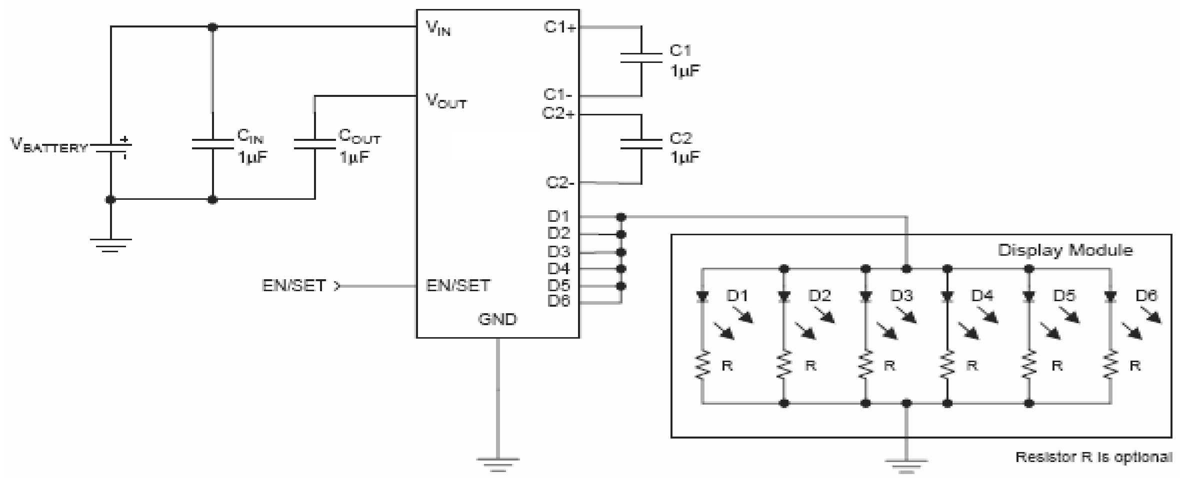
- **Typical LN2113/LN2114 Application Circuit:**



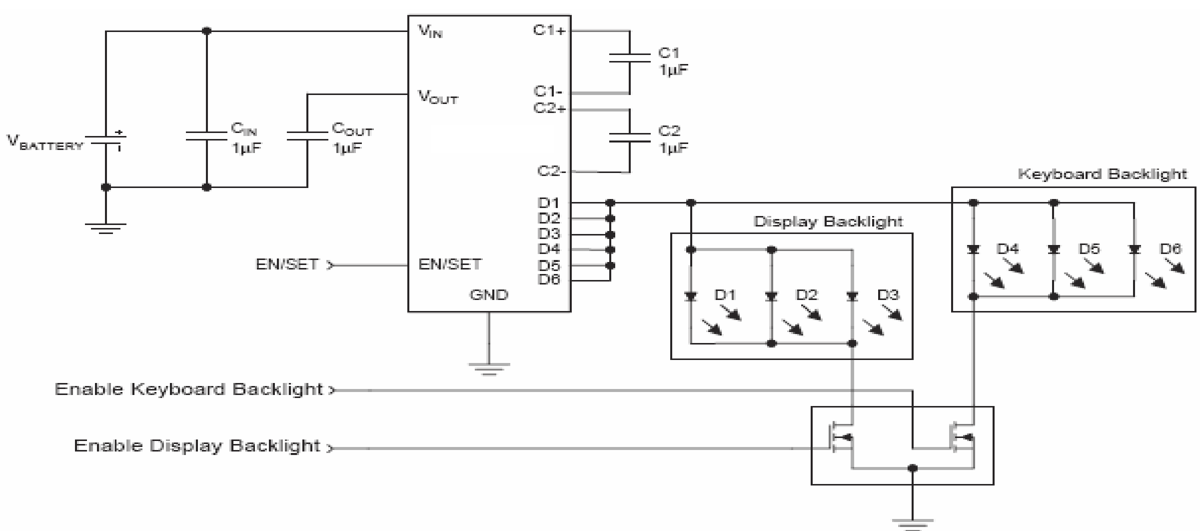


- **Driving white LED display module backlights and individual white LEDs connected in parallel**

The LN2113/LN2114 D1 to D6 outputs are true constant current sources capable of driving up to 20mA each over the operation input voltage range. Since these outputs are true constant current sources, they may be connected in parallel to drive a single power output. Any combination of outputs (D1 to D6) may be connected in parallel. The maximum total output current is a sum of how many current sources are parallel connected. This feature is particularly useful to power pre-manufactured display modules that are pre-wired with white LED backlights connected in a parallel circuit configuration. All outputs can be connected in parallel to drive groups of LEDs as well. The internal current source reference circuit bases feedback from current sensed on the D1 output. For best operation, the only requirement for this application is that the output D1 should always be connected to the load circuit.



LN2114 drive backlight module of the application circuit

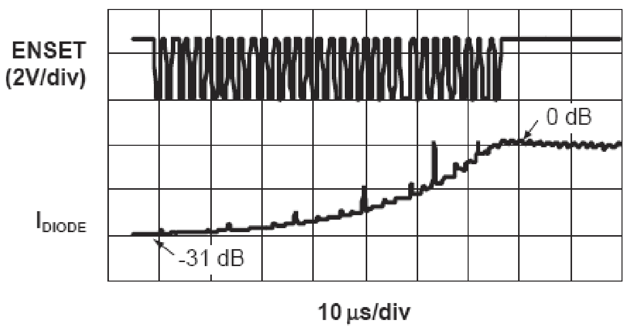


LN2114 drive multiple modules of the application circuit example

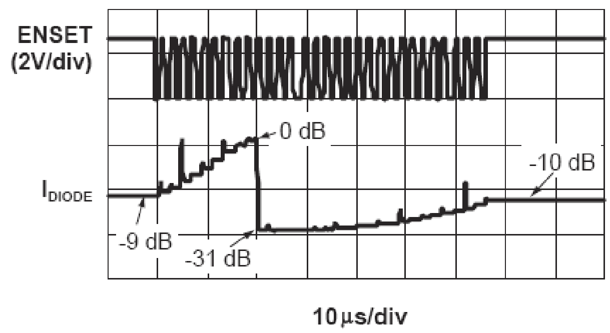
■ Typical Characteristics

V_{IN} = 3.5V, C_{IN} = C_{OUT}= C1 = C2 = 1μF, T_A =25°C, unless otherwise noted.

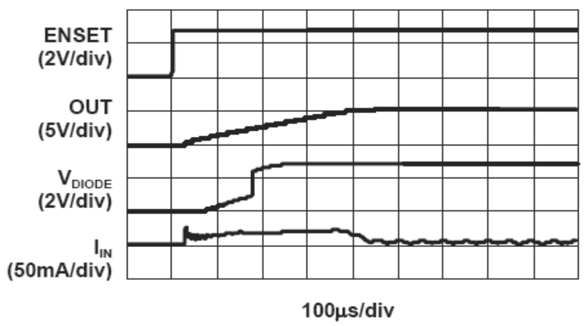
I_{DIODE} Response -31dB to 0dB



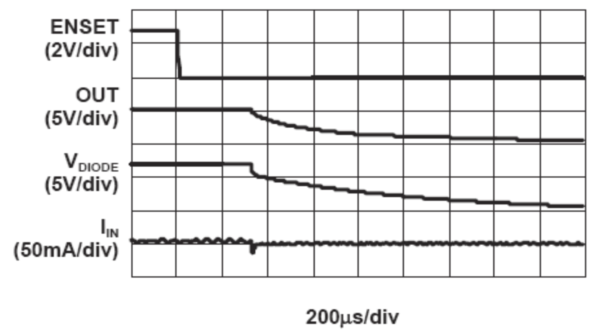
I_{DIODE} Response -9dB to -10dB



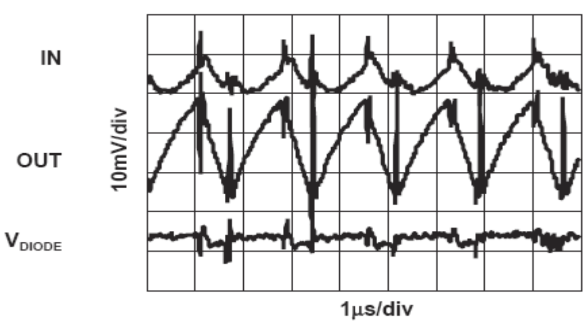
Turn-On



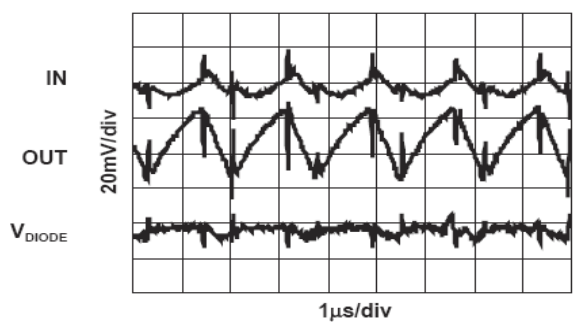
Turn-Off



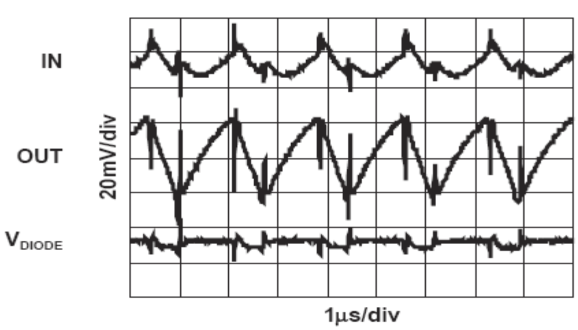
40mA Load Characteristics



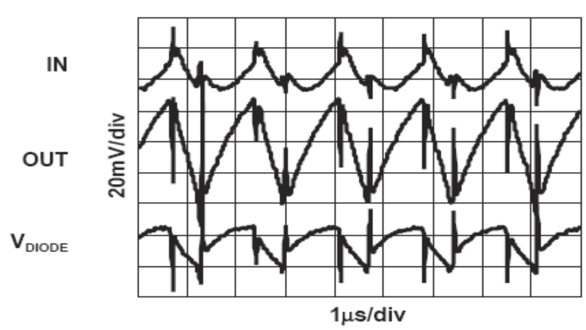
60mA Load Characteristics



80mA Load Characteristics

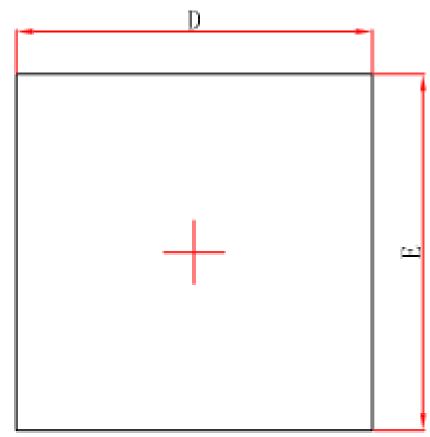


120mA Load Characteristics

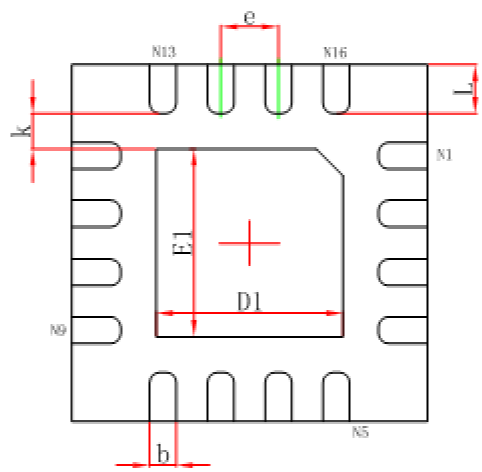


■ Package Information

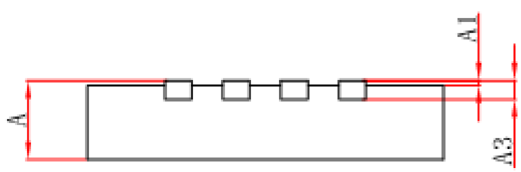
- **QFN4×4-16**



Top View



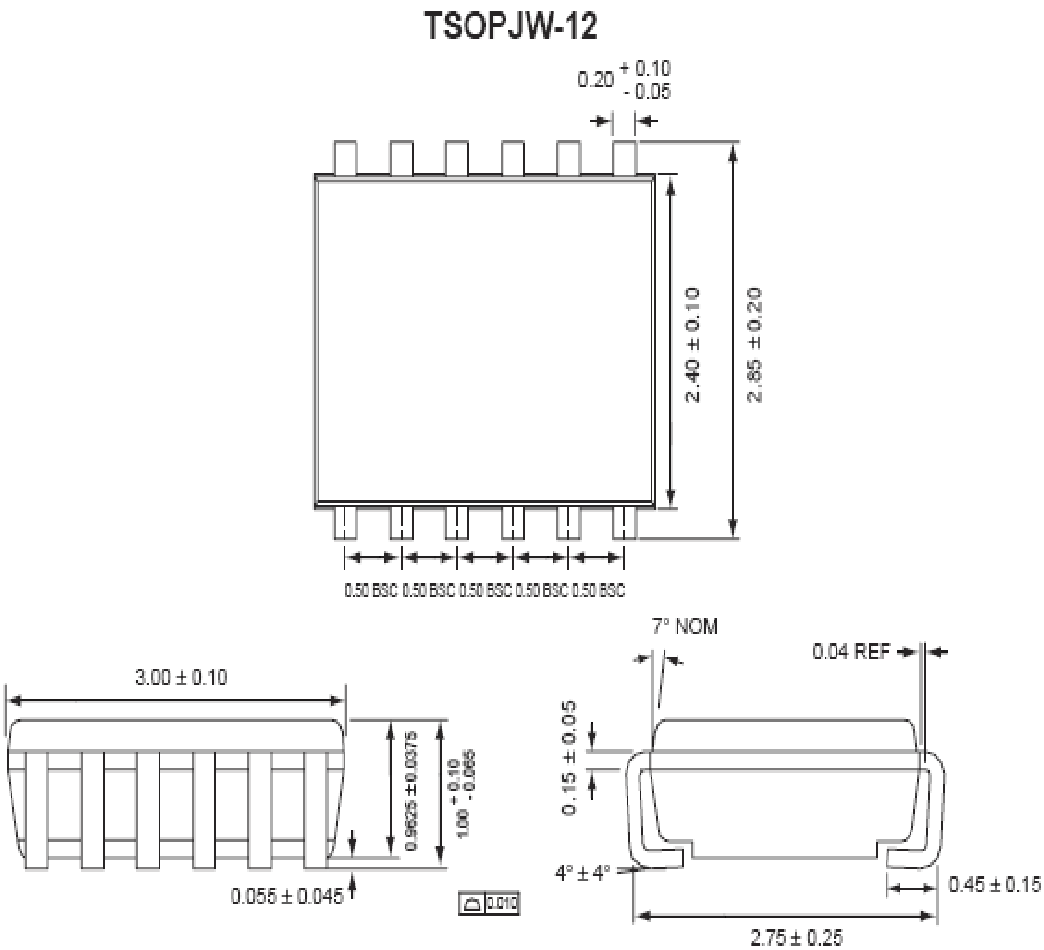
Bottom View



Side View

Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min.	Max.	Min.	Max.
A	0.700/0.800	0.800/0.900	0.028/0.031	0.031/0.035
A1	0.000	0.050	0.000	0.002
A3	0.203REF.		0.008REF.	
D	3.900	4.100	0.154	0.161
E	3.900	4.100	0.154	0.161
D1	2.000	2.200	0.079	0.087
E1	2.000	2.200	0.079	0.087
k	0.200MIN.		0.008MIN.	
b	0.250	0.350	0.010	0.014
e	0.650TYP.		0.026TYP.	
L	0.450	0.650	0.018	0.026

- **TSOPJW-12**



TSOPJW-12
0.20 + 0.10 - 0.05
2.40 ± 0.10
2.85 ± 0.20
0.50 BSC 0.50 BSC 0.50 BSC 0.50 BSC 0.50 BSC
7° NOM
0.04 REF
3.00 ± 0.10
0.9625 ± 0.0375
1.00 + 0.10 - 0.065
0.15 ± 0.05
4° ± 4°
0.45 ± 0.15
0.055 ± 0.045
0.010
2.75 ± 0.25