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April 1st, 2010
Renesas Electronics Corporation

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DATA SHEET

MOS INTEGRATED CIRCUIT
μPD168830

1CH BUCK OR BOOST SELECTABLE CONSTANT CURRENT DRIVER IC WITH EXTERNAL POWER MOSFET

μPD168830 is a single channel constant current driver IC with external power MOSFET. One from “Buck” or “Boost” topology is selectable by the arrangement of external components and MODE pin setting. This IC can drive single or multiple LEDs in series with external power MOSFETs. This IC controls soft-start slope at initial start-up. Also it controls intermittent current by PWM signal.

FEATURE

- Flexible choice of Buck or Boost is available (one from Buck topology or Boost topology) by the arrangement of external power-MOSFET, Shottkey barrier diodes and other external components and MODE pin setting.
- High output current: 1500 mA Max. (set by external current sense resistor)
- Chopping frequency = 1 MHz Max. (set by external resister and capacitor)
- Wide input voltage range (9 to 38 V)
- On/Off and dimming control using PWM
- Thermal Protection function
- Over current protection
- Over voltage protection (Boost mode)
- Under-voltage lock-out function for CVDD
- Stand-by (Enable) terminal
- Efficient software development and various control, combined with All Flush MCU of NEC Electronics Corporation

APPLICATION

- LED Lighting
- Industrial heaters
- Industrial Lighting
- LCD Back-light
- Illuminated signs, etc.

ORDERING INFORMATION

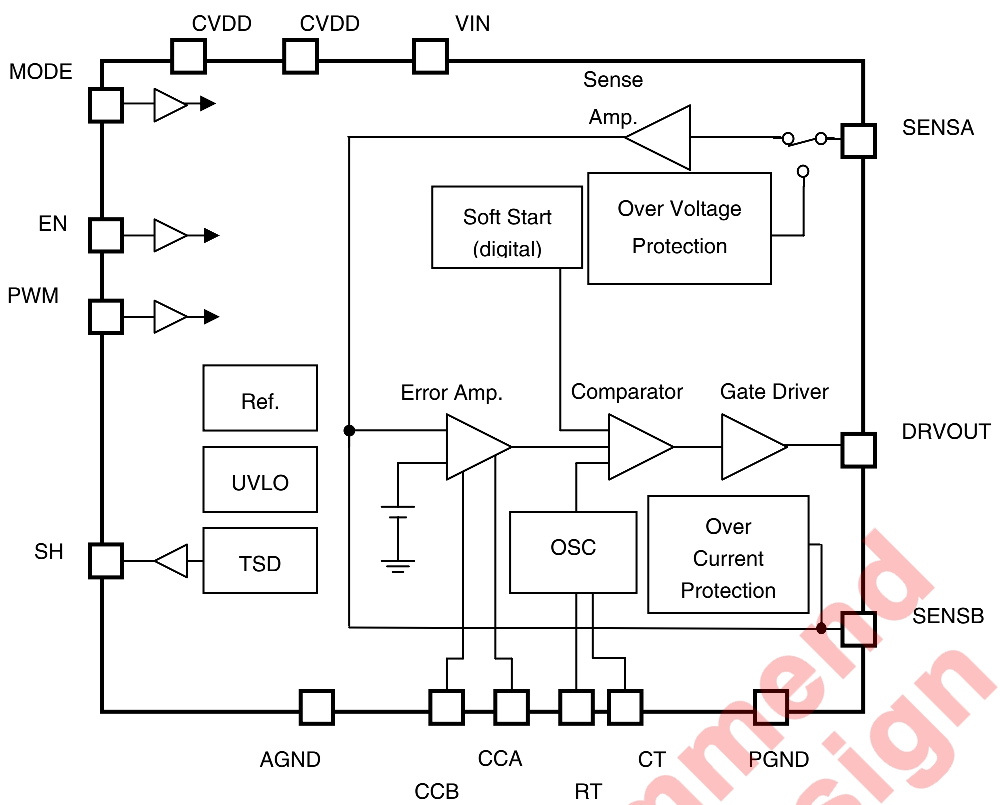
μPD168830MA-6A5-E1-A

QUALITY LEVEL

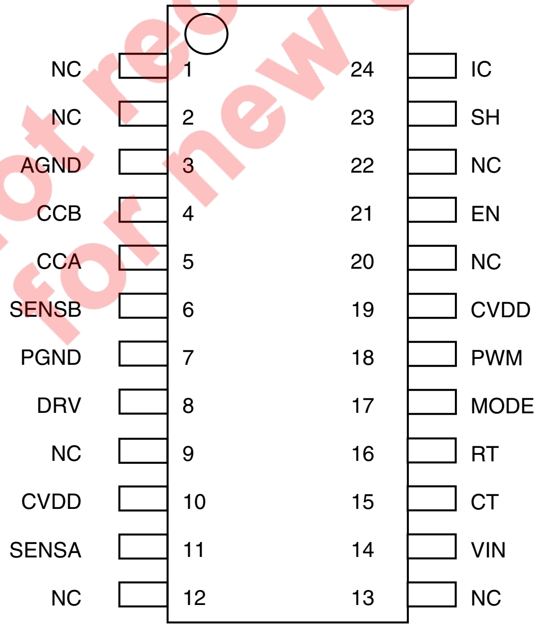
Standard

Document No. S20300EJ1V0DS00 (1st edition)
Date Published March 2010 NS
Printed in Japan

BLOCK DIAGRAM



PIN CONNECTION



PIN LAYOUT

Pad No.	Pad Name	I/O	Pin Identification
1	NC	-	No connection
2	NC	-	No connection
3	AGND	-	Analog ground
4	CCB	-	Capacitor for Phase dissipation
5	CCA	-	Capacitor for Phase dissipation P
6	SENSB	I	Current sense at Boost mode
7	PGND	-	Power ground
8	DRV	O	Gate drive output for Nch MOSFET
9	NC	-	No connection
10	CVDD[Note]	-	Power supply for control and gate-driver section
11	SENSA	I	Current monitor pin at Buck mode/voltage monitor pin for over voltage protection at Boost mode
12	NC	-	No connection
13	NC	-	No connection
14	VIN	-	Power supply for load
15	CT	-	Capacitor for triangular oscillator
16	RT	-	Resistor for triangular oscillator
17	MODE	I	Mode select in put (H: Buck, L: Boost) with pull-down (200 kΩ)
18	PWM	I	PWM pulse input pin for dimming control with pull-down (200 kΩ), High active
19	CVDD[Note]	-	Power supply for control and gate-driver section
20	NC	-	No connection
21	EN	I	Enable signal with pull-down(200 kΩ), High active
22	NC	-	No connection
23	SH	O	Alert output indicating thermal shut down "H" only at TSD
24	IC	I	Internally connected pin (must be opened at nominal operation)

Note The pin No.10 and 19 must be connected directly with wide and short wiring pattern as possible.

DEVICE DESCRIPTION

μ PD168830 is the single channel constant current driver IC with external Power MOSFETs. One of “Buck” or “Boost” topology can be chosen. Power supply voltage of 9 to 38 V is recommended and 5.0 V for control section is needed. Constant load current upto 1.5 A is set by external current sensing resister “Rs” as Rs = 0.115 (V)/ILOAD. Dimming is controlled by the PWM signal input to turn on/off each control circuit. And at the initial start-up, the digital slow-start function controls rush current.

CHOICE OF TOPOLOGY

One from “Buck” or “Boost” topology can be selected by the arrangement of external components and MODE pin setting. MODE pin should be fixed to GND directly to choose 〝Boost〞 topology (see **APPLICATION EXAMPLE (2)**). Or MODE pin should be fixed to CVDD to choose 〝Buck〞 topology (see **APPLICATION EXAMPLE (1)**). Please never connect unsuitable external components against MODE setting.

Mode	Topology
L	Boost
H	Buck

LOAD CURRENT SETTING

Target Current value is set by the value of current sensing resistor “R_s”.
Maximum LOAD current is defined by $R_s \times I_{LOAD} = 0.115$ V
We recommend the tolerance of R_s = +/-1% or less, because it effects to the current tolerance directly.

Example

R_s (Ω)	I_{LOAD} (A)	PRS (W)
0.33	0.35	0.04
0.18	0.64	0.073
0.12	0.96	0.11
0.082	1.4	0.16

CHOICE OF EXTERNAL POWER MOSFET

External power MOSFET can be selected in accordance to the necessary voltage, current and heating.

We recommend high speed MOSFETs for DC/DC converters which can be driven at V_{gs} = 5 V. It helps to improve the total efficiency.

Recommended External Power MOSFET (Unless otherwise specified, T_A = 25°C)

Item	Symbol	Test Condition	MIN.	TYP.	MAX.	Unit
Threshold gate voltage of external MOSFET	V_{gst}		1.5	2.0	2.5	V
Gate voltage at ON state of external MOSFET	V_{gs}		4.0	4.5	5.0	V

Remark External Power MOSFET for Example

I_{LOAD} =< 0.75 A

Nch: μPA2756 (NEC: Dual), 2SK2055 (NEC: Single)

0.75 A < I_{LOAD} = < 1.5 A

Nch: 2SK3377 (NEC: Single), 2SK2414 (NEC: Single)

PROTECTION CIRCUIT

μPD168830 has four kinds of protection circuits. Each Protection works as indicated bellow.

Operation of each protection circuit

Protection Circuit	Protection Operation	Status After Operation	SH Output
Thermal	Halt	Protection kept (Latched operation)	H
Over-voltage	Halt		L
Over-current	Halt		L
Low-voltage (UVLO)	Halt	Automatic recovery	L

Thermal shut-down function is the final protection for safety and it works higher than 150°C.

Once junction temperature exceeds 150°C, reliability of device is not guaranteed any more.

Thermal shutdown starts to function from 400 μs after EN rises.

Over-voltage and over-current protection neglect the pulse shorter than 12 μs TYP. to avoid miss-operation caused by noise.

Maximum Chopping Duty is limited to 80% max. to avoid to reduce over-shoot current.

ELECTRICAL CHARACTERISTICS

Absolute Maximum Rating (Unless otherwise specified, T_A = 25°C)

Item	Symbol	Test Condition	Maximum Rating	Unit
Input voltage	V_{in}		-0.3 to 42	V
Power supply voltage	CV_{DD}		-0.3 to 6	V
Current sense voltage	V_{sensA}	SENSA at Boost	-0.3 to 42	V
		SENSA at Buck	V_{in}-5 to V_{in}	V
Current sense voltage	V_{sensB}	SENSB at Boost	-0.3 to CV_{DD}	V
Drive output voltage	V_{drvout}		-0.3 to CV_{DD}	V
Logic input voltage	V_I	EN, PWM	-0.3 to CV_{DD}	V
Gate Drive peak current	I_{drv_peak}	To drive power- MOSFET, F_{chop} = 1 MHz, pulse width = 10 ns	700	mA
Total Power Dissipation	P_t	TA = 25°C PWB: based on JEDEC, 101.5 × 114.5 mm, t = 1.6 mm, 4 layers, FR-4	0.5	W
Storage Temperature	T_{st}		-55 to 150	°C
Junction Temperature	T_j		150	°C

Recommended Operating Condition (Unless otherwise specified, T_A = 25°C)

Item	Symbol	Test Condition	MIN.	TYP.	MAX.	Unit
Input voltage[Note1]	V_{in}	At Buck-mode (V_{in} > V_{out})	9		38	V
		At Boost-mode (V_{in} < V_{out})	9		28	
Output voltage[Note2]	V_{sensA}	At Boost-mode (V_{in} < V_{out})			37	V
Power supply voltage[Note1]	CV_{DD}		4.5	5.0	5.5	V
Recommended frequency for PWM	F_{pwm}	PWM Duty = 50%			500	Hz
Recommended duty cycle range for PWM pins[Note3]	D_{pwm}	PWM, *see **Notes** bellow.	0		100	°C
Operating Temperature	T_{op}		-40		85	°C
Junction Temperature	T_j		-40		125	°C
PWM wait time	t_{wait}	Wait time after EN rise	100			μs
Gate driver output average current	I_{drv}	C_{load} = 1000 pF		30		mA

Notes 1. Power-on: CVDD have to be started before Vin is supplied. Power-off: Vin have to be dropped before CVDD is stopped.

2. Recommended maximum load number in series: 7 pcs. in case of LED (depends on maximum chopping PWM duty)

3. Duty ratio of load current versus that of "PWM" around 0% and 100% are not linear. The compensation by MCU is recommended.

Electrical Characteristics (Tested at wafer level)

(Test conditions: Buck-mode, V_{IN} = 30 V, CV_{DD} = 5.0 V, Temp = 25°C, no-external Power MOSFET unless otherwise specified)

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Generals						
Operating current consumption	I_{opCVDD}	EN = High, PWM = High, CVDD terminal		2.0	3.0	mA
	I_{opVIN}	MODE = Low, EN = High, PWM = High, Vin terminal			60	
		MODE = High, EN = High, PWM = High, Vin terminal			60	
Standby current consumption	I_{stby1}	EN = Low, Mode = Low (at Boost mode), CVDD terminal			10	μA
	I_{stby2}	EN = Low, Mode = High, CVDD terminal			60	
Gate driver switch section						
Driver 'On' resistance	$R_{on(source)}$	I_{source} = 100 mA		7	12	Ω
	$R_{on(sink)}$	I_{sink} = 100 mA		7	12	
Protection section						
UVLO threshold voltage	V_{luvlo}	Lower threshold	-	3.3	-	V
	V_{hys_uvlo}	Hysteresis width	-	0.3	-	
SH output high voltage	V_{SHH}	I_{out} = 10 mA	0.8 × CV_{DD}		CV_{DD}	V
SH output low voltage	V_{SHL}	I_{out} = -10 mA	0		0.2 × CV_{DD}	V
Over-current protection threshold voltage[Note]	V_{tsensb}	At both mode	0.315	0.35	0.385	V
Over-voltage protection[Note]	V_{ovp}	At Boost mode	38	39.5	41	V
Logic control section						
High input level	V_{IH}	EN	0.7 × CV_{DD}		CV_{DD}	V
Low input level	VIL	with internal	0		0.3 × CV_{DD}	V
Pull down resistance	Rpd	Pull-down (200 kΩ)	100	200	300	kΩ
Reference voltage section						
Reference voltage timing section	V_{ref}	Tested at comparator-output	0.102	0.115	0.128	V
Soft-start time	t_{so}	Internal timing	32		128	μs
Current amp. output (High voltage (Vin) side)						
Output voltage	V_{tcsens}	Mode = High Vin - Vsensa = 0.115 V Measured at V_{SENSB}	0.105	0.115	0.125	V

Note Debounce time at Boost mode is 8 μs Min.

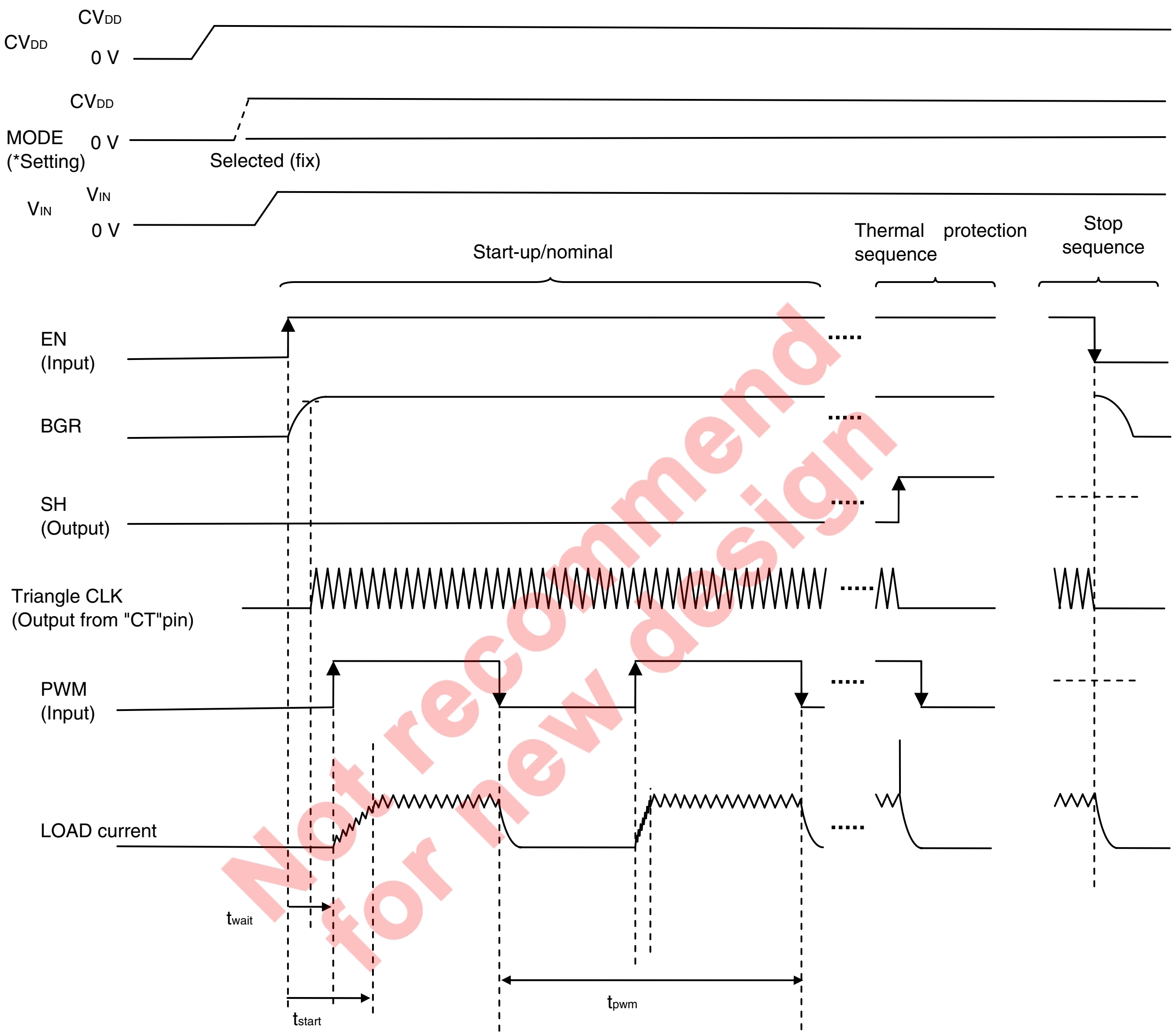
Remark Thermal shutdown should work over 150°C.

Functional Description and Timing Chart

Average LOAD current is controlled by the PWM signal applied to PWM terminal.

Slow start will be added automatically by internal circuit.

Timing chart



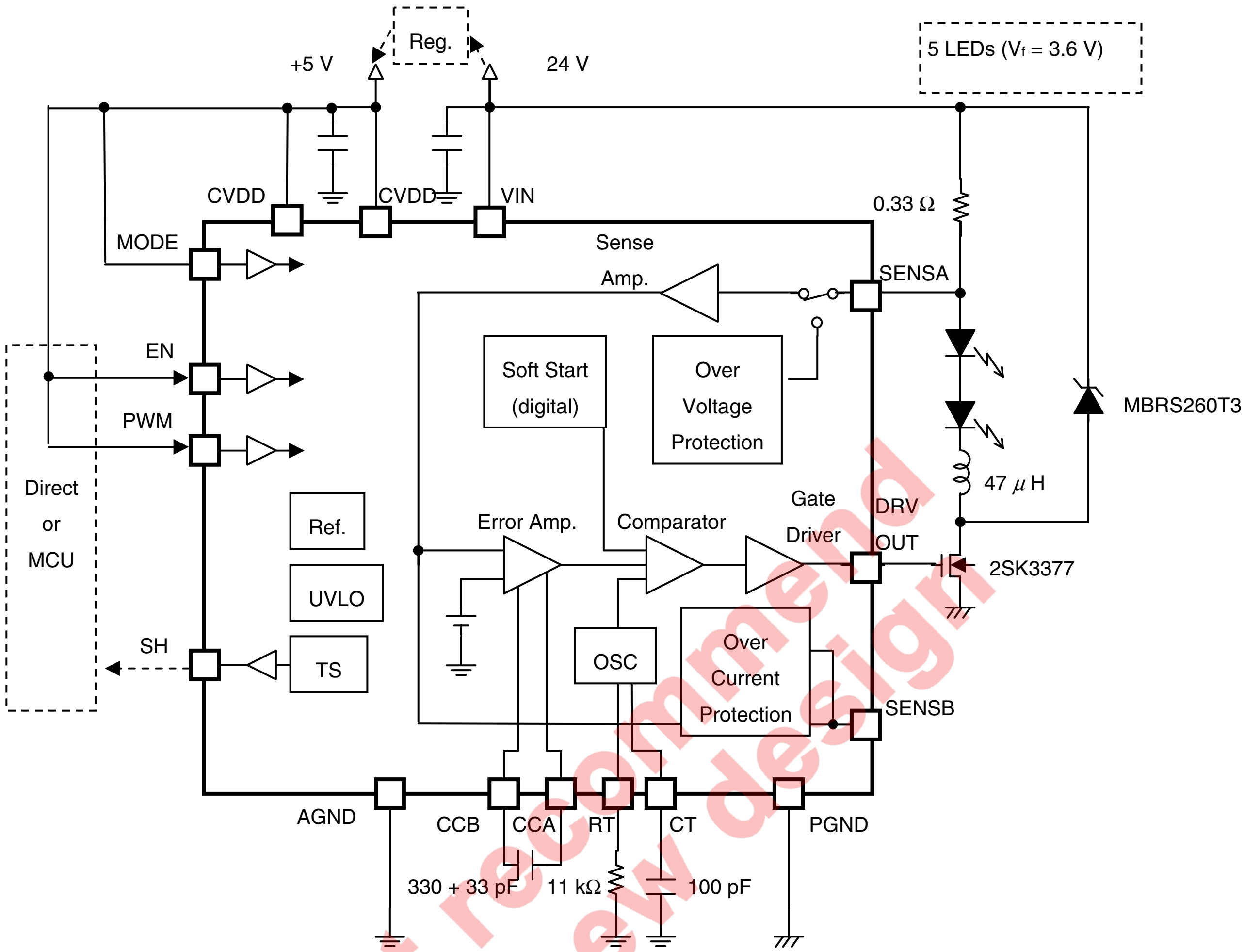
t_{start}: Total start-up time (from EN = Lo → Hi up to LOAD current = 90% of nominal)

t_{pwm}: Cycle time of PWM

Remark CPU must wait for PWM wait time (t_{wait}: 100 μs) before it send PWM signal.

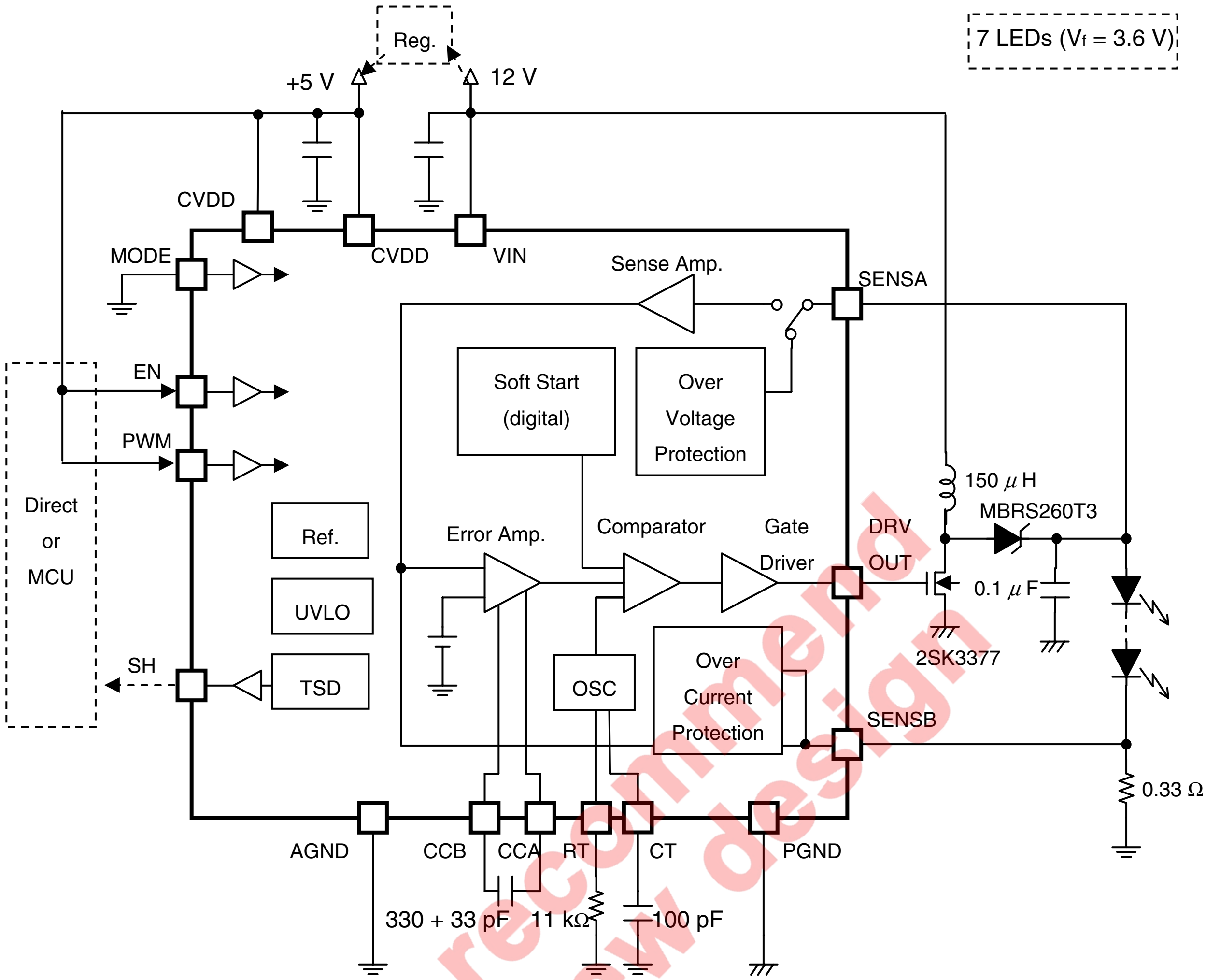
APPLICATION EXAMPLE

(1) Buck mode



Remark The circuit diagram is only for reference and NEC Electronics does not guarantee the actual performance. Please evaluate enough before mass-production.

(2) Boost Mode



Remark The circuit diagram is only for reference and NEC Electronics does not guarantee the actual performance. Please evaluate enough before mass-production.

APPLICATION NOTE

Product Overview

The μ PD168830 is a constant current LED driver IC that uses the switching mode control method and supports choice from the Buck mode or Boost mode. This IC uses the Buck mode if the total forward voltage (V_f) of the LEDs connected in series is lower than the power supply voltage, or the Boost mode if this total is higher than the power supply voltage.

Buck Mode Application

Basic Buck Mode Operation

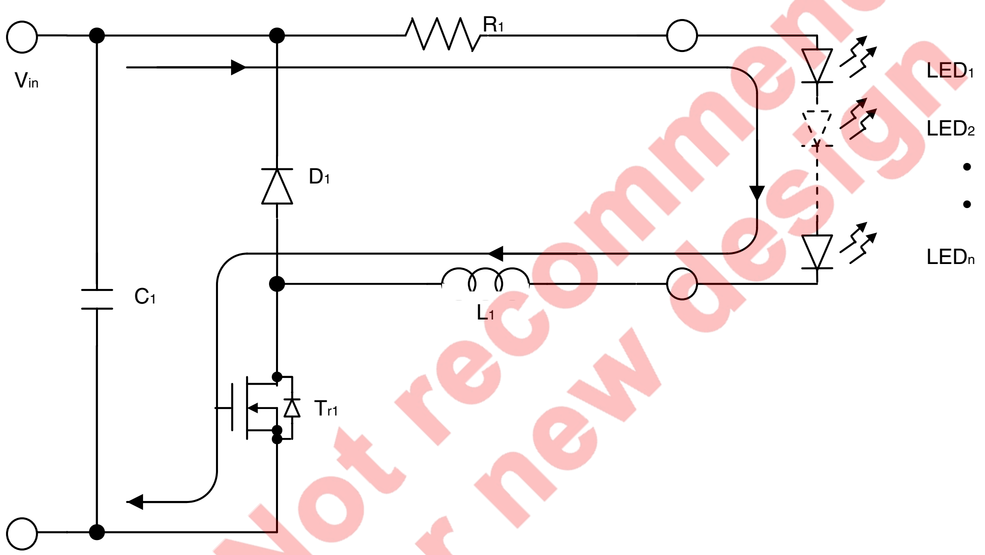
The operation in the Buck mode is shown below.

If T_{r1} is on, the current flows along the route in Figure 1-1. The amount of current flowing to L_1 is shown by equation (1-1).

$$I_L = I_0 + \frac{V_{in} - 0.115 - N \bullet V_f - R_{on} \bullet I_L}{L} \bullet t_{on} \quad \ldots(1\text{-}1)$$

(t_{on} : ON interval time of T_{r1})

Figure 1-1. Current Flow Route When T_{r1} is On

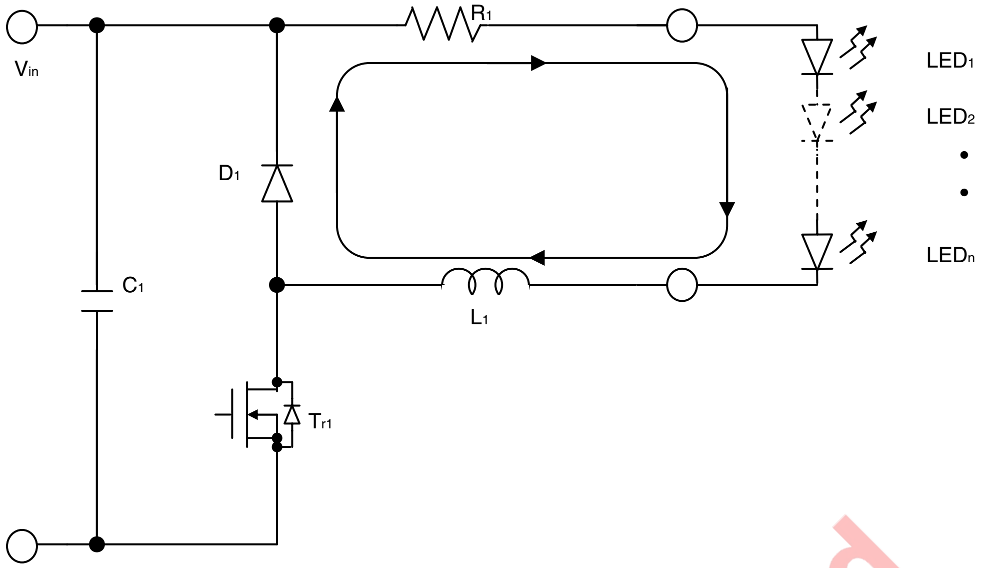


If T_{r1} is off, the back electromotive force generated at L_1 causes D_1 to conduct, and the current flows along the route in Figure 1-2. At this time, the amount of current flowing to L_1 is shown by equation (1-2).

$$I_L = I_p - \frac{0.115 + N \bullet V_f + V_d}{L} \bullet t_{off} \quad \ldots(1\text{-}2)$$

(t_{off} : OFF interval time of T_{r1})

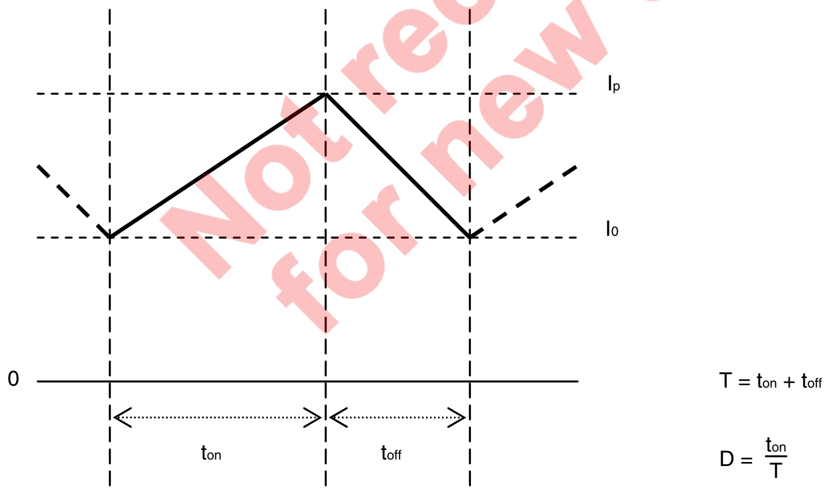
Figure 1-2. Current Flow Route When T_{r1} is Off



Current flows to L_1 as shown in Figure 1-3, and, in the steady state, because the current changes during the on and off periods are balanced, assuming D to represent the T_{r1} on-duty value results in equation (1-3).

$$\frac{1-D}{D} = \frac{V_{in} - 0.115 - N \bullet V_f - R_{on} \bullet I_L}{0.115 + N \bullet V_f + V_d} \quad \ldots(1\text{-}3)$$

Figure 1-3. Current Flows to L_1



For the Buck mode, the current flowing to the LED is kept constant by controlling the T_{r1} on-duty value so as to maintain the relationship described above.

Buck mode design procedure

Determine the IC operating frequency (switching frequency).

Calculate the operating duty based on the input and output voltages (due to the number of LEDs).

Because the T_{r1} and D_1 values have not been selected, calculate the operating duty by using equation (1-4), which is the result of simplifying (1-3) based on the assumption that the current detection voltage (0.115), R_{on}, and V_d values are insignificant compared to the input voltage Vin and output voltage $N \bullet V_f$.

$$\frac{1 - D}{D} = \frac{V_{in} - N \bullet V_f}{N \bullet V_f}$$

$$D = \frac{N \bullet V_f}{V_{in}} \quad \ldots(1\text{-}4)$$

Determine the L value based on the LED current.

For the Buck mode, because the current flowing to L is the LED current, calculate the current change ΔI according to the permissible ripple current specification, and determine the L value.

$$L = \frac{(V_{in} - N \bullet V_f) \bullet D \bullet T}{\Delta I} \quad \ldots(1\text{-}5)$$

The current ripple is inversely proportional to L, but so is the response speed, so it is preferable to select an L value such that the ΔI value does not fall below 5% of the LED current.

Input capacitor determination

Calculate the current flowing to the input capacitor based on the on period and LED current.

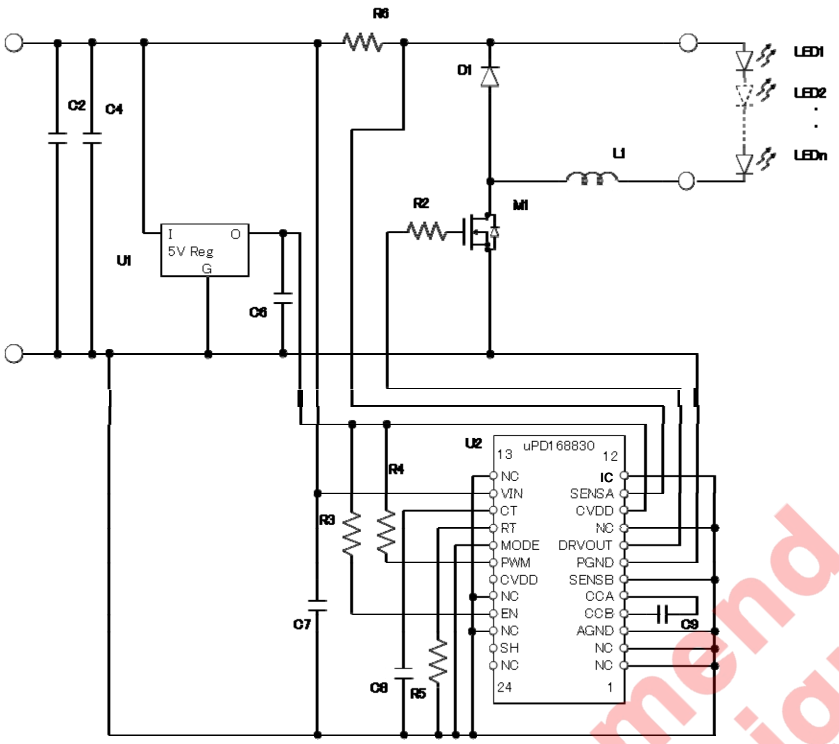
Because the current flowing to the input capacitor depends on the output impedance of the used DC power supply, there is no perfect way to calculate it. One way to estimate the current is to assume that all the switching current is supplied by the input capacitor, and therefore take the alternating component of the current during the t_{on} period in Figure 1-3 to be the current flowing to the capacitor. Under this condition, ΔQ, the amount of electricity charged or discharged by the capacitor, can be used to determine the capacitance C such that the input voltage fluctuation ΔV is sufficiently small (5% of the input voltage or less).

$$\Delta Q = (1 - D) \bullet \frac{I_p + I_0}{2} \bullet t_{on}$$

$$C = (1 - D) \bullet \frac{I_p + I_0}{2 \Delta V} \bullet t_{on} \quad \ldots(1\text{-}6)$$

When selecting the capacitor, pay attention so that the power consumption caused by the permissible ripple current does not exceed the specifications as well as to the capacitance.

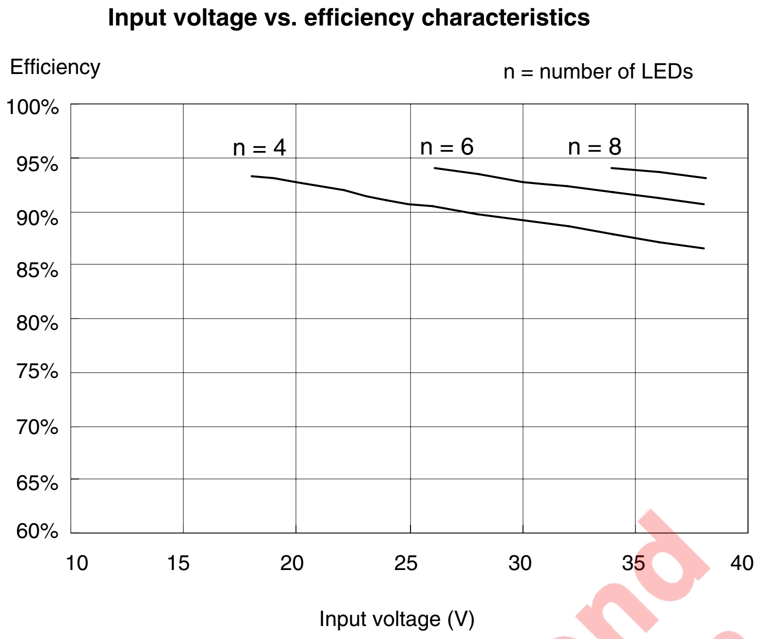
Buck mode application example

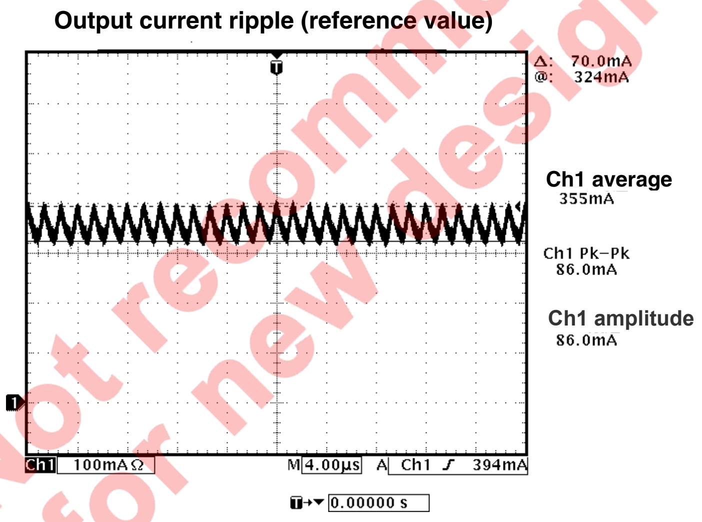


Part List

Part Number	Ratings	Maker Name	Part Number	Ratings	Maker Name
C2	47 μF, 50 V		U1	μPD168830	NEC Electronics
C4	0.1 μF, 50 V		U2	μPC7805AHF	NEC Electronics
C6	0.47 μF, 50 V				
C7	0.1 μF, 50 V		R2	22 Ω	
C8	100 pF, 50 V		R3	10 kΩ	
			R4	10 kΩ	
L1	22 μH		R5	15 kΩ	
			R6	0.33 Ω	
M1	2SK3377	NEC Electronics			

Input voltage vs. efficiency characteristics (reference value)





Boost mode application

Basic Boost mode operation

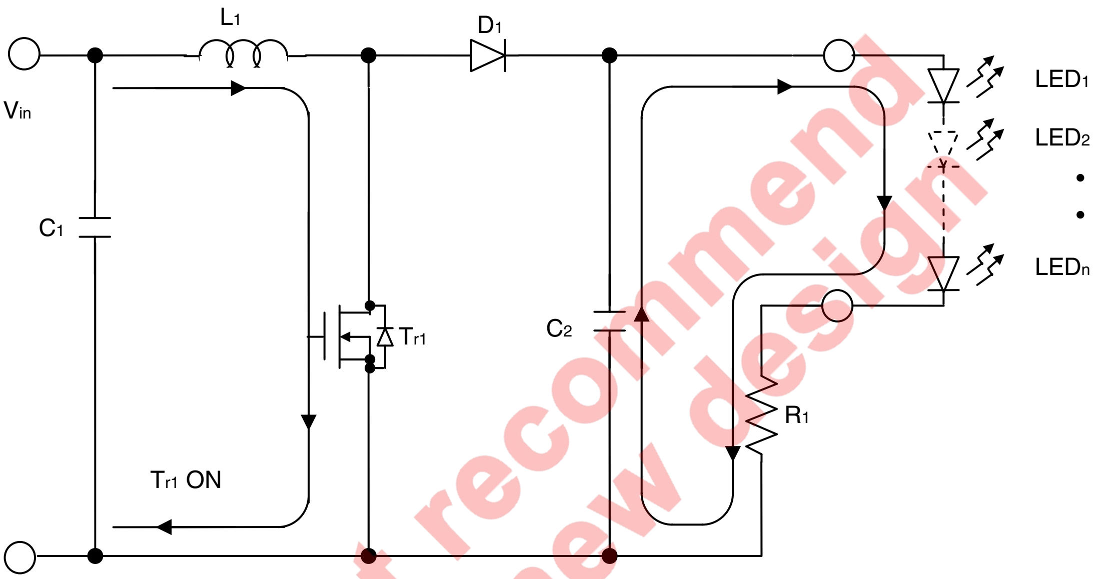
The basic operation of the Boost mode is the same as that of a general Boost-type DC-DC converter, and the current is controlled by adjusting the applied voltage in accordance with the LED V_f-I_f characteristic.

When T_{r1} is on, the current flows as shown in Figure 2-1, and L_1 accumulates energy. If I_0 is assumed to be the initial current, I_L, the current flowing to L_1 at this time is shown by equation (2-1).

$$I_L = I_0 + \frac{V_{in} - R_{on} \bullet I_L}{L} \bullet t_{on} \quad \ldots(2\text{-}1) \qquad (t_{on}: \text{ON interval time of } T_{r1})$$

Because no power is supplied by the input during the period when T_{r1} is on, the output voltage is maintained by the output smoothing capacitor, and the LED current is continuously supplied.

Figure 2-1. Current Flow Route When T_{r1} is On



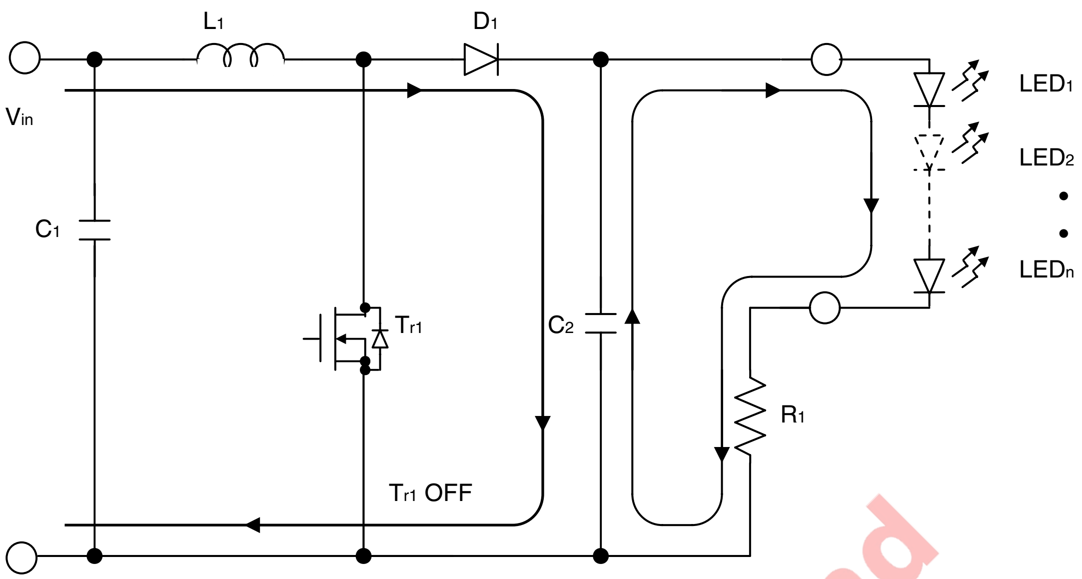
Next, by turning T_{r1} off, a high output voltage is obtained by adding the back electromotive force generated at L_1 to the input voltage, as shown in Figure 2-2. V_o, the output voltage at this time, is expressed by equation (2-2).

$$V_o = N \bullet V_f + 0.115 \ldots(2\text{-}2)$$

Because the voltage generated at L_1 is equivalent to (V_o - V_{in} - V_d), the current flowing to L_1 can be calculated using equation (2-3).

$$I_L = I_p - \frac{N \bullet V_f + 0.115 - V_{in} - V_d}{L} \bullet t_{off} \quad \ldots(2\text{-}3) \qquad (t_{off}: \text{OFF interval time of } T_{r1})$$

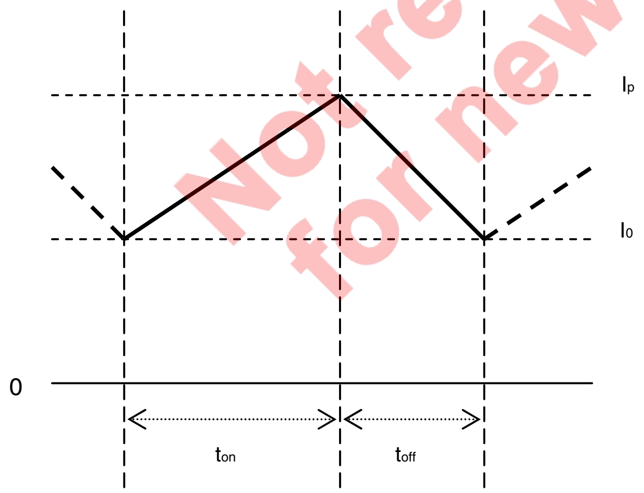
Figure 2-2. Current Flow Route When T_{r1} is Off



Current flows to L_1 as shown in Figure 2-3, and, in the steady state, because the current changes during the on and off periods are balanced, assuming D to represent the T_{r1} on-duty value results in equation (2-4).

$$\frac{1 - D}{D} = \frac{V_{in} - R_{on} \bullet I_L}{N \bullet V_f + 0.115 - V_{in} - V_d} \quad \ldots(2\text{-}4)$$

Figure 2-3. Current That Flows to L_1



$T = t_{on} + t_{off}$

$D = \frac{t_{on}}{T}$

When L_1 decreases, the average voltage is kept at a constant level, the current slope increases, and I_p and I_0 change. The state in which I_0 is at 0 is called the *critical state*, and I_0 is a positive value during normal use. Because the current flowing to L is uninterrupted (continuous) in this state, this state is called the *continuous mode*. If the L_1 inductance decreases more, the current flowing to L_1 is interrupted, and this state is called the *discontinuous* mode. In the discontinuous mode, the relationship between the duty and I/O voltage described above holds during the period when current is conducted, and the operation does not depend on the T_{r1} on and off periods. Therefore, care is required because the output voltage is no longer restricted by the maximum on-duty value.

Boost mode design procedure

Calculate the operating duty based on the input and output voltages (the number of LEDs).

Because the T_{r1} and D_1 values have not been selected, calculate the operating duty by using equation (2-5), which is the result of simplifying (2-4) based on the assumption that the current detection voltage (0.115), R_{on}, and V_d values are insignificant compared to the input voltage Vin and output voltage N•Vf.

$$\frac{1 - D}{D} = \frac{V_{in}}{N \bullet V_f}$$

$$D = \frac{N \bullet V_f}{V_{in} + N \bullet V_f} \quad \text{...(2-5)}$$

Calculate I_{in} based on the output power, efficiency η, and input voltage. This is the average current flowing to L_1.
(Here, the efficiency η is set in the range of 0.75 to 0.95 which are the general efficiency values.)

$$I_{in} = \frac{N \bullet V_f \bullet I_{out}}{V_{in} \bullet \eta} \quad \text{...(2-6)}$$

To determine the L_1 value, determine the current change ΔI. In the Boost mode, the current flowing to L_1 and the current flowing to the LED are separate, so ΔI can be specified relatively freely, but, when operating in the continuous mode, ΔI must be less than (Iin × 2).

Output smoothing capacitor determination

Because the output voltage ripple appears as LED current ripple, determine the output voltage ripple ΔV_o by referring to the LED V_f-I_f characteristic.

Calculate the minimum necessary capacitance based on the output voltage ripple and current flowing to the capacitor.

The output smoothing capacitor is only charged up during the period when T_{r1} is off, and the output current (LED current) is constant during all periods, so the alternating component of the current during the t_{off} period in Figure 2-3 is the current flowing to the capacitor.

Equation (2-7) is used to calculate the necessary capacitance based on the electric charge change ΔQ and the potential change by the ESR of the capacitor.

$$\Delta Q = \frac{I_p + I_0}{2} \bullet t_{off}$$

$$C_o = \frac{I_p + I_0}{2} \bullet \frac{(1 - D) \bullet T}{\Delta V_o - ESR \bullet I_p} \quad \text{...(2-7)}$$

If using layered ceramic for the output capacitor, the ESR can mostly be ignored, but, because the capacitance of such a capacitor is decreased by the applied voltage, specify a capacitance two to three times greater than the usual required capacitance. In addition, if using a capacitor that has a large ESR, such as an aluminum electrolytic capacitor, the ESR•Ip value has more control than ΔQ. So, pay attention so that the power consumption caused by the permissible ripple current does not exceed the specifications.

Input capacitor determination

Because the current flowing to the input capacitor depends on the output impedance of the used DC power supply, there is no perfect way to calculate it. One way to estimate the current is to assume that all the switching current is supplied by the input capacitor, and therefore take the alternating component of the current of L_1 in Figure 2-3 to be the current flowing to the capacitor. Under this condition, ΔQ, the amount of electricity charged or discharged by the capacitor, can be used to determine the capacitance Ci such that the input voltage fluctuation ΔVi is sufficiently small (5% of the input voltage or less).

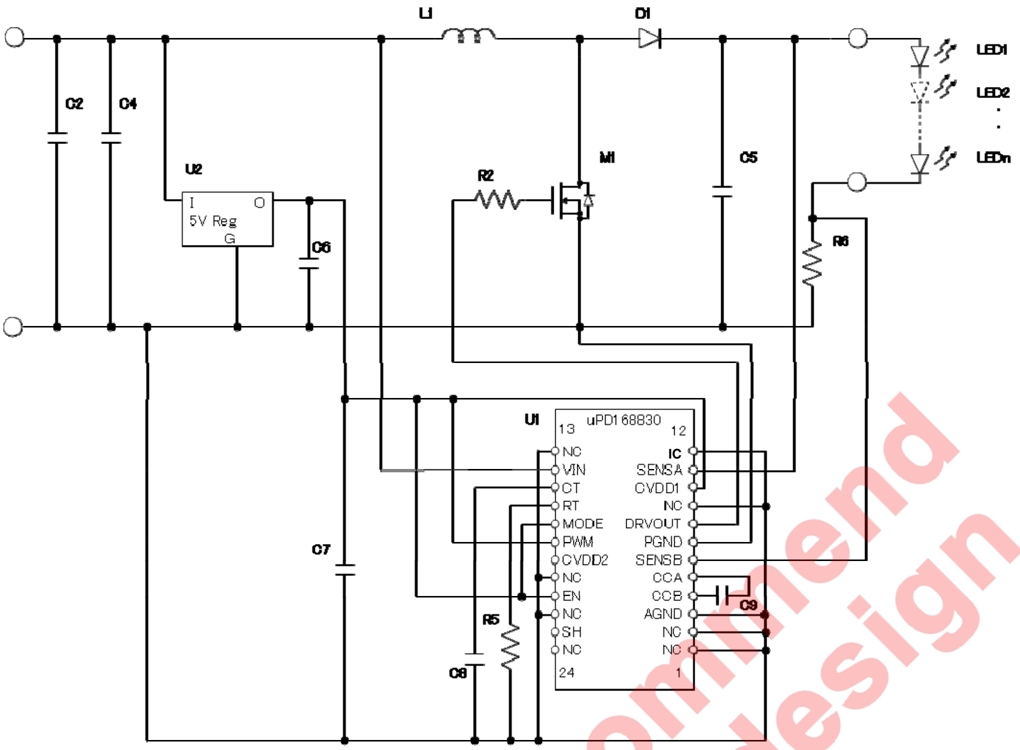
$$\Delta Q = \frac{I_p - I_0}{2} \bullet T$$

$$C_i = \frac{I_p - I_0}{2 \Delta V_i} \bullet T \quad \text{...(2-8)}$$

Boost mode application example

Application circuit specifications

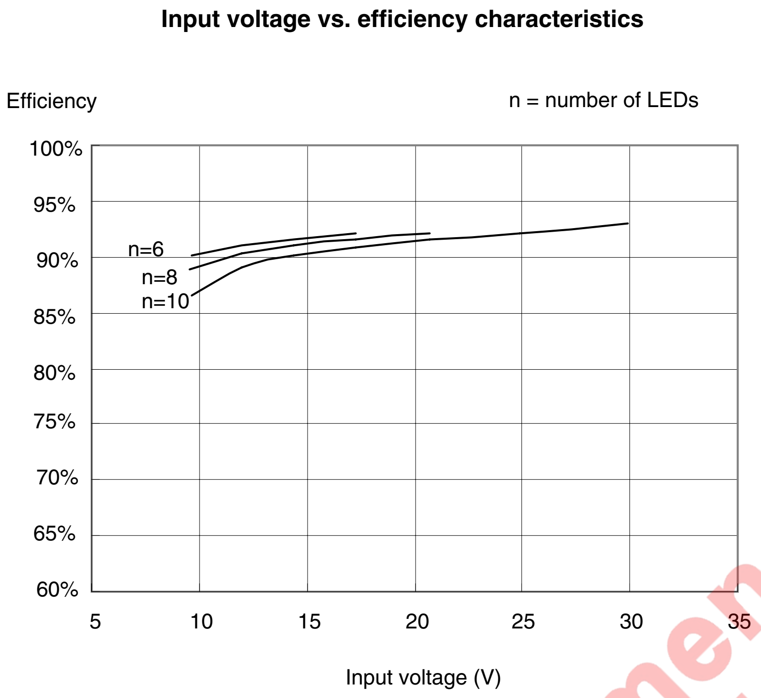
Input voltage: 9 to 32 V, output current: 350 mA, number of LEDs that can be connected: 5 to 10 pcs.

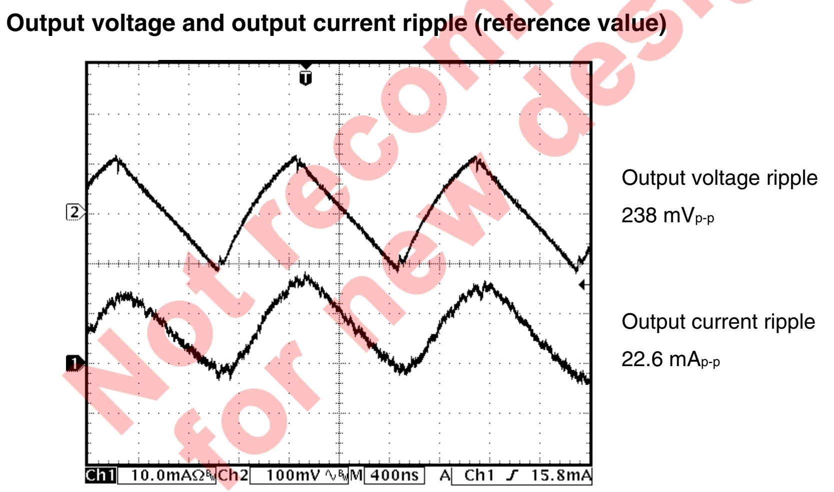


Part List

Part Number	Ratings	Maker Name	Part Number	Ratings	Maker Name
C2	1.0 μF, 50 V		M1	2SK3377	NEC Electronics
C4	0.1 μF, 50 V				
C5	2.2 μF, 50 V		U1	μPD168830	NEC Electronics
C6	0.47 μF, 50 V		U2	μPC7805AHF	NEC Electronics
C7	0.1 μF, 50 V				
C8	100 pF, 50 V		R2	22 Ω	
			R5	15 kΩ	
L1	22 μH		R6	0.33 Ω	

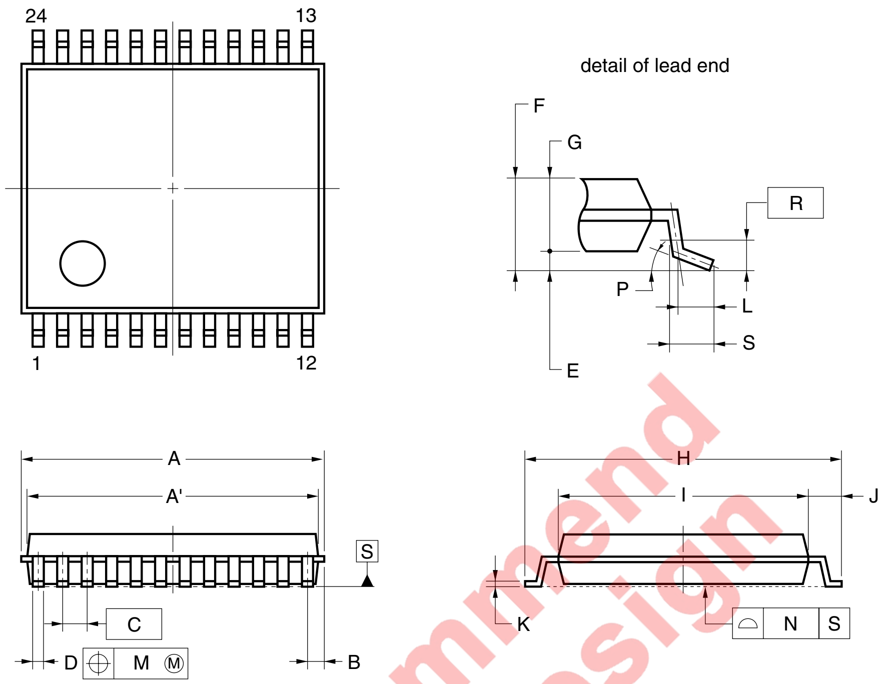
Input voltage vs. efficiency characteristics (reference value)





OUTLINE DRAWING

24-PIN PLASTIC TSSOP (5.72 mm (225))



NOTE

Each lead centerline is located within 0.10 mm of its true position (T.P.) at maximum material condition.

ITEM	MILLIMETERS
A	6.65±0.10
A'	6.5±0.1
B	0.575
C	0.5 (T.P.)
D	0.22±0.05
E	0.1±0.05
F	1.2 MAX.
G	1.0±0.05
H	6.4±0.1
I	4.4±0.1
J	1.0±0.1
K	0.17±0.025
L	0.5
M	0.10
N	0.08
P	$3^{\circ}{}^{+5^{\circ}}_{-3^{\circ}}$
R	0.25
S	0.6±0.15

P24MA-50-6A5

RECOMMENDED SOLDERING CONDITIONS

The μPD168830 should be soldered and mounted under the following recommended conditions.
For soldering methods and conditions other than those recommended below, contact an NEC Electronics sales representative.
For more technical information, see the following website.

Semiconductor Device Mount Manual (**http://www.necel.com/pkg/en/mount/index.html**)

Type of Surface Mount Device

μPD168830MA-6A5[Note]

Soldering Method	Soldering Conditions	Symbol
Infrared reflow	Package peak temperature: 260°C Time: 10 seconds MAX. at maximum temperature, 60 seconds MAX. at 220°C or higher Preheating time at 160 to 180 °C: 60 to 120 s Count: Three times, Number of days: non Flux: Rosin-based flux with low chlorine (0.2 Wt% or below) is recommended.	IR60-00-3

Note Pb-free (This product does not contain Pb in external electrode and other parts).

Caution Do not use different soldering methods together.

NOTES FOR CMOS DEVICES

(1) VOLTAGE APPLICATION WAVEFORM AT INPUT PIN: Waveform distortion due to input noise or a reflected wave may cause malfunction. If the input of the CMOS device stays in the area between VIL (MAX) and VIH (MIN) due to noise, etc., the device may malfunction. Take care to prevent chattering noise from entering the device when the input level is fixed, and also in the transition period when the input level passes through the area between VIL (MAX) and VIH (MIN).

(2) HANDLING OF UNUSED INPUT PINS: Unconnected CMOS device inputs can be cause of malfunction. If an input pin is unconnected, it is possible that an internal input level may be generated due to noise, etc., causing malfunction. CMOS devices behave differently than Bipolar or NMOS devices. Input levels of CMOS devices must be fixed high or low by using pull-up or pull-down circuitry. Each unused pin should be connected to VDD or GND via a resistor if there is a possibility that it will be an output pin. All handling related to unused pins must be judged separately for each device and according to related specifications governing the device.

(3) PRECAUTION AGAINST ESD: A strong electric field, when exposed to a MOS device, can cause destruction of the gate oxide and ultimately degrade the device operation. Steps must be taken to stop generation of static electricity as much as possible, and quickly dissipate it when it has occurred. Environmental control must be adequate. When it is dry, a humidifier should be used. It is recommended to avoid using insulators that easily build up static electricity. Semiconductor devices must be stored and transported in an anti-static container, static shielding bag or conductive material. All test and measurement tools including work benches and floors should be grounded. The operator should be grounded using a wrist strap. Semiconductor devices must not be touched with bare hands. Similar precautions need to be taken for PW boards with mounted semiconductor devices.

(4) STATUS BEFORE INITIALIZATION: Power-on does not necessarily define the initial status of a MOS device. Immediately after the power source is turned ON, devices with reset functions have not yet been initialized. Hence, power-on does not guarantee output pin levels, I/O settings or contents of registers. A device is not initialized until the reset signal is received. A reset operation must be executed immediately after power-on for devices with reset functions.

(5) POWER ON/OFF SEQUENCE: In the case of a device that uses different power supplies for the internal operation and external interface, as a rule, switch on the external power supply after switching on the internal power supply. When switching the power supply off, as a rule, switch off the external power supply and then the internal power supply. Use of the reverse power on/off sequences may result in the application of an overvoltage to the internal elements of the device, causing malfunction and degradation of internal elements due to the passage of an abnormal current. The correct power on/off sequence must be judged separately for each device and according to related specifications governing the device.

(6) INPUT OF SIGNAL DURING POWER OFF STATE : Do not input signals or an I/O pull-up power supply while the device is not powered. The current injection that results from input of such a signal or I/O pull-up power supply may cause malfunction and the abnormal current that passes in the device at this time may cause degradation of internal elements. Input of signals during the power off state must be judged separately for each device and according to related specifications governing the device.

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