MAP3204

4-channel LED Driver for High Brightness LEDs

MAP3204 – 4-Channel LED Driver for High Brightness LEDs

General Description

The MAP3204 is a 4-channel LED driver optimized for LED backlight application targeting mid and large size LCD module. It uses the boost MOSFET externally and 4-channel current sources internally for driving high brightness white LEDs

Input voltage of the MAP3204 is ranged from 8V ~ 36V and max. LED current is 150mA per channel. It can increase the output voltage depending on the drain voltage rating of boost MOSFET.

It features PWM dimming control and internal soft-start and has protections like output over-voltage, Boost over-current, LED short/open, SBD open and UVLO.

The MAP3204 is available in 16 leads E-TSSOP and 20 leads SOIC package with Halogen-free (fully RoHS compliant).

Features

- 8V to 36V Input Voltage Range
- Drive up to 4 Channels
- 150mA Output Current per Channel
- Programmable Boost Switching Frequency : 100kHz to 500kHz
- PWM Dimming : up to 22kHz
- Current Mode Control
- Boost Over Current Protection
- Output Over Voltage Protection
- LED Short/Open Protection
- SBD Open / Output Short Protection
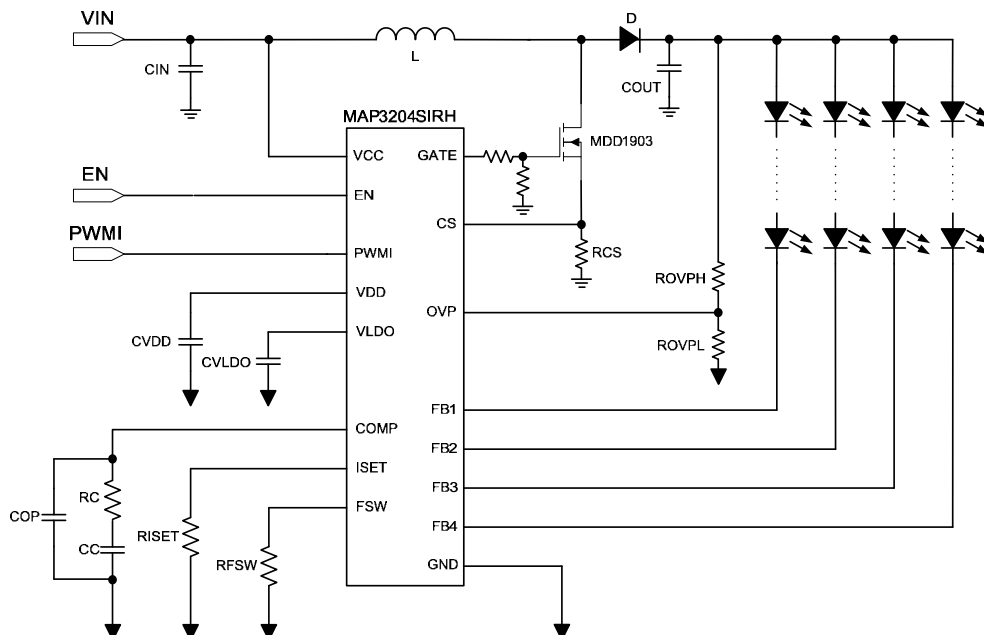- UVLO
- 16 leads E-TSSOP and 20 leads SOIC

Applications

- High Brightness white LED backlighting for mid and large size LCD module
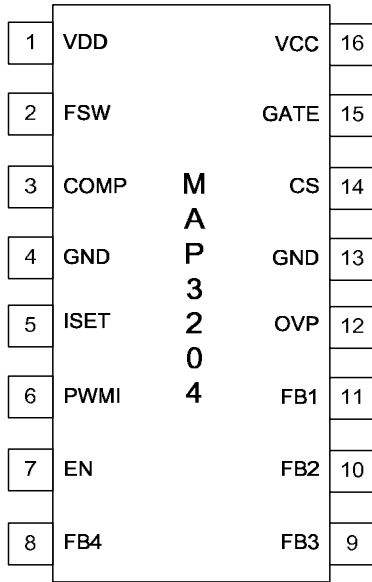- General LED lighting applications

Ordering Information

Part Number	Top Marking	Ambient Temperature Range	Package	RoHS Status
MAP3204SIRH	MAP3204	-40℃ to +85℃	20 leads SOIC	Halogen Free
MAP3204TERH	MAP3204	-40℃ to +85℃	16 leads TSSOP with E-Pad	Halogen Free

Typical Application

MAP3204 – 4-Channel LED Driver for High Brightness LEDs

Pin Configuration

1	VDD		VCC	16
2	FSW		GATE	15
3	COMP	M A P 3 2 0 4	CS	14
4	GND		GND	13
5	ISET		OVP	12
6	PWMI		FB1	11
7	EN		FB2	10
8	FB4		FB3	9

16 leads E-TSSOP

1	VCC		GATE	20
2	VDD		CS	19
3	FSW		NC	18
4	COMP	M A P 3 2 0 4	GND	17
5	GND		VLDO	16
6	ISET		OVP	15
7	PWMI		NC	14
8	EN		NC	13
9	FB4		FB1	12
10	FB3		FB2	11
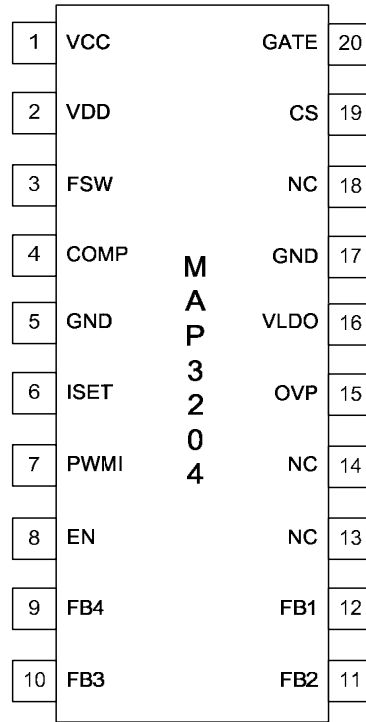
20 leads SOIC

Functional Block Diagram

MAP3204 – 4-Channel LED Driver for High Brightness LEDs
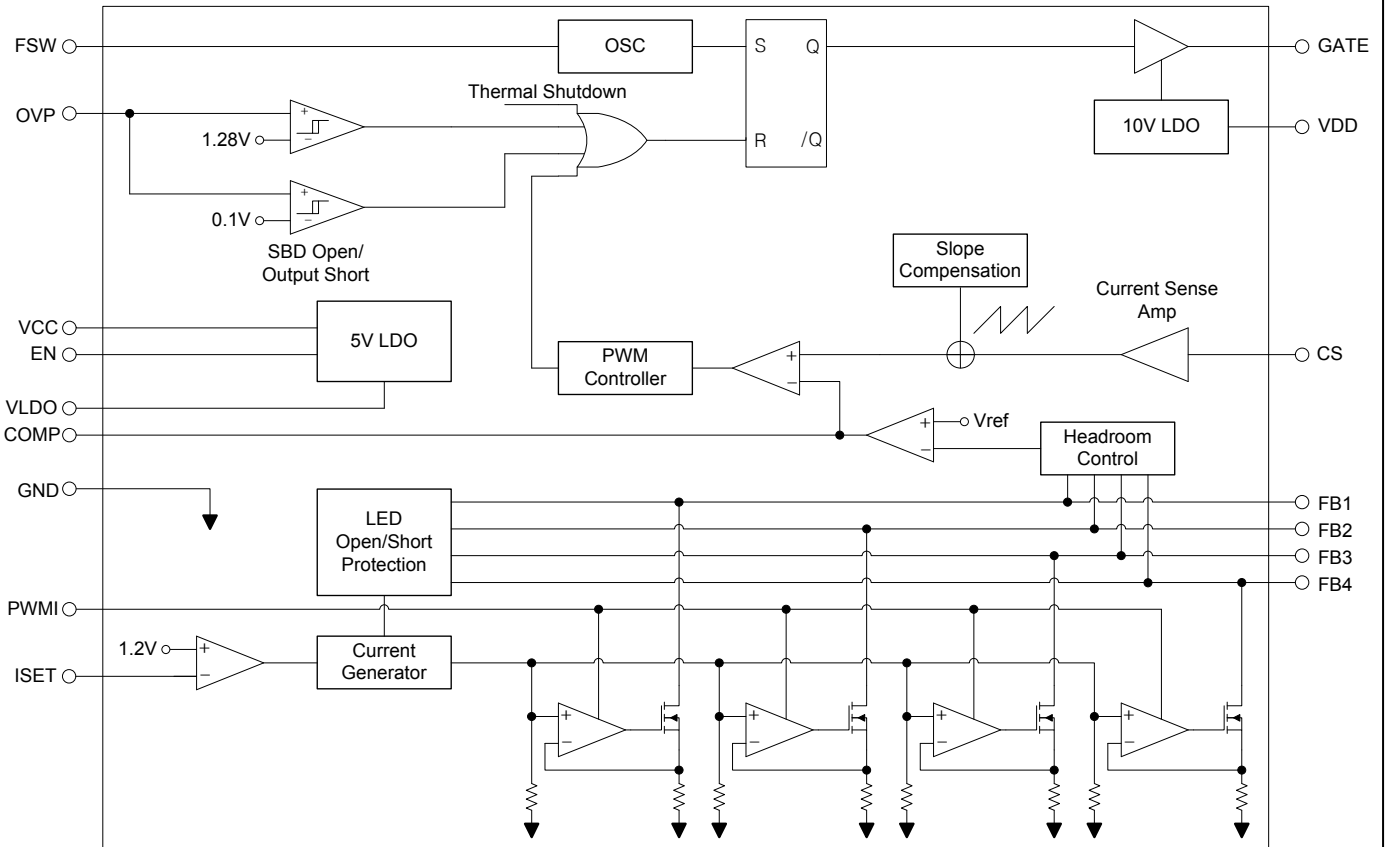
Pin Description

Name	16leads E-TSSOP	20leads SOIC	Description
VCC	**16**	**1**	Power supply input. Need external input capacitor.
GND	**4, 13**	**5, 17**	Ground
VDD	**1**	**2**	Internal 10V Regulator Output. Connect to 2.2uF capacitor
FSW	**2**	**3**	Booster switching frequency adjustment pin (Note 1)
COMP	**3**	**4**	Internal error amplifier compensation pin (Note 2)
ISET	**5**	**6**	Max. LED current adjustment pin (Note3)
EN	**7**	**8**	Enable pin. Active High.
PWMI	**6**	**7**	PWM signal input for dimming (Note 4)
FB1	**11**	**12**	LED current sink for Ch1
FB2	**10**	**11**	LED current sink for Ch2
FB3	**9**	**10**	LED current sink for Ch3
FB4	**8**	**9**	LED current sink for Ch4
OVP	**12**	**15**	Over voltage sense pin (Note 5)
CS	**14**	**19**	Boost current sense pin (Note 6)
GATE	**15**	**20**	Gate driver output for external power MOSFET
VLDO	**-**	**16**	Internal 5V Regulator Output. Connect to 2.2uF capacitor
NC	**-**	**13, 14, 18**	Connect to ground for heat-sinking purpose
-	Exposed PAD	**-**	Connect to ground by multiple vias for heat-sinking purpose (Note 7)

Note 1: Connect external resistor to set the oscillator frequency from 100kHz to 500kHz.
Note 2: Connect external capacitor and resistor to COMP pin. Refer to a typical application diagram.
Note 3: The resistor value on ISET pin will control the full scale level of sink current on FB- pins. Do not leave this pin open.
Note 4: This external PWM signal is used for brightness control.
Note 5: Connect center node of resistive voltage divider from output to ground. Refer to a typical application diagram.
Note 6: Connect external resistor to PGND to sense the external power MOSFET drain current.
Note 7: Not connected internally.

Absolute Maximum Ratings[Note 1]

Symbol	Parameter	Min	Max	Unit
V_{CC}	Supply Voltage	-0.3	36	V
V_{GATE}	Gate Driver Output	-0.3	14	V
V_{VDD}	VDD Pin	-0.3	14	V
V_{EN}, V_{CS}, V_{PWMI}, V_{COMP}, V_{OVP}, V_{FSW} V_{ISET}	Input Voltage Signal Level on EN, CS, PWMI, COMP, OVP, FSW, ISET	-0.3	7	V
$V_{FB1\sim4}$	LED Current Sink Pin	-0.3	65	V
$I_{FB1\sim4}$	LED Current Sink Pin		200	mA
T_{PAD}	Soldering Lead/ Pad Temperature 10sec		300	°C
T_J	Junction Temperature	-40	+150	°C
T_S	Storage Temperature	-65	+150	°C
ESD	HBM on All Pins (Note 2)	-2000	+2000	V
	MM on All Pins (Note 3)	-200	+200	

Note 1: Stresses beyond the above listed maximum ratings may damage the device permanently. Operating above the recommended conditions for extended time may stress the device and affect device reliability. Also the device may not operate normally above the recommended operating conditions. These are stress ratings only.
Note 2: ESD tested per JESD22A-114.
Note 3: ESD tested per JESD22A-115.

Recommended Operating Conditions [Note 1]

	Parameter	Min	Max	Unit
V_{CC}	Supply Input Voltage	8	36	V
$I_{FB1\sim4}$	LED Current Sink Pin	50	150	mA
$V_{FB1\sim4}$	LED Current Sink Pin		65	V
T_A	Ambient Temperature (Note 2)	-40	+85	°C

Note 1: Normal operation of the device is not guaranteed if operating the device over outside range of recommended conditions.
Note 2: The ambient temperature may have to be derated if used in high power dissipation and poor thermal resistance conditions.

Package Thermal Resistance [Note 1]

	Parameter	θJA	θJC	Unit
MAP3204SIRH	20 Leads SOIC	54	26	℃/W
MAP3204TERH	16 Leads E-TSSOP	46	8	℃/W

Note 1: Measured on JESD51-7, Multi-layer PCB

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Electrical Characteristics

Unless noted, V_{IN} = 12V, C_{IN} = 1.0μF, and typical values are tested at T_A = 25°C. **Boldface** values indicate -40°C to +85°C of T_A.

Parameter		Test Condition	Min	Typ	Max	Unit
General Input Output						
V_{CC}	Input Voltage Range		**8.0**		**36**	V
I_Q	Quiescent Current	Driving FBs at minimum setting with no load		3		mA
I_{GND}	Ground Pin Current in Shutdown	V_{CC} = 12V, V_{EN} = 0V No Load Current on FBs		40		μA
V_{EN}	Logic Input Level on EN pin	V_{EN_L} : Logic Low			0.8	V
		V_{EN_H} : Logic High	2.0			
$R_{EN\_PULLDOWN}$	Pull-down resistor on EN pin			500		kΩ
V_{UVLO}	Under-Voltage Lock-Out Threshold Voltage on VDD pin	Release UVLO		6.0	7.5	V
		Lockout UVLO	4.0	5.5		
Oscillator						
f_{SW}	Internal Oscillator Frequency	R_{FSW}=250kΩ	**180**	**200**	**220**	kHz
		R_{FSW}=100kΩ	**450**	**500**	**550**	
D_{max}	Maximum Duty Cycle		85	90		%
Reference						
V_{VDD}	10V LDO Voltage	V_{CC} > 12V, No load current	**9**	**10**	**11.5**	V
V_{LDO}	5V LDO Voltage	V_{CC} > 8V, No load current	**4.5**	**5**	**5.5**	V
Boost MOSFET Driver						
V_{GATE}	Gate Drive Voltage	V_{IN} > 12V	9	10	11.5	V
I_{SINK}	Gate Source Current		20			mA
I_{Source}	Gate Sink Current		20			mA
t_{RISE}	Gate Output Rising Time	1nF load capacitance		100	500	ns
t_{FALL}	Gate Output Falling Time	1nF load capacitance		100	500	ns
Protection						
T_{SD}	Thermal Shutdown Temperature	Shutdown Temperature		150		°C
		Hysteresis, ΔT_{SD}		25		
V_{OVP}	Over-Voltage Threshold Level on OVP pin	Rising Over-Voltage Limit on OVP pin	1.23	1.28	1.33	V
		Hysteresis, ΔV_{OVP}	0.05		0.12	
$V_{LEDSHORT}$	LED Short Protection Threshold	FB1 ~ FB4		5.5		V
$V_{SBDOPEN}$	SBD Open Protection Threshold on OVP pin			0.1		V
t_{SCP}	LED Short Protection Time	f_{SW}=500kHz (Note 2)		8.192		ms
V_{CS}	Boost Over Current Protection Threshold	Gate Duty-Cycle=90%	0.306	0.360	0.414	V
$V_{LEDOPEN}$	LED Open Protection Threshold	I_{LED}=50mA		0.05		V
		I_{LED}=150mA		0.15		V
LED Current Sink Regulator						
$V_{FB1~4}$	Minimum FB1~FB4 voltage for the operation to sink 150mA	I_{SET}=150mA		0.8		V
I_{FB}	Current Accuracy	I_{LED}=100mA			**±3**	%
Km	Current Matching (Note 1)	I_{LED}=100mA			**±2.5**	%
I_{FB_max}	Current Sink max Current			**150**		mA
PWM Interface						
f_{PWM}	PWM dimming frequency		0.1		22	kHz
V_{PWMI}	Logic Input Level on PWMI pin	V_{PWMI_L} : Logic Low			0.8	V
		V_{PWMI_H} : Logic High	2.2			
I_{PWM}	Leakage Current on PWMI pin	V_{PWM}=1V			2	μA
t_{PWMON_MIN}	Minimum On-Duty	f_{PWM}=1kHz		10		us

(Note 1) $$Km[\%] = \pm \frac{I_{\max} - I_{\min}}{I_{\max} + I_{\min}} \times 100$$ (Note 2) $$tscp = \frac{1}{fsw} \times 4096$$

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Application Information

CURRENT MODE BOOST SWITCHING CONTROLLER OPERATION

The MAP3204 employs current mode control boost architecture that has a fast current sense loop and a slow voltage feedback loop. Such architecture achieves a fast transient response that is essential for the LED backlight application.

DYNAMIC HEADROOM CONTROL

The MAP3204 features a proprietary Dynamic Headroom Control circuit that detects the lowest voltage from any of the FB1-FB4 pins. This lowest channel voltage is used as the feedback signal for the boost controller. Since all LED stacks are connected in parallel to the same output voltage, the other FB pins will have a higher voltage, but the regulated current source circuit on each channel will ensure that each channel has the same current.

INTERNAL 5V/10V REGULATOR

The MAP3204 has built-in 5V LDO regulator to supply internal analog and logic blocks. The LDO is powered up when the EN pin is Logic High.

A 10V LDO is used to drive external MOSFET connected to the GATE pin. A 2.2uF bypass capacitor is required for stable operation of the LDO.

DIMMING SCHEME

When PWMI signal stays at low level (<0.8V) for a long time, the MAP3204 turns off the boost circuitry, but internal circuit is enabled so the MAP3204 increases the output voltage promptly.

The minimum dimming on duty is 1% at 1kHz = 10us.

PARALLEL OPERATION

Even the MAP3204 has 4Ch and 150mA LED current capability per channel, 2Ch and 300mA application can be supported by tying 2FBs into 1ch, so the LED current capability can be increased to 300mA.

BOOST SWITCHING FREQUENCY ADJUSTMENT

The switching frequency of the MAP3204 should be programmed between 100kHz and 500kHz by an external resistor connected between the FSW pin and ground. Do not leave this pin open. The approximate operating boost switching frequency can be calculated by following equation.

$$f_{sw}[MHz] = \frac{50}{R_{FSW}[k\Omega]}$$

LED CURRENT ADJUSTMENT

The full scale LED drive current of the MAP3204 should be programmed up to 150mA by an external resistor connected between the ISET pin and ground. Do not leave this pin open. The LED current can be set by following table.

ILED [mA]	RISET [kΩ]			
	Used 4-CH	Used 3-CH	Used 2-CH	Used 1-CH
50	216			
60	184			
70	159			
80	139			
90	123	RISET (4-CH) x 1.025	RISET (4-CH) x 1.05	RISET (4-CH) x 1.08
100	111			
110	100			
120	92			
130	85			
140	79			
150	73			

Due to internal GND impedance, the LED current increases with increase of the number of open channel. If there are open channels, specific weight should be multiplied to 4-channel RISET with the number of open channel. For example, the RISET value is 111kΩ for 100mA LED current for 4-channel application, but in case of 3-channel application, the RISET should be chosen by 113.8kΩ(=111 × 1.025).

It is needed fine tuning for these RISET values considering deviation of resistors and etc.

OVER VOLTAGE PROTECTION

To protect the boost converter when the load is open, or the output voltage becomes excessive for any reason, the MAP3204 features a dedicated overvoltage feedback input. The OVP pin is connected to the center tap of a resistive voltage-divider from the high voltage output (see the typical application). When the OVP pin voltage exceeds typical 1.28V, a comparator turns off the external power MOSFET. This switch is re-enabled after the OVP pin voltage drops hysteresis(ΔOVP) below the protection threshold. This over voltage protection feature ensures the boost converter fail-safe operation when the LED channels are disconnected from the output.

It is recommended that the OVP voltage be set to 1.2 times of output voltage. The OVP level can be calculated with the following equation.

$$V_{OUT\_OVP} = 1.28 \times \frac{R_{OVPH} + R_{OVPL}}{R_{OVPL}}$$

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BOOST OVER-CURRENT PROTECTION

The MAP3204 features Over-Current Protection (OCP) by sensing CS pin voltage. This CS pin is used for inductor current sensing for current mode control as well.

The internal OCP sensing voltage decreases with increase of gate duty-cycle due to internal slope compensation which ensures stable CCM operation.

Following graph shows the relationship between gate duty cycle and internal OCP sensing voltage

Vcs_typ vs. Duty Cycle
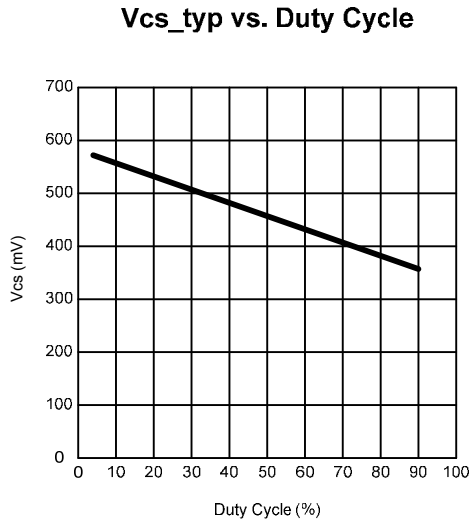
In order to avoid touching the current limit during normal operation, the voltage across the current sensing resistor Rcs should be less than 80% of the worst case current limit voltage.

$$R_{CS} = 0.8 \times \frac{V_{CS}}{I_{L\_PEAK}}$$

LED OPEN PROTECTION

In case the voltage on LED current sink pins (FB1~4) are below LED open protection threshold voltage due to LED open, the output voltage is boosted up to OVP level. The MAP3204 automatically ignores the corresponding channel and remaining string(s) will continue operation.

The operation is resumed recycling the EN pin or applying a complete power-on-reset(POR).

If all the strings are open, the output voltage remains between OVP_high and OVP_low level.

LED SHORT PROTECTION

If the voltage at any of the FB1-4 pins exceeds a threshold of approximately 5.5V due to LED short during normal operation, the MAP3204 turns off the corresponding string after LED short protection time(tscp) and the remaining string(s) will continue operation. The operation is resumed recycling the EN pin or applying a complete power-on-reset(POR).

## DIODE OPEN / OUTPUT SHORT-CIRCUIT PROTECTION

When OVP pin voltage is less than 0.1V, the MAP3204 turns off the external MOSFET. This protects the driver from damage if the output schottky diode is open(defective or poor solder contact), or output voltage is short to ground.

TURN-OFF SEQUENCE
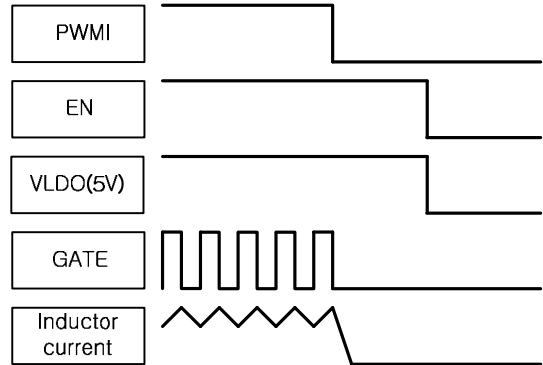
To avoid abnormal GATE turn-on at turn-off, PWMI should be turned-off in advance of EN off.

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OPERATION TIMING CHART
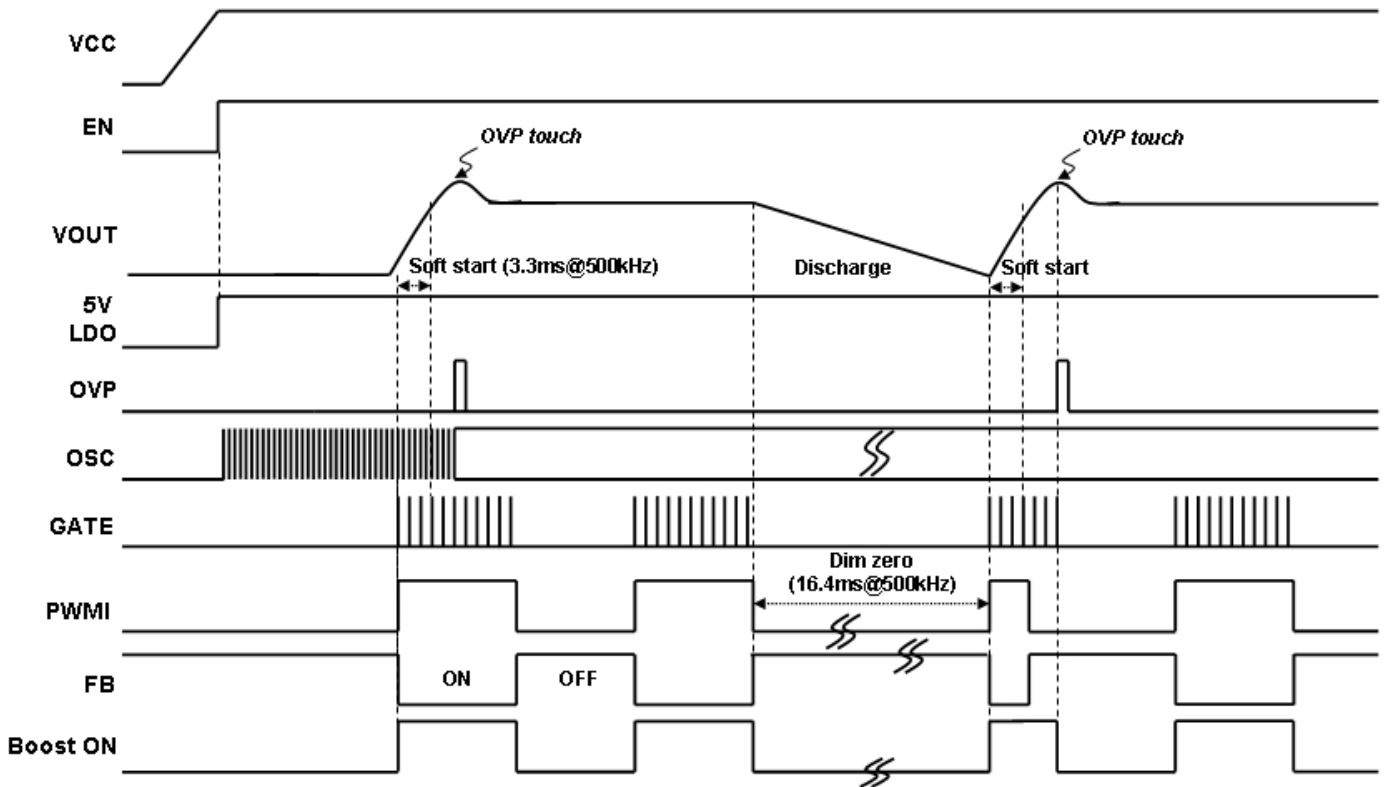
After the enable turns on, the internal 5V LDO is powered up and the internal oscillator starts oscillation. If the PWMI signal remains low at the initial state, the gate drive output to the external MOSFET also remains low, so the boost controller dose not step up the output voltage. As soon as the PWMI signal turns on over than at least 1% duty cycle at fPWMI=1kHz, the controller performs soft-start and continues regulation throughout the PWMI on duty. In the meantime each FB's are turned on simultaneously and the constant current flows the LEDs. The timing between PWMI and FB is approximately same.

The MAP3204 boosts the output voltage only in condition that Vcc is applied and EN and PWMI is turned-on. And it is guaranteed that there is no abnormal operation with regard to turn-on sequence. But in case that Vcc(Vin) is applied lastly after EN and PWMI is turned-on, the start-up current is increased because the output voltage is boosted from 0V to OVP level.

If the PWMI signal remains low state over than 16.4ms at 500kHz boost switching frequency during normal operation, the controller regards it as dim-zero condition. Because of discharge of output capacitor through the OVP sensing resistors during the dim-zero time, the output voltage getting declined. So the controller performs soft-start to boost the output voltage until it reaches the over-voltage-protection level with regarding the dimming duty cycle as 100%. For this reason, some extra switching can be seen when the on duty of PWMI signal is less than the internal boost on period.

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EXTERNAL COMPONENTS SELECTION

Inductor

The inductor value should be decided before system design. Because the selection of the inductor affects the operating mode of CCM(Continuous Conduction Mode) or DCM(Discontinuous Conduction Mode). In CCM operation, inductor size should be bigger, even though the ripple current and peak current of inductor can be small. In DCM operation, even ripple current and peak current of inductor should be large while the inductor size can be smaller.

The inductor DC current or input current can be calculated as following equations.

$$I_{IN} = \frac{V_{OUT} \times I_{OUT}}{V_{IN} \times \eta}$$

η – Efficiency of the boost converter

Then the duty ratio is,

$$D = \frac{V_{OUT} - V_{IN} + V_D}{V_{OUT} + V_D}$$

V_D – Forward voltage drop of the output rectifying diode

When the boost converter runs in DCM (L < Lcritical), it takes the advantages of small inductance and quick transient response. The inductor peak current is,

$$I_{L\_peak\_DCM} = \frac{V_{IN} \times D}{f_{SW} \times L}$$

The converter will work in CCM if L > Lcritical, generally the converter has higher efficiency under CCM and the inductor peak current is,

$$I_{L\_peak\_CCM} = I_{IN} + \frac{V_{IN} \times D}{2 f_{SW} \times L}$$

Input Capacitor

In boost converter, input current flows continuously into the inductor; AC ripple component is only proportional to the rate of the inductor charging, thus, smaller value input capacitors may be used. Ensure the voltage rating of the input capacitor is suitable to handle the full supply range.

A capacitor with low ESR should be chosen to minimize heating effects and improve system efficiency.

Output Capacitor

The output capacitor acts to smooth the output voltage and supplies load current directly during the conduction phase of the power switch. Output ripple voltage consists of the discharge of the output capacitor during the FET ton period and the voltage drop due to load current flowing through the ESR of the output capacitor. The ripple voltage is shown in following equation.

$$\Delta V_{OUT} = \frac{I_{OUT} \times D}{C_{OUT} \times f_{SW}} + I_{OUT} \times ESR$$

Assume a ceramic capacitor is used. The minimum capacitance needed for a given ripple can be estimated by following equation.

$$C_{OUT} = \frac{(V_{IN} - V_{OUT}) \times I_{OUT}}{V_{OUT} \times f_{SW} \times \Delta V_{OUT}}$$

Output Rectifying Diode

Schottky diodes are the ideal choice for MAP3204 due to their low forward voltage drop and fast switching speed. Make sure that the diode has a voltage rating greater that the possible maximum output voltage. The diode conducts current only when the power switch is turned off.

Loop Compensation

The MAP3204 controls in current mode. Current mode easily achieves compensation by consisting simple single pole from double pole that LC filer makes at voltage mode. In general, crossover frequency is selected from 1/3 ~ 1/6 range of the switching frequency. If fc is large, there is possibility of oscillation to occur, although time response gets better.

On the other hand, if fc is small, time response will be bad, while it has improved stability, which may cause over shoot or under shoot in abnormal condition.

Layout Consideration

A gate drive signal output from GATE pin becomes noise source, which may cause malfunction of IC due to cross talk if placed by the side of an analog line. It is recommended to avoid placing the output line especially by the side of CS, ISET, FSW, OVP, COMP as far as possible.

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Physical Dimensions
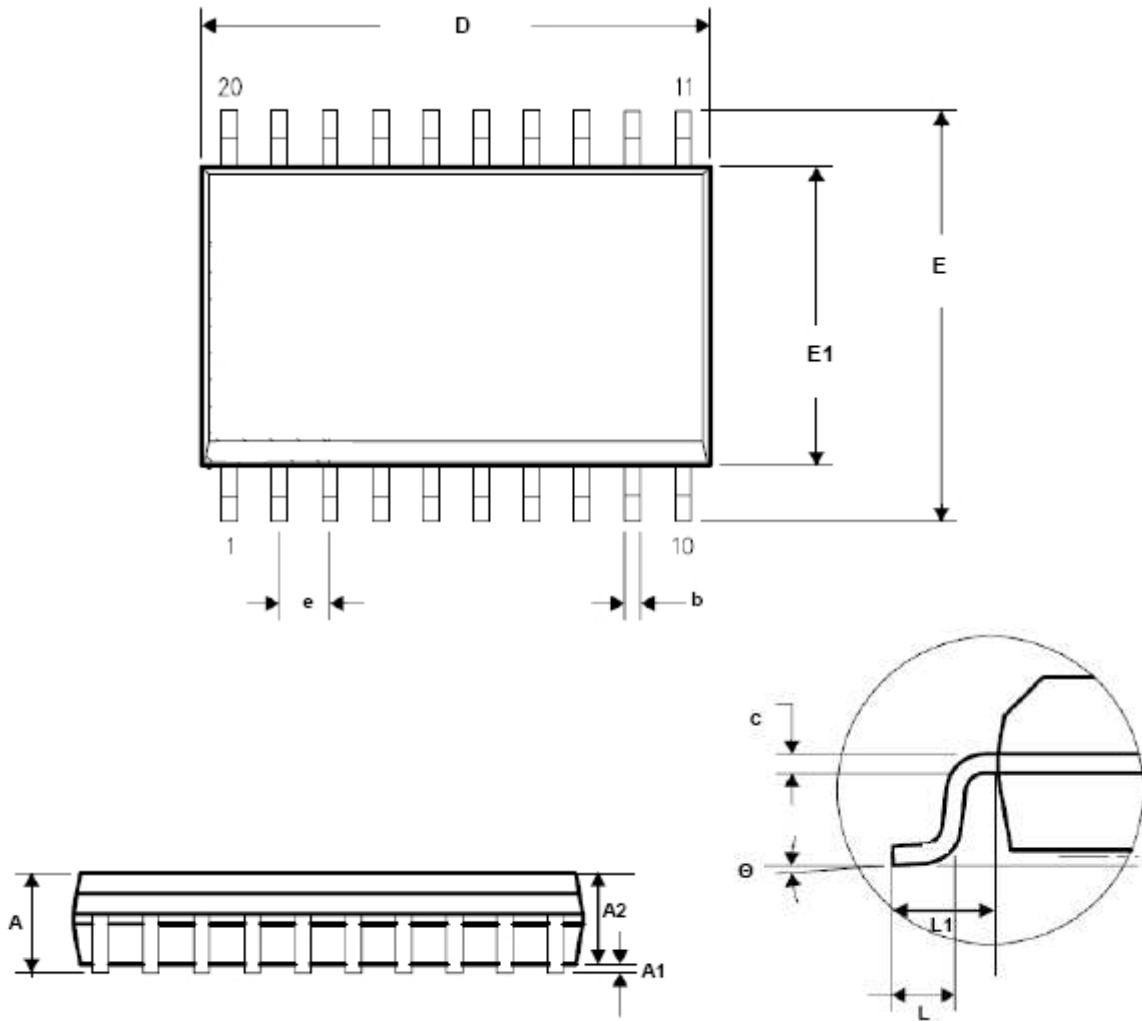
20 Leads SOIC
(Top view)

Symbol	Dimension		
	Min	Norm	Max
A			2.65
A1	0.05		0.30
A2	2.05		2.40
b	0.31		0.51
c	0.20		0.33
D	12.54		13.00
E	10.00		10.65
E1	7.30		7.70
e	1.27 BSC		
L	0.40		1.27
L1	1.40 REF		
ɵ	0°		8°

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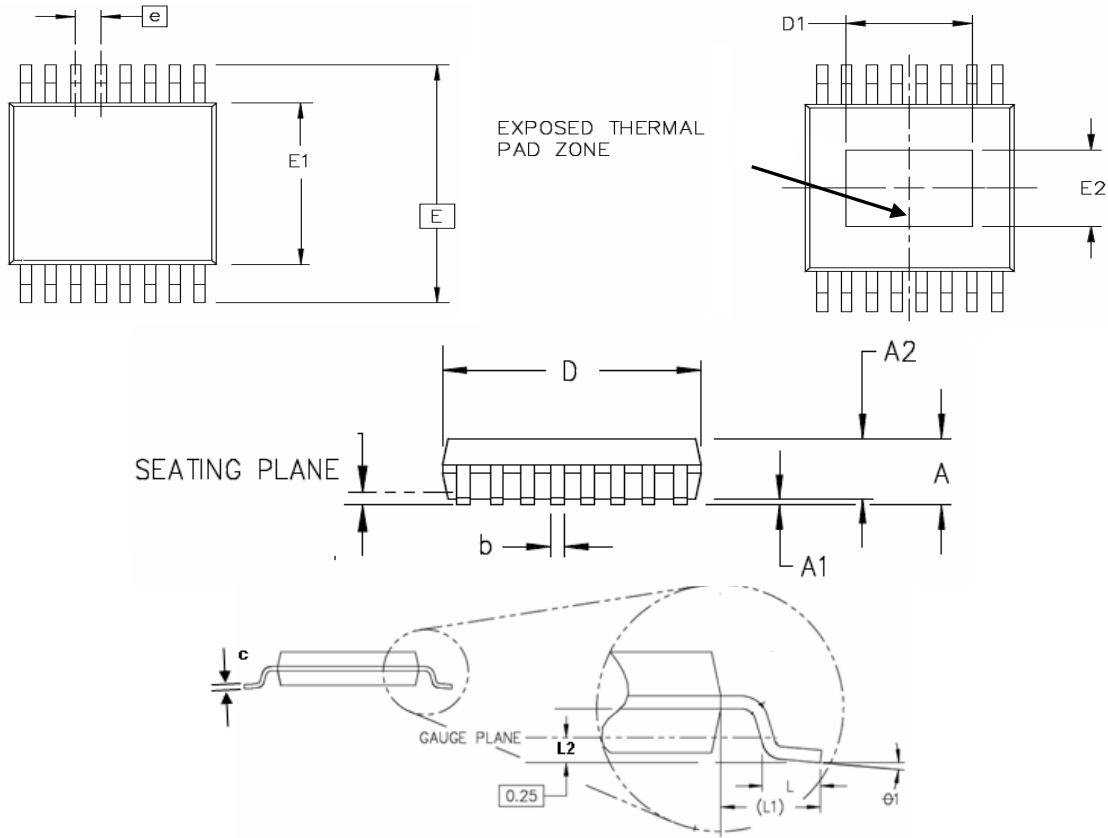
16 Leads TSSOP
(Top view)

Symbol	Dimension		
	Min	Norm	Max
A			1.20
A1	0.00		0.15
A2	0.80		1.05
b	0.19		0.30
C	0.09		0.20
D	4.90		5.10
D1	2.20		
E		6.40 BSC	
E1	4.30		4.50
E2	2.20		
e		0.65 BSC	
L	0.45		0.75
L1		1.00 REF	
L2		0.25 REF	
ɵ1	0°		8°

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MagnaChip Semiconductor Ltd.
891, Daechi-Dong, Kangnam-Gu, Seoul, 135-738 Korea
Tel : 82-2-6903-3451 / Fax : 82-2-6903-3668 ~9
www.magnachip.com