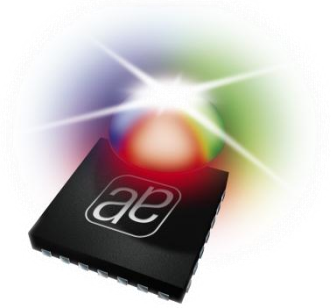
AS3696

4 channel white LED controller for general lighting applications

Product specification



General Description

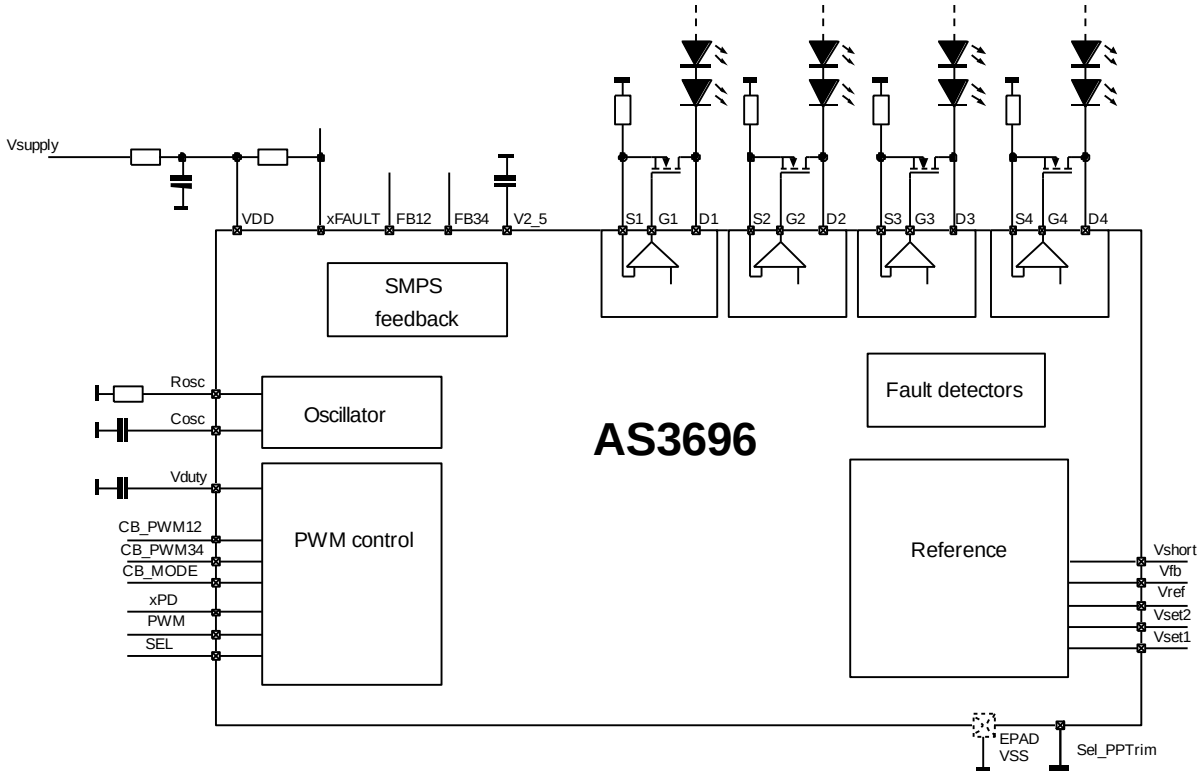
The AS3696 is a 4 channels precision LED controller with PWM inputs or internal PWM generator for driving external FETs in precise lighting applications. Build in safety features include thermal shutdown as well as open and short LED detection.

- 2x2 Channel LED driver
- Output current only limited by external FET
- Build in shunt regulator
- Absolute current accuracy +/- 1%
- Channel to channel accuracy +/- 1%
- Normal Mode
  - Linear current control with external voltage
  - Digital PWM control with PWM input
  - Build in PWM-generator with analog duty cycle control
- Current Boost Mode
  - Linear current control with external voltage
  - Digital PWM control with 2 PWM inputs
- Open LED detection and auto-turnoff
- Short LED detection and auto-turnoff
- Temperature shutdown
- 2x automatic supply regulation feedback
- Package QFN 32pin 5x5mm, 0.5mm pitch
- Package TQFP 32pin 7x7mm, 0.8mm pitch

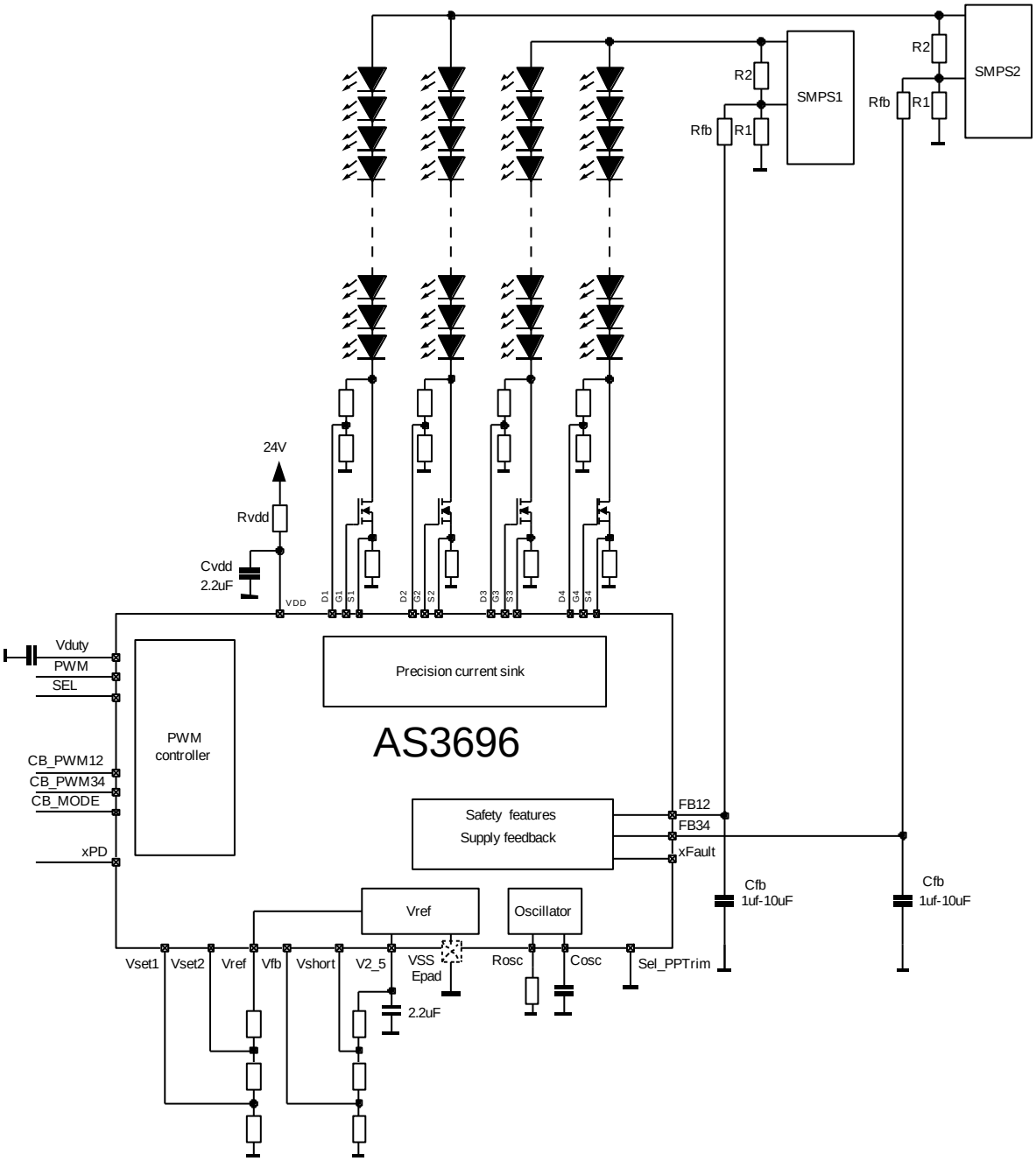
Applications

- Commercial, industrial and retail lighting
- Streetlights
- Large panel LED backlighting

1 Block Diagram



2 Typical Application



3 Electrical Characteristics

3.1 Absolute Maximum Ratings

Stresses beyond those listed may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these or any other conditions beyond those indicated in Section "Electrical Characteristics" is not implied.

Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Symbol	Parameter	Min	Max	Unit	Note
V_{DDMAX}	Supply voltage	-0.3	5.4	V	Voltage limit due to internal shunt regulator.
$V_{IN\_2.5V}$	Maximum voltage	-0.3	V2_5 +0.3V	V	Applicable for 2.5V pins (1)
V_{IN_5V}	Maximum voltage	-0.3	VDD +0.3V	V	Applicable for 5V pins (2)
V_{IN_50V}	Maximum voltage	-0.3	50	V	Applicable for 50V pins (3)
I_{latch}	Latch-Up immunity	-100	+100	mA	Norm: EIA/JESD78
T_{STRG}	Storage Temperature Range	-55	150	°C	Maximum Junction Temperature
	Humidity	5	85	%	Non condensing
V_{ESD_LV}	Electrostatic Discharge on all pins (except D1...D4)	-2000	2000	V	Norm: MIL 883 E Method 3015 Human body model
V_{ESD_HV}	Electrostatic Discharge on pins D1 ... D4	-4000	4000	V	Norm: MIL 883 E Method 3015 Human body model
T_{BODY}	Body Temperature during Soldering		260	°C	according to IPC/JEDEC J-STD-020C

Note: (1) Pins: V2_5, Vfb
(2) Pins: All pins except V2_5, D1-D4, Vfb
(3) Pins: D1 – D4

3.2 Operating Conditions

3.2.1 General

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
Rthja	Thermal resistance junction – ambient	QFN32		30		°C/W
P_{DERATE}	PT Derating Factor	QFN32	33			mW/ °C
Tamb	Ambient Temperature		-30		85	°C
Tj	Junction Temperature		-30		115	°C

3.2.2 Power supply

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
VDDint	Supply Voltage VDD shunt regulator operation	Shunt regulator operation. Supply current has to be limited between 10mA and 30mA by external resistor	5.0	5.2	5.5	V
IDDmax	Maximum shunt regulator current				30	mA
VDDext	Supply Voltage VDD	no shunt regulator operation. No external current limiting resistor needed	4.0	4.5	4.9	V

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
VDD_POR	Power on reset level	Circuit stays in power down until VDD_POR is reached. G1 – G4 is pulled to GND during power down	2.4		3.0	V
IDD_q	Quiescent current	VDD= 5V, Default setting, PWM = 0		1		mA
IDD_r	Supply current	VDD = 5V, PWM = 240Hz, Duty = 50%		2.5	10	mA
V2_5	V2_5 regulator output		2.4	2.5	2.6	V
I2_5	V2_5 output current				1	mA
Vref	Reference voltage		1.24	1.25	1.26	V
Rvref	Output resistance Vref			300		Ω

3.2.3 Current outputs

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
Vdx	Output voltage pins Dx				50	V
Rdx	Input resistance in Dx	PWM = 0 U_DX=16V PWM = 1	1 0.1			MΩ MΩ
Vgx	Max output voltage pin Gx	Igx = 1mA	VDD-0.5		VDD	V
Igx	Max output current pin Gx				1	mA
Rsx	Input resistance pin Sx		1			MΩ
Iled_250	Current accuracy	Trimmed during production ILED =100mA, Temp = 25°C, external NMOS-Transistor used, Vset1 = 250mV (excluding error of external Rset)	-1.0		+1.0	%
Ich_250	Channel to channel Current accuracy	Trimmed during production ILED =100mA, Temp = 25°C, external NMOS-Transistor used, Vset1 = 250mV (excluding error of external Rset)	-1.0		+1.0	%
Iled_all	Current accuracy	Tjunction = -20°C to +100°C Vset1 = 200mV to 500mV (1) external NMOS-Transistor used, (excluding error of external Rset)	-2.0		+2.0	%

Note: (1) It is not recommended to use Vset < 200mV in order to minimize influences from PCB-layout and noise.

3.2.4 Feedback circuit, fault detectors

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
IFBmax	Feedback current maximum			300		uA
RFBmin	Minim output resistance	VDx = 0.3V		300	1000	Ω
IFB_g	FB transconductance	IFB_g = $\Delta I_{FB}/\Delta V_{Dx}$		-3		mA/V
Vfb	Feedback voltage trip point	Trip voltage at Pins Dx	0		3	V
Vshort	Short LED detector Voltage	Short LED detection level voltage Short will be detected if: ((V_Dx -VsetX) /5 + VsetX) > Vshort	0		2	V
Tovtemp	Over temperature limit		130	140	150	°C

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
Thyst	Over termperature hysteresis			10		°C

3.2.5 PWM-inputs

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
fPWM	PWM-input frequency	Pins: PWM, CB_PWM12, CB_PWM34	0		1	kHz

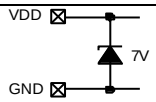
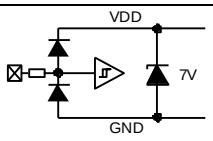
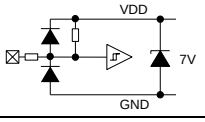
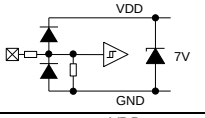
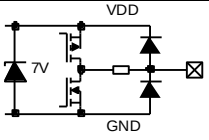
3.2.6 Oscillator

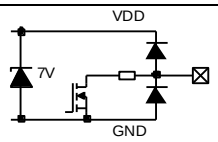
Symbol	Parameter	Conditions	Min	Typ	Max	Unit
UrefH	Reference Voltage high		3.1	3.2	3.3	V
UrefL	Reference Voltage low		0.0	0.1	0.2	V

3.2.7 Digital pins

Symbol	Parameter	Min	Typ	Max	Unit	Note
V_{IH}	High Level Input voltage	1.3		VDD	V	
V_{IL}	Low Level Input voltage	-0.3		0.8	V	
VoH	High Level output voltage	VDD-0.3			V	I=mA
VoL	Low Level output voltage			VDD-0.3	V	I=mA
VoL_PD	Low level output voltage open drain outputs			VDD-0.3	V	I=mA
R_pu	Input resistance PullUp inputs		300		kΩ	
R_pd	Input resistance PullDown inputs		300		kΩ	

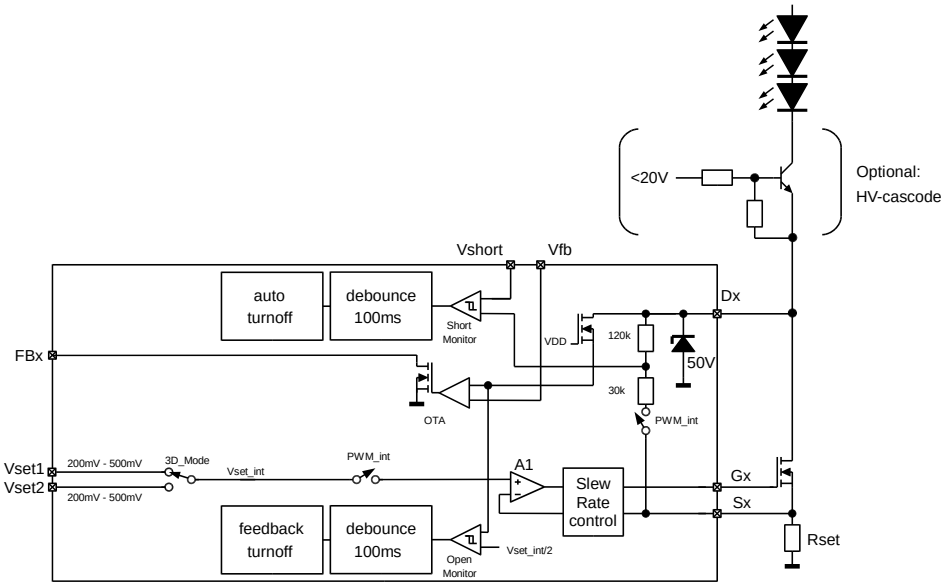
3.3 Pins equivalent circuit

VDD	
Digital inputs	
Digital inputs Pull up	
Digital inputs Pull Down	
Digital outputs push/pull	

Digital output open drain	

4 Detailed Block description

4.1 Current outputs



4.1.1 Precision current sink

All current sinks are built with an internal error amplifier A1 and an external power transistor. The external transistor should be a NMOS type to keep the current accuracy.
The output current during PWM=1 can be calculated:

$Iled = \frac{Vset1}{Rset}$ in normal mode (CB_Mode = 0)

$Iled = \frac{Vset2}{Rset}$ in Current Boost mode (CB_Mode = 1)

4.1.2 Output voltage monitoring

In order to monitor the proper DCDC output voltage the voltage at pin “Dx” is measured during PWM=1. If this voltage is too low a comparator turns on a transconductance amplifier which is able to control the output voltage of the external power supply via pin FB1 or FB2.

4.1.3 Open LED detection

If a LED-string is broken the voltage at pin Dx gets lower than Vset_int/2. This status is detected and accumulated by a comparator during PWM=1. If the accumulated status lasts longer than 100ms, a fault is indicated and the corresponding power feedback function is turned off. After 500ms the fault is reset and the detection starts again.
For proper detection the PWM high time has to be longer than 500us.

4.1.4 Short LED detection

Shorted LEDs in a LED-string will cause higher voltage at pin “Dx”. A higher voltage during PWM=1 is detected by a comparator and will trigger a “short LED detection” fault. The duration of the fault is

accumulated and if the time exceeds 100ms a fault is indicated and the output is turned off. If the high-time of the waveform is shorter than 100ms it will take more periods to trigger this fault. After 500ms the channel is turned on again. A short will be detected if:

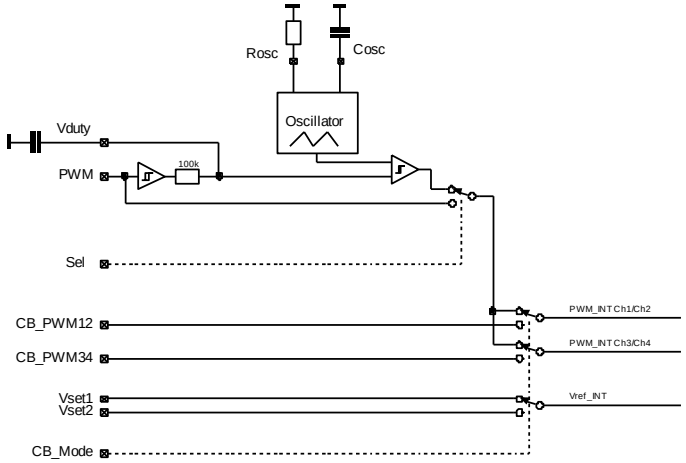
((V_Dx -VsetX) /5 + VsetX) > Vshort

For proper detection the PWM high time has to be longer than 500us.

4.2 PWM controller

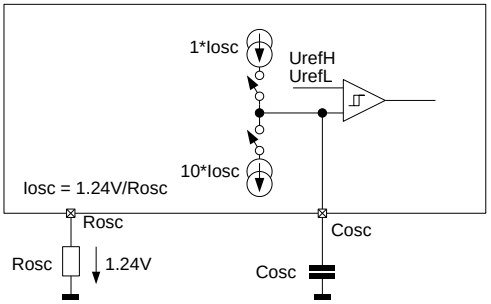
The PWM controller can operate in normal mode or current boost mode. Depending on the mode different output currents can be set.

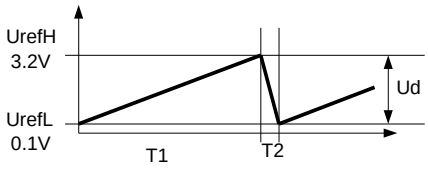
"3D-Mode"	"SEL"	Mode	Comment	Vref_INT
0	0	Normal PWM external	External PWM is used as PWM_INT	Vset1
0	1	Normal PWM internal	PWM-frequency is generated by internal oscillator PWM-duty cycle is set by voltage on pin "Vduty" Vduty can either be an external voltage (PWM=0) or can be derived from the PWM signal by filtering with an ext capacitor	Vset1
1	X	Current boost mode	CB_PWM12 is used for driving Channels 1 and 2 CB_PWM34 is used for driving Channels 3 and 4	Vset2



4.3 Oscillator

The build in oscillator can be used to generate internal PWM frequencies. The external Capacitor is charged with the current 1.24V/Rosc and discharged with the current 1.24V*10/Rosc.



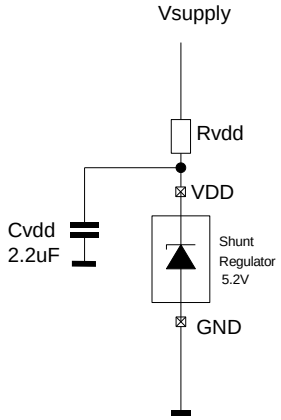


$U_d = U_{refH} - U_{refL} = 3.1V,$ $T_1 = \frac{U_d * R_{osc} * C_{osc}}{1.24V},$ $T_2 = \frac{U_d * R_{osc} * C_{osc}}{10 * 1.24V}$

The Oscillator frequency can be calculated: $f_{osc} = \frac{1.24V}{3.1V * R_{osc} * C_{osc}} * \frac{10}{11} = \frac{0.3636}{R_{osc} * C_{osc}}$ [Hz]

4.4 Power supply

The device has a build in electronic Zener-diode at pin VDD for building a shunt regulator. To obtain a 5.2V regulated supply, a series resistor Rvdd has to be connected in series to the internal zener diode. An external capacitor Cvdd is used to filter the supply on the pin VDD.



The external resistor Rvdd has to be calculated according to the following formula:

$R_{VDD} = \frac{V_{Supply} - 5.2V}{10mA}$ Vsupply...Minimum Supply voltage

Power dissipation of Rvdd; $P_{Rvdd} = \frac{(V_{Supply} - 5{,}2V)^2}{R_{VDD}}$

To ensure proper operation the minimum supply voltage should be choosen as Vsupply.
If a stable supply voltage between 4V and 5V is available in the system this supply can also be used for VDD. In that case there is no need for the series resistor Rvdd.

4.5 Safety features

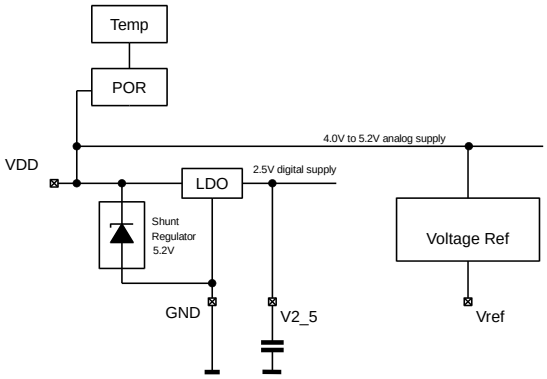
4.5.1 Temperature shutdown

If the die temperature reaches 140°C all outputs are turned off. If the die temperature goes below 130°C the outputs are turned on again.

4.5.2 xPD input

In addition to the build in power on reset circuit there is an external power down input “xPD” available. This gives the possibility to keep the outputs turned off until all blocks of the LED-driver circuits are fully working (DCDC, MCU ...)

4.6 Reference circuit

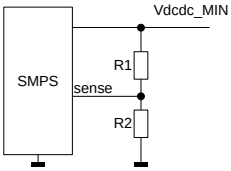


The reference circuit generates an internal supply voltage of 2.5V for the digital logic.

4.7 Dynamic feedback control

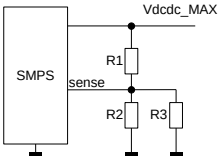
The output of pins “FB12” and “FB34” can be used to control any external power supply for best power efficiency. Every power supply senses its output voltage with a resistive voltage divider. This voltage divider can be modified to set the output voltage between a minimum output voltage VMIN and a maximum output voltage VMAX. The design of the dynamic feedback control is done in 3 steps.

Step 1: Set the resistors R1,R2 in the power supply according to the minimum output voltage



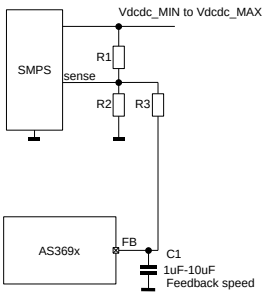
$$Vout_{MIN} = \frac{(R1+R2)}{R2} * V_{sense}$$

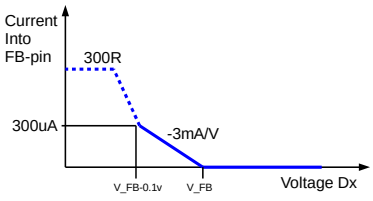
Step 2: Add the Resistors R3 in the power supply according to the maximum output voltage



$$Vout_{MAX} = \frac{(R1+R2||R3)}{R2||R3} * V_{sense}$$

Step 3: Connect R3 to the feedback pin “FBxx”.
C1 should be chosen according to the speed requirements of the feedback loop.





The characteristic of the feedback function can be seen in the diagram. The final output voltage of is determined by the setting of VFB and the current that is drawn from the external voltage divider.

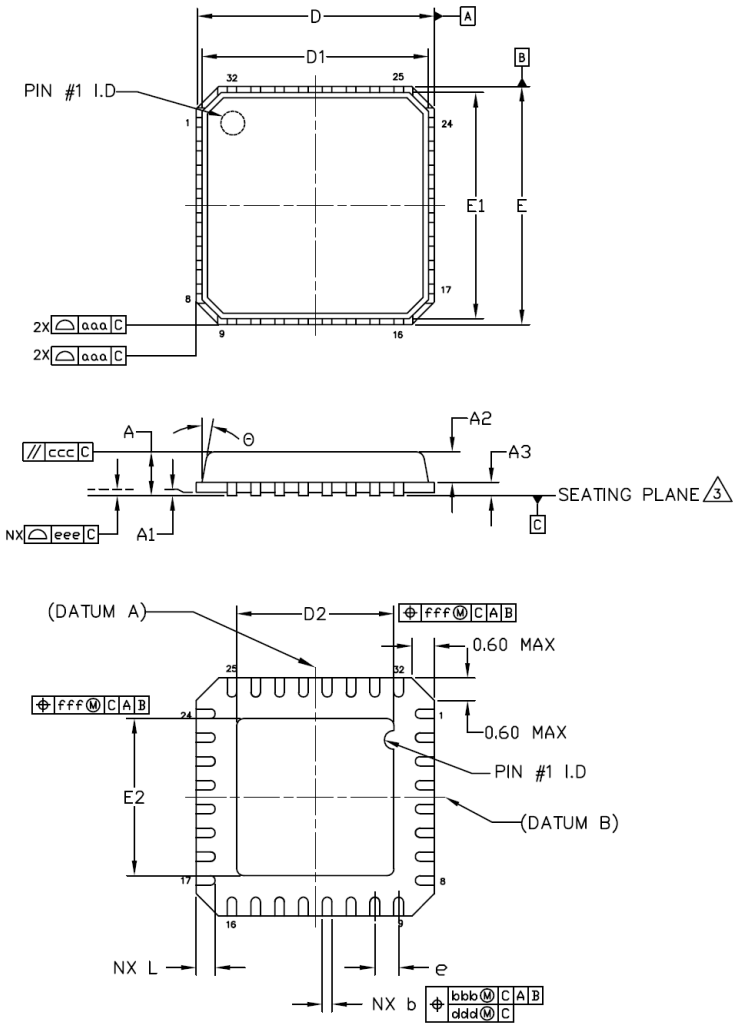
5 Pinout and Packaging

5.1 Pinout QFN32, TQFP32

Pin Nr	Pin Name **QFN Package**	Pin Name **TQFP package**	Pin Type	Description
1	D1	D1	AIO	Connect to Drain of external Transistor
2	G1	G1	AIO	Connect to Gate of external Transistor
3	V2_5	V2_5	AIO	Supply output. Connect 2.2uF bypass capacitor to GND
4	Vfb	Vfb	AIO	Trip point voltage for outputs D1 – D4
5	Vduty	Vduty	AIO	Analog duty cycle control input
6	FB12	FB12	AIO	Power supply feedback output1 and output2
7	FB34	FB34	AIO	Power supply feedback output3 and output4
8	**Vref**	**VSS**	**AIO**	**Reference voltage output (QFN), VSS (TQFP)**
9	Vset1	Vset1	AIO	Reference voltage input in normal mode
10	Vset2	Vset2	AIO	Reference voltage input in 3D mode
11	Rosc	Rosc	AIO	Resistor of RC-oscillator
12	Cosc	Cosc	AIO	Capacitor of RC-oscillator
13	PWM	PWM	DI-PD	PWM input
14	CB_Mode	CB_Mode	DI-PD	Mode select input
15	CB_PWM12	CB_PWM12	DI-PD	PWM input in Current Boost Mode for channel1 and channel2
16	CB_PWM34	CB_PWM34	DI-PD	PWM input in Current Boost Mode for channel3 and channel4
17	SEL	SEL	DI-PD	PWM input select in normal mode
18	SEL_PPtrim	SEL_PPtrim	DI-PD	Connect to VSS. This pin is used for factory trimming.
19	xFAULT	xFAULT	DO-OD	Fault output. Active low
20	xPD	xPD	DI-PU	Power down input. Active low
21	Vshort	Vshort	AIO	Short LED detection threshold voltage
22	VDD	VDD	AIO	Shunt voltage regulator input.
23	G4	G4	AIO	Connect to Gate of external Transistor
24	D4	D4	AIO	Connect to Drain of external Transistor
25	S4	S4	AIO	Connect to Source of External Transistor and to Resistor RSET
26	S3	S3	AIO	Connect to Source of External Transistor and to Resistor RSET
27	D3	D3	AIO	Connect to Drain of external Transistor
28	G3	G3	AIO	Connect to Gate of external Transistor
29	G2	G2	AIO	Connect to Gate of external Transistor
30	D2	D2	AIO	Connect to Drain of external Transistor
31	S2	S2	AIO	Connect to Source of External Transistor and to Resistor RSET
32	S1	S1	AIO	Connect to Source of External Transistor and to Resistor RSET
EP	VSS		AIO	Exposed PAD. Connect to VSS **(QFN)**

AIO	Analog Pin
DI	Digital input
DI-PU	Digital input with pull up resistor
DI-PD	Digital input with pull down resistor
DO	Digital output
DO-OD	Digital output open drain

5.2 Package Drawing QFN32



REF.	MIN	NOM	MAX
A	0.80	0.90	1.00
A1	0	0.02	0.05
A2	–	0.65	1.00
A3	–	0.20 REF	–
L	0.35	0.40	0.45
θ	0°	–	14°
b	0.18	0.25	0.30
D		5.00 BSC	
E		5.00 BSC	
e		0.50 BSC	
D2	3.40	3.50	3.60
E2	3.40	3.50	3.60
D1	–	4.75 BSC	–
E1	–	4.75 BSC	–
aaa	–	0.15	–
bbb	–	0.10	–
ccc	–	0.10	–
ddd	–	0.05	–
eee	–	0.08	–
fff	–	0.10	–
N		32	

NOTE:

1. DIMENSIONS & TOLERANCEING CONFIRM TO ASME Y14.5M–1994.
2. ALL DIMENSIONS ARE IN MILLIMETERS. ANGELS ARE IN DEGREES.
3. COPLANARITY APPLIES TO THE EXPOSED HEAT SLUG AS WELL AS THE TERMINAL.
4. RADIUS ON TERMINAL IS OPTIONAL.
5. N IS THE TOTAL NUMBER OF TERMINALS.

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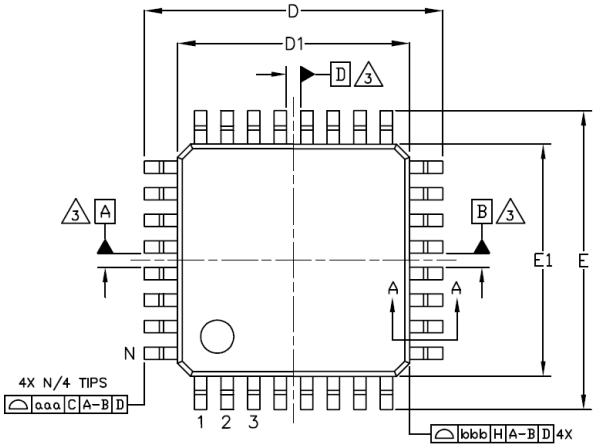
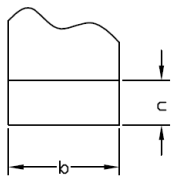
ASSEMBLY ENGINEERING

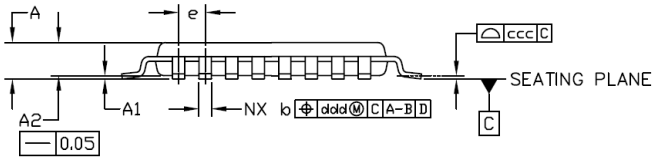
DRAWN RH8	DATE 2010.12.15	REV. N/C	TITLE PUNCHED QFN, 5x5x0.9mm 32 LEAD, 3.50mm SQ. ePAD	REFERENCE DOCUMENT JEDEC MO – 220 LATEST REVISION
CHECKED GBO	DATE 2010.12.15		DRAWING NO. QSJ	UNIT
APPROVED MKR	DATE 2010.12.15	SHEET 1 OF 1	DIMENSION AND TOLERANCE	SCALE NOT IN SCALE

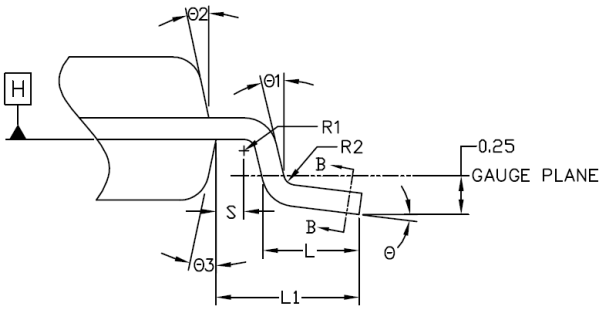
5.3 Package Drawing TQFP32





SECTION B–B





SECTION A–A

REF.	MIN	NOM	MAX
A	–	–	1.20
A1	0.05	–	0.15
A2	0.95	1.00	1.05
b	0.30	0.35	0.45
c	0.09	–	0.20
D		9.00 BSC	
D1		7.00 BSC	
E		9.00 BSC	
E1		7.00 BSC	
e		0.80 BSC	
L	0.45	0.60	0.75
L1		1.00 REF	
R1	0.08	–	–
R2	0.08	–	0.20
S	0.20	–	–
θ	0°	3.5°	7°
θ1	0°	–	–
θ2	11°	12°	13°
θ3	11°	12°	13°
aaa	–	0.20	–
bbb	–	0.20	–
ccc	–	0.10	–
ddd	–	0.20	–
N		32	

NOTE:

1. DIMENSIONS & TOLERANCEING CONFIRM TO ASME Y14.5M–1994.
2. ALL DIMENSIONS ARE IN MILLIMETERS. ANGELS ARE IN DEGREES.
3. DATUMS A & B TO BE DETERMINED AT DATUM H.

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DRAWN RH8	DATE 2010.12.17	REV. N/C	TITLE TQFP 7x7x1.0mm, 32 LEAD,	REFERENCE DOCUMENT JEDEC MS – 026 LATEST REVISION
CHECKED GBO	DATE 2010.12.17		DRAWING NO. BPX	UNIT
APPROVED MKR	DATE 2010.12.17	SHEET 1 OF 1	DIMENSION AND TOLERANCE	SCALE NOT IN SCALE

6 Ordering information

Part Number	Marking	Package Type	Delivery Form	Description
AS3696-ZQFT	AS3696	QFN32	Tape and Reel in Dry Pack	Package size = 5x5mm, Pitch = 0.5mm, Pb-free;
AS3696-ZTQT	AS3696	TQFP32	Tape and Reel in Dry Pack	Package size = 7x7mm, Pitch = 0.8mm, Pb-free;

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Contact Information

Headquarters
austriamicrosystems AG
A-8141 Schloss Premstätten, Austria

T. +43 (0) 3136 500 0
F. +43 (0) 3136 5692

For Sales Offices, Distributors and Representatives, please visit:

http://www.austriamicrosystems.com/contact