

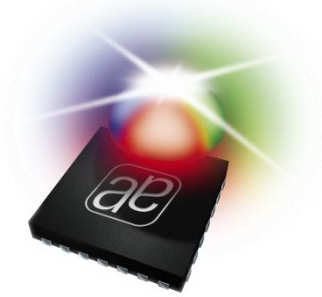
AS3696

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.

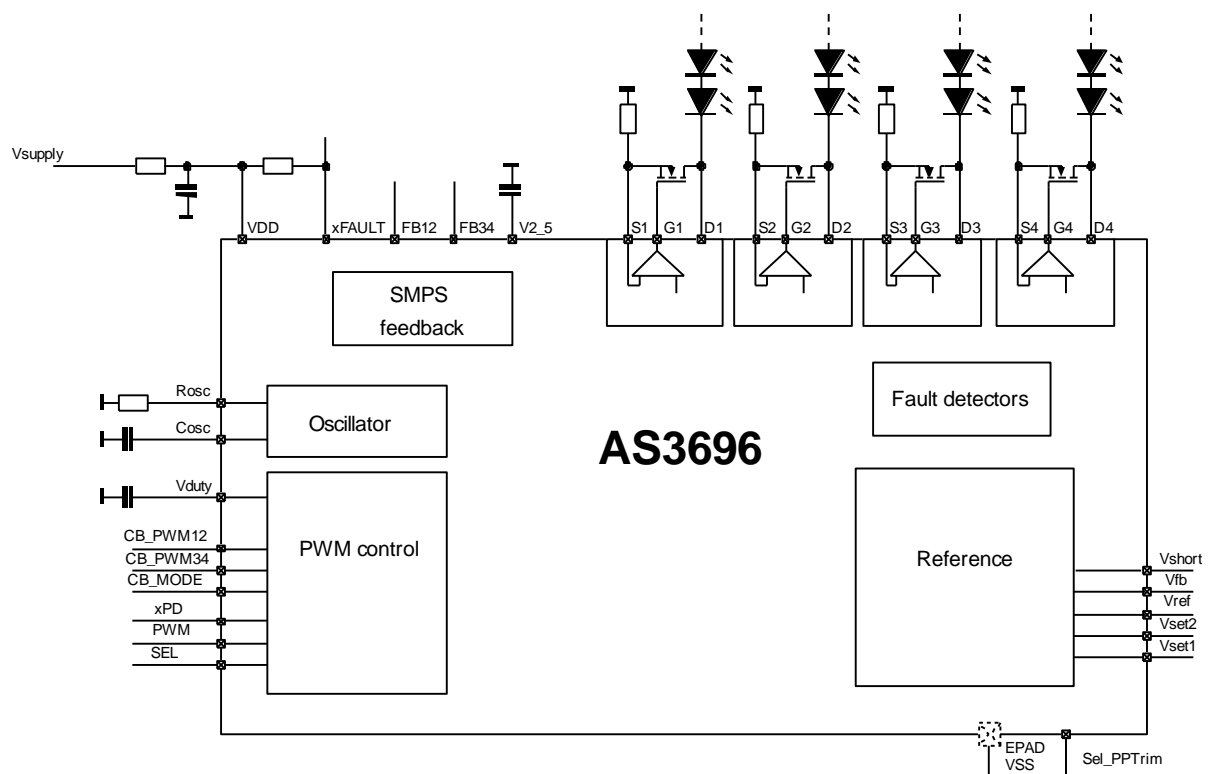


- 2x2 Channel LED driver
- Output current only limited by external FET
- Build in shunt regulator
- Absolute current accuracy +/- 1%
- Channel to channel accuracy +/- 1%
- Normal Mode
 - Linear current control with external voltage
 - Digital PWM control with PWM input
 - Build in PWM-generator with 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

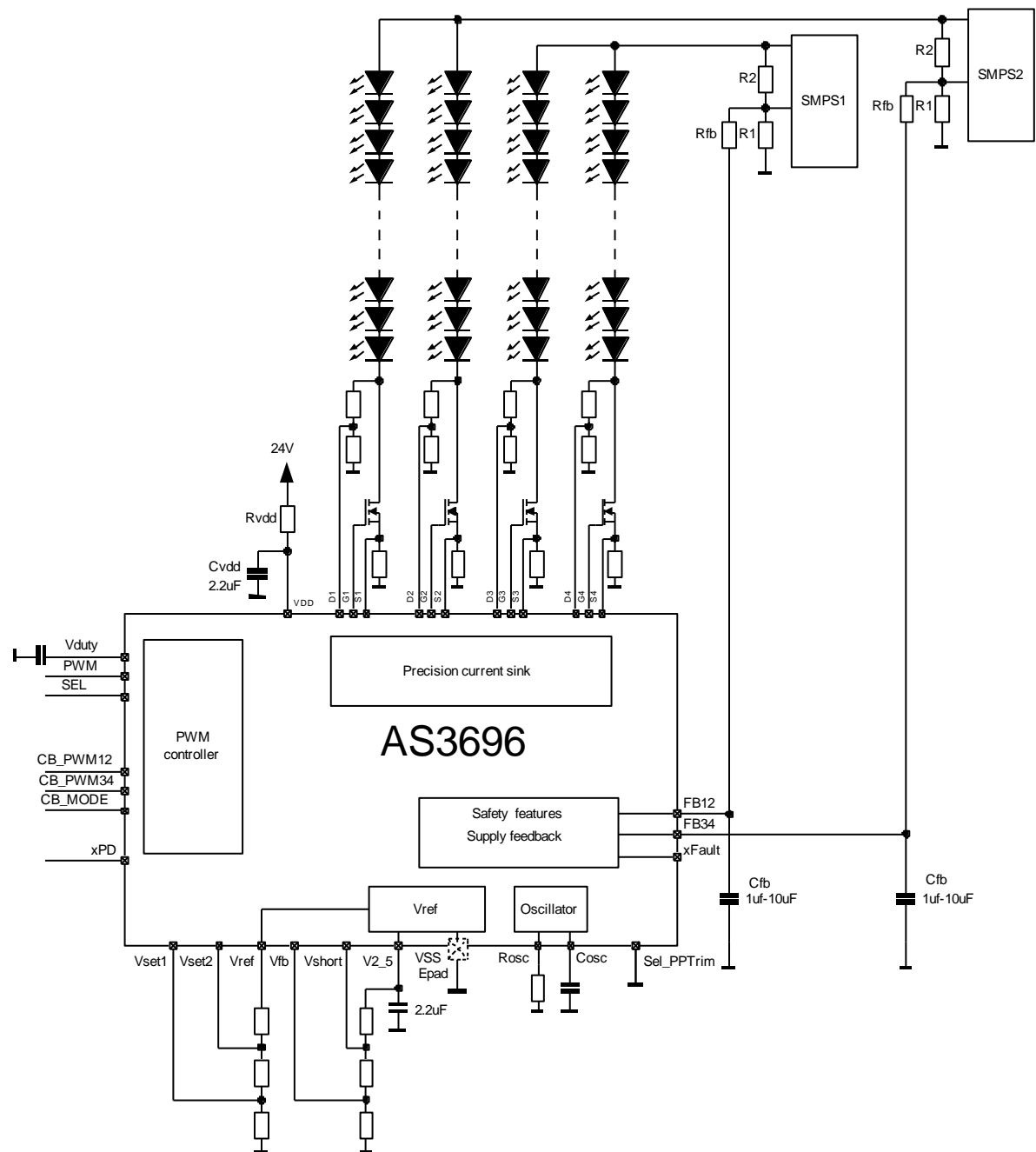
Applications

- 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 |
|--------------------|---|-------|---------------|------|---|
| VDDMAX | Supply voltage | -0.3 | 5.4 | V | Voltage limit due to internal shunt regulator. |
| VIN_2.5V | Maximum voltage | -0.3 | V2_5 +0.3V | V | Applicable for 2.5V pins ⁽¹⁾ |
| VIN_5V | Maximum voltage | -0.3 | VDD +0.3V | V | Applicable for 5V pins ⁽²⁾ |
| VIN_50V | Maximum voltage | -0.3 | 50 | V | Applicable for 50V pins ⁽³⁾ |
| I _{latch} | Latch-Up immunity | -100 | +100 | mA | Norm: EIA/JESD78 |
| TSTRG | Storage Temperature Range | -55 | 150 | °C | Maximum Junction Temperature |
| | Humidity | 5 | 85 | % | Non condensing |
| VESD_LV | Electrostatic Discharge on all pins (except D1...D4) | -2000 | 2000 | V | Norm: MIL 883 E Method 3015 Human body model |
| VESD_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 |
|---------------------|--|------------|-----|-----|-----|-----------|
| R _{thja} | Thermal resistance junction – ambient | QFN32 | | 30 | | °C/W |
| P _{DERATE} | PT Derating Factor | QFN32 | 33 | | | mW/ °C |
| T _{amb} | Ambient Temperature | | -30 | | 85 | °C |
| T _j | Junction Temperature | | -30 | | 115 | °C |

3.2.2 Power supply

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|--------------------|---|--|-----|-----|-----|------|
| VDD _{int} | 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 |
| IDD _{max} | Maximum shunt regulator current | | | | 30 | mA |
| VDD _{ext} | 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 | | μA |
| RFBmin | Minim output resistance | VDx = 0.3V | | 300 | 1000 | Ω |
| IFB_g | FB transconductance | IFB_g = ΔI _{FB} / ΔV _{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: $((V_{Dx} - V_{setX}) / 5 + V_{setX}) > V_{short}$ | 0 | | 2 | V |
| Tovtemp | Over temperature limit | | 130 | 140 | 150 | °C |

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|--------|-----------------------------|------------|-----|-----|-----|------|
| Thyst | Over temperature 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 |

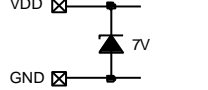
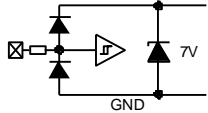
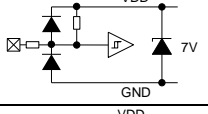
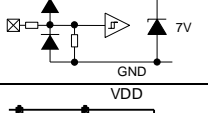
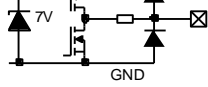
3.2.6 Oscillator

| 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 |

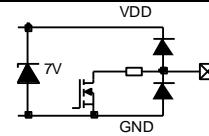
3.2.7 Digital pins

| 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 | |
| V _{OH} | High Level output voltage | VDD-0.3 | | | V | I=mA |
| V _{OL} | Low Level output voltage | | | VDD-0.3 | V | I=mA |
| V _{OL_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

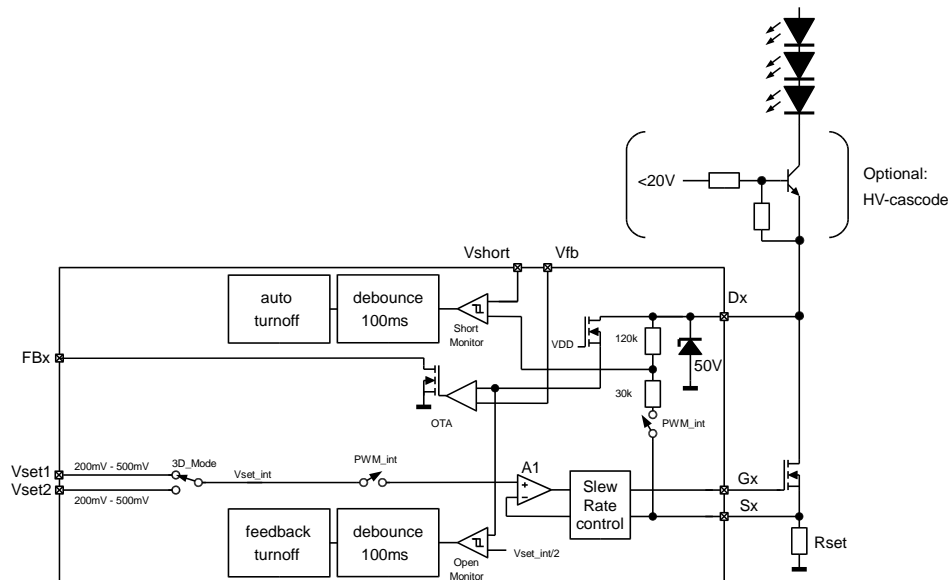
| | |
|---------------------------|--|
| VDD |  |
| Digital inputs |  |
| Digital inputs Pull up |  |
| Digital inputs Pull Down |  |
| Digital outputs push/pull |  |

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:

$$I_{led} = \frac{V_{set1}}{R_{set}} \quad \text{in normal mode (CB_Mode = 0)}$$

$$I_{led} = \frac{V_{set2}}{R_{set}} \quad \text{in Current Boost mode (CB_Mode = 1)}$$

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 $V_{set_int}/2$. 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:

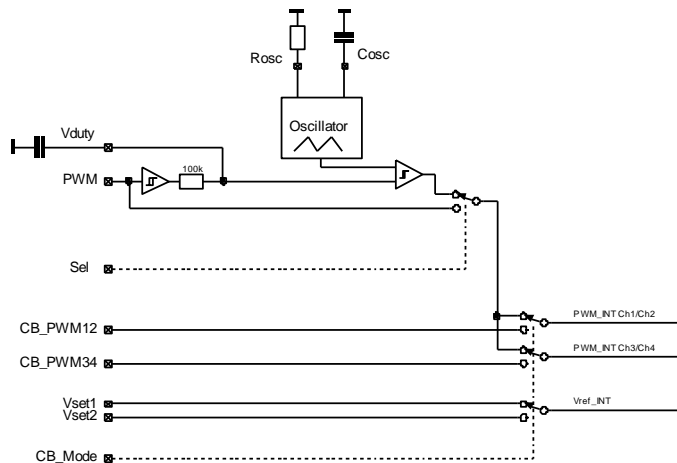
$$((V_{Dx} - V_{setX}) / 5 + V_{setX}) > V_{short}$$

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

4.2 PWM controller

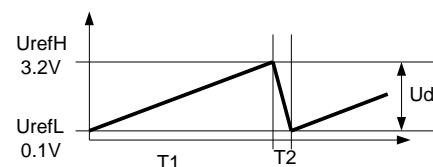
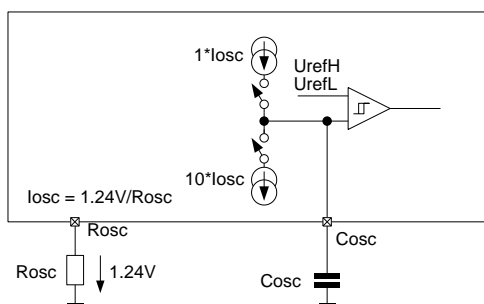
The PWM controller can operate in normal mode or current boost mode. Depending on the mode different output currents can be set.

| "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 $1.24V/R_{osc}$ and discharged with the current $1.24V \cdot 10/R_{osc}$.



$$U_d = U_{refH} - U_{refL} = 3.1V,$$

$$T_1 = \frac{U_d \cdot R_{osc} \cdot C_{osc}}{1.24V},$$

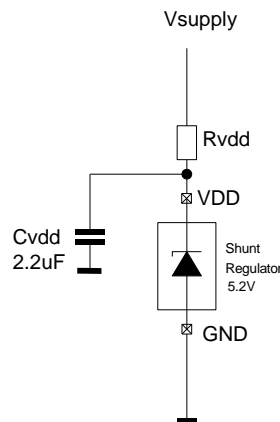
$$T_2 = \frac{U_d \cdot R_{osc} \cdot C_{osc}}{10 \cdot 1.24V}$$

The Oscillator frequency can be calculated:

$$f_{osc} = \frac{1.24V}{3.1V \cdot R_{osc} \cdot C_{osc}} \cdot \frac{10}{11} = \frac{0.3636}{R_{osc} \cdot C_{osc}} [Hz]$$

4.4 Power supply

The device has a built-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:

$$R_{VDD} = \frac{V_{supply} - 5.2V}{10mA} \quad V_{supply} \dots \text{Minimum Supply voltage}$$

Power dissipation of Rvdd;

$$P_{Rvdd} = \frac{(V_{supply} - 5.2V)^2}{R_{VDD}}$$

To ensure proper operation the minimum supply voltage should be chosen 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

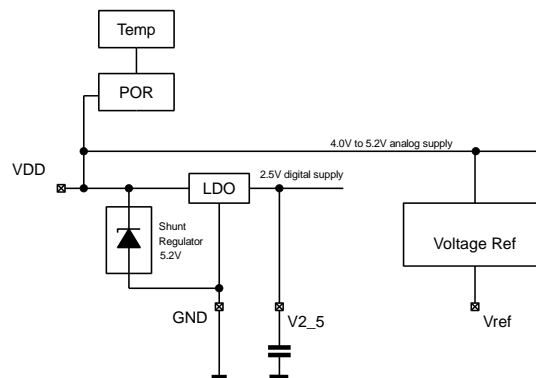
4.5.1 Temperature shutdown

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 built-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

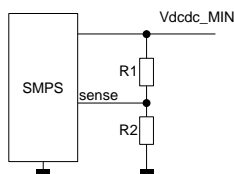


The reference circuit generates an internal supply voltage of 2.5V for the digital logic.

4.7 Dynamic feedback control

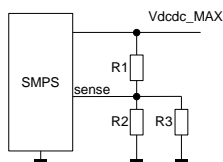
The output of pins “FB12” and “FB34” can be used to control any external power supply for best power efficiency. Every power supply senses its output voltage with a resistive voltage divider. This voltage divider can be modified to set the output voltage between a minimum output voltage V_{MIN} and a maximum output voltage V_{MAX} . 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



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

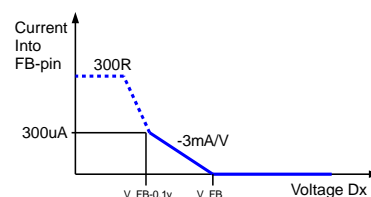
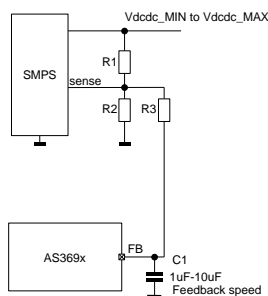
Step 2: Add the Resistors R3 in the power supply according to the maximum output voltage



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

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.

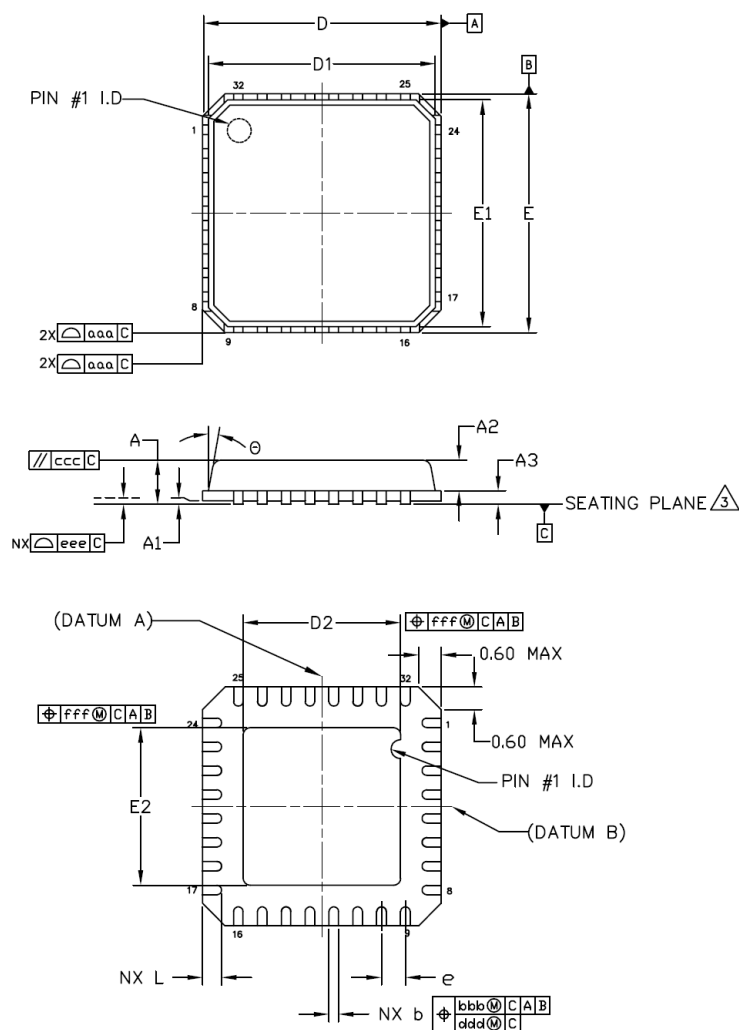
5 Pinout and Packaging

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 |
| F2 | 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:

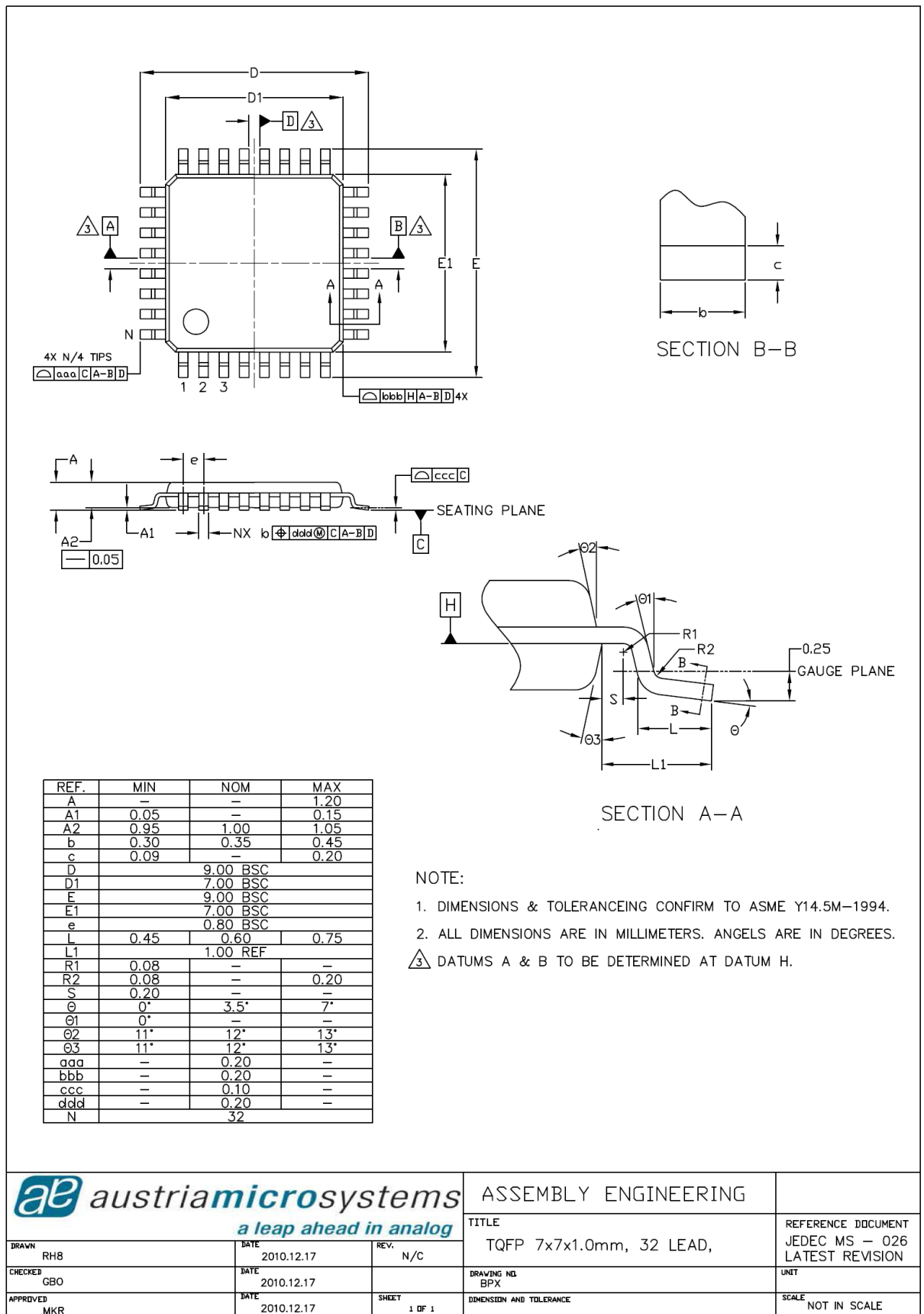
- DIMENSIONS & TOLERANCEING CONFIRM TO ASME Y14.5M-1994.
- ALL DIMENSIONS ARE IN MILLIMETERS. ANGLES ARE IN DEGREES.
- COPLANARITY APPLIES TO THE EXPOSED HEAT SLUG AS WELL AS THE TERMINAL.
- RADIUS ON TERMINAL IS OPTIONAL.
- N IS THE TOTAL NUMBER OF TERMINALS.

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| | | | | |
|-----------------|--------------------|-----------------|---|---|
| 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. QJ | UNIT |
| APPROVED MKR | DATE 2010.12.15 | SHEET 1 OF 1 | DIMENSION AND TOLERANCE | SCALE NOT IN SCALE |

5.3 Package Drawing TQFP32



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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