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The technical content of this austriamicrosystems datasheet is still valid.

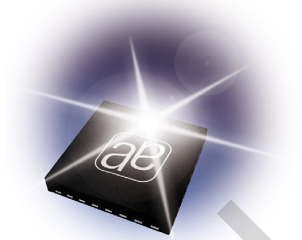
Contact information:

Headquarters:
ams AG
Tobelbaderstrasse 30
8141 Unterpremstaetten, Austria
Tel: +43 (0) 3136 500 0
e-Mail: ams_sales@ams.com

Please visit our website at **www.ams.com**

AS3636

Xenon Driver IC with LED Driver and Life Time Counter



1 General Description

The AS3636 is a highly integrated photoflash charger including IGBT driver, inductive DCDC boost autofocus/video LED driver, an indicator LED driver and it includes system level ESD protection and a breakable fuse.

The AS3636 includes flash timeout, over- and undervoltage, overtemperature and LED short circuit protection functions. To reduce production test time a broken transformer or a broken coil is detected.

The AS3636 is controlled by an I^2C interface with a dedicated STROBE input. Additionally the TORCH input controls the torch function. An interrupt output is available to signal an error condition to the controller.

The device includes 11 Bytes EEPROM, and an automatic life time counter to count the number of flashes performed.

The AS3636 is available in a space-saving WL-CSP package and operates over the -30ºC to +85ºC temperature range.

Warning: Lethal voltages are present on applications using AS3636! Do not operate without training to handle high voltages.

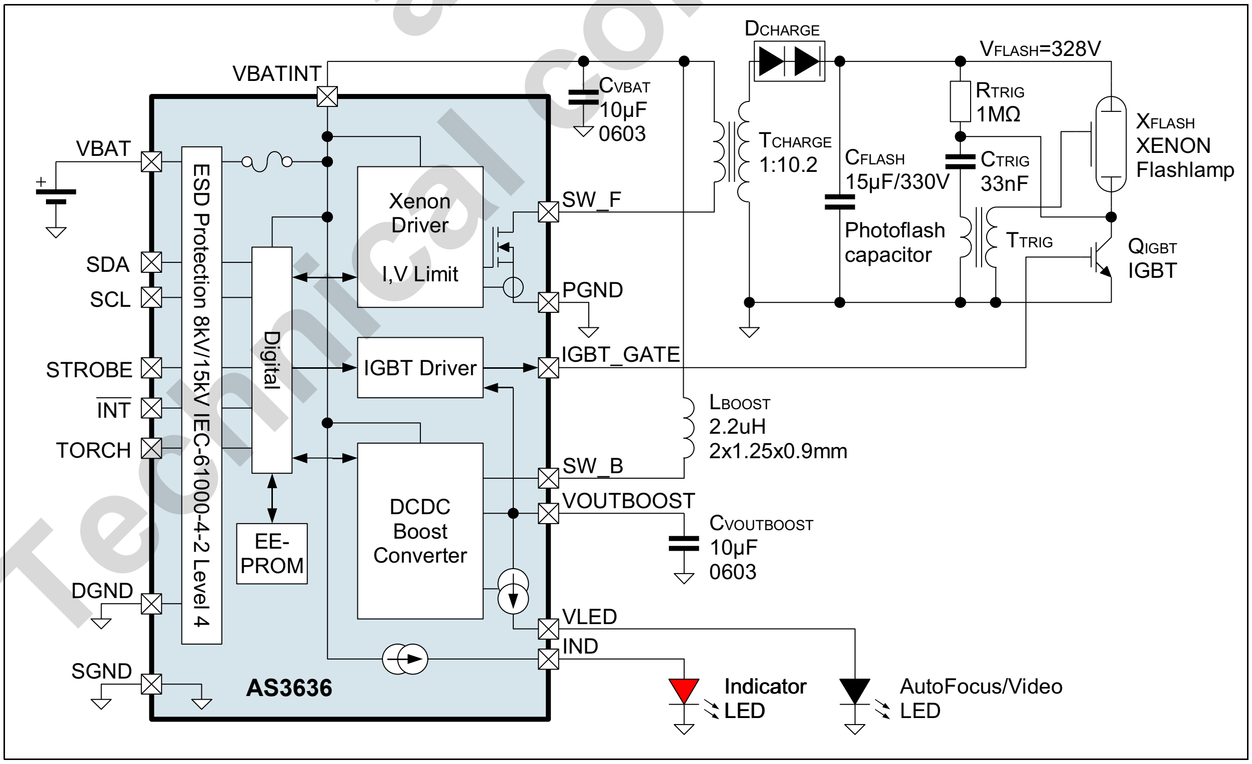
2 Key Features

- Xenon driver
  - Adjustable recharge timings
  - Adjustable current limits
  - In-production trimmable end of charge voltage
- IGBT Driver
  - Trimmable IGBT voltages
  - Trimmable IGBT driving waveform
  - Internal flash duration timer
  - External STROBE input
- DCDC Boost Converter
  - Autofocus/video LED current source
  - Voltage supply for IGBT
- Integrated one time breakable fuse in supply path
- Integrated system level ESD protection according to IEC-61000-4-2 Level 4 (8kV contact, 15kV air discharge)
- Available in tiny WL-CSP Packages 4x4 balls 0.5mm pitch, 2.0 x 2.15 x 0.6 mm

3 Applications

Xenon Flash with LED Torch for mobile phones

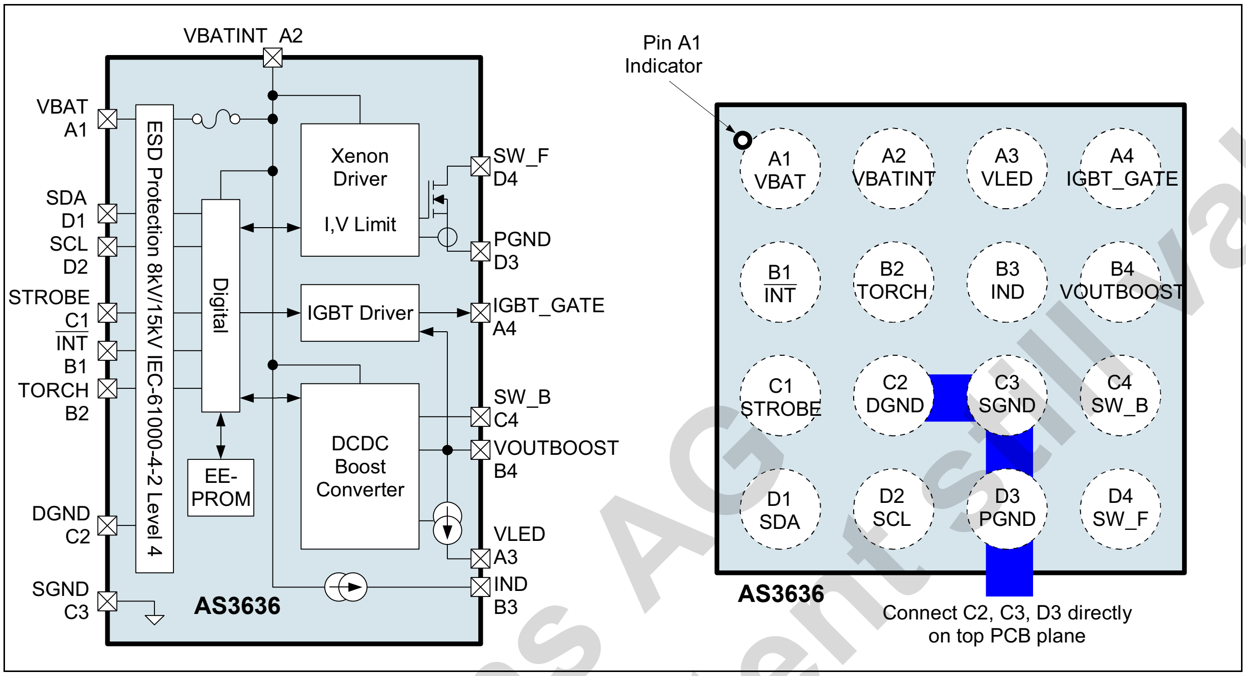
Figure 1. AS3636 Typical Operating Circuit



4 Pinout

Pin Assignment

Figure 2. Pin Assignments (Top View)



Pin Description

Table 1. Pin Description for AS3636

Pin Number	Pin Name	Description
A1	VBAT	Power supply voltage input
A2	VBATINT	Fuse output and internal power supply input - make a short connection to capacitor C_{VBAT}
A3	VLED	Autofocus (AF) / Torch LED output
A4	IGBT_GATE	Drive signal output for IGBT Transistor
B1	$\overline{\text{INT}}$	Interrupt output, open drain, active low
B2	TORCH	Torch signal input pin; internal pulldown resistor; connect to GND if not used
B3	IND	(Red) Indicator LED output - connect to GND if not used (set ILP=0)
B4	VOUTBOOST	DCDC Boost converter output - make a short connection to $C_{VOUTBOOST}$
C1	STROBE	Strobe signal input pin to synchronize the flash pulse - usually connected to the camera processor; internal pulldown resistor to GND
C2	DGND	Digital ground supply - connect directly to ground (GND)
C3	SGND	Analog signal ground - connect directly to ground (GND)
C4	SW_B	DCDC Boost converter switching node - connect to coil L_{BOOST}
D1	SDA	serial data input for I^2C interface
D2	SCL	serial clock input for I^2C interface
D3	PGND	Power ground for Xenon and DCDC Boost - connect directly to ground (GND)
D4	SW_F	Xenon DCDC converter switching node - connect to transformer T_{CHARGE}

5 Absolute Maximum Ratings

Stresses beyond those listed in Table 2 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 Table 3, "Electrical Characteristics," on page 4 is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Table 2. Absolute Maximum Ratings

Parameter	Min	Max	Units	Comments
VBAT, VBATINT to GND	-0.3	+7.0	V	
SDA, SCL, STROBE, $\overline{\text{INT}}$, TORCH, IGBT_GATE, SW_B, VOUTBOOST, VLED, $\overline{\text{IND}}$ to GND	-0.3	VBATINT + 0.3	V	max. 7.0V
SW_F to GND	-0.3	+55.0	V	
VOUTBOOST to SW_B	-0.3		V	**Note:** Diode VOUTBOOST / SW_B
SGND, DGND, PGND to GND	0.0	0.0	V	Connect SGND, DGND and PGND to GND directly below the pad
Input Pin Current without causing latchup	-100	+100	mA	JESD78
Continuous Power Dissipation (T_A = +70ºC)				
Continuous power dissipation		1	W	P_T[1]
Continuous power dissipation derating factor		14.7	mW/ºC	P_{DERATE}[2]
Electrostatic Discharge				
ESD pins VBAT, SDA, SCL, STROBE, $\overline{\text{INT}}$, TORCH		±15000	V	Air Discharge to module; IEC 61000 -4 -2 test bench[3]
		±8000	V	Contact Test to module; IEC 61000 -4 -2 test bench[3]
ESD HBM		±2000	V	JEDEC JESD22-A114F
ESD CDM		±500	V	Norm: JEDEC JESD 22-C101E
ESD MM		±100	V	Norm: JEDEC JESD 22-A115-B
Temperature Ranges and Storage Conditions				
Junction Temperature		+150	ºC	Internally limited (overtemperature protection), max 20000s
Storage Temperature Range	-55	+125	ºC	
Humidity	5	85	%	Non condensing
Body Temperature during Soldering		+260	ºC	according to IPC/JEDEC J-STD-020
Moisture Sensitivity Level (MSL)	MSL 1			Represents a max. floor life time of unlimited
Fuse				
Fuse Melting time - I_{FUSE_LIMIT}		1000	ms	at 1.5A
	typ. 100		ms	at 2A
Fuse operating current - I_{FUSE}		650	mA	

1. Depending on actual PCB layout and PCB used
2. P_{DERATE} derating factor changes the total continuous power dissipation (P_T) if the ambient temperature is not 70ºC. Therefore for e.g. T_{AMB}=85ºC calculate P_T at 85ºC = P_T - P_{DERATE} * (85ºC - 70ºC)
3. Assembled on PCB board (requires capacitor C_{VBAT}); system test for completed module (fully capsuled), no permanent interruption of operation; proper layout required; an ESD pulse might trigger a reset of AS3636

6 Electrical Characteristics

V_{BAT} = +2.7V to +4.4V, T_{AMB} = -30ºC to +85ºC, unless otherwise specified. Typical values are at V_{BAT} = +3.7V, T_{AMB} = +25ºC, unless otherwise specified.

Table 3. Electrical Characteristics

Symbol	Parameter	Condition	Min	Typ	Max	Unit
General Operating Conditions						
V_{BAT}	Supply Voltage		2.7	3.7	4.4	V
$V_{BATFUNCTIONAL}$	Supply Voltage	AS3636 functionally working, but not all parameters fulfilled (after voltage has been above V_{UVLO} before)	2.5		5.5	V
$I_{SHUTDOWN}$[1]	Shutdown Current	Shutdown or standby mode, V_{BAT}<3.7V, 0ºC < T_{AMB} < 50ºC; SCL=SDA=TORCH=STROBE=0V		0.5	1.0	µA
I_{STANBY}[1]	Standby Current	Shutdown or standby mode, V_{BAT}<3.7V, 0ºC < T_{AMB} < 50ºC; TORCH=STROBE=0V		1.0	10.0	µA
$I_{STROBEWAIT}$	Current when AS3636 is waiting for strobe	DCDC operating, IGBT driver enabled		5		mA
T_{AMB}	Operating Temperature		-30	25	85	ºC
V_{UVLO}	Undervoltage Lockout	Undervoltage lookout is only enabled if the Xenon Charger or DCDC step up converter is running; Falling V_{VIN}	2.3	2.4	2.5	V
		Undervoltage lookout is only enabled if the Xenon Charger or DCDC step up converter is running; Rising V_{VIN}	V_{UVLO} +0.05	V_{UVLO} +0.1	V_{UVLO} +0.15	V
T_{OVTEMP}	Overtemperature Protection	Junction temperature		144		ºC
$T_{OVTEMPHYST}$	Overtemperature Hysteresis	Junction temperature		5		ºC
Fuse						
R_{FUSE}	Fuse resistance	Fuse melting times: see Table 2 on page 3			0.2	Ω
EEPROM						
t_{EE_WRITE}	EEPROM writing time		10	14.5	24	ms
n_{MAX_WRITE}	EEPRIM writing cycles	T_{AMB} < 85ºC			100k	Cycles
Xenon Capacitor Charger						
$V_{TRIPRANGE}$	Programming range of V_{TRIP}	6 bit programming measured on pin SW_F Allows in-circuit trimming of the final charged voltage V_{FLASH} on capacitor C_{FLASH}	28.5		34.8	V
$V_{TRIP\Delta}$	Comparator trip voltage accuracy	V_{FLASH}=328V, T_J=15ºC...50ºC using nominal valued components	-0.5		+0.5	%
		V_{FLASH}=328V using nominal valued components	-1.5		+0.5	%
η	Charging Efficiency	System Target only; depends on external components used	60			%
V_{SW}	Maximum voltage on pin SW				50	V
I_{SW}	Switching current limit	Accuracy at typical setting	-13%	750	+10%	mA
		Adjustable range by register switch_current_selection (see page 31)	375	750	900	mA
t_{EOC_DET}		end of charge comparator trigger time - see Figure 20, "AS3636 Internal Circuit," on page 11	128	138	148	ns

Table 3. Electrical Characteristics (Continued)

Symbol	Parameter	Condition	Min	Typ	Max	Unit
$R_{NMOS\_SW\_F}$	On resistance of switch	between SW_F and PGND		0.4	0.7	Ω
DCDC Step Up Converter						
$V_{VOUTBOOST}$	DCDC Boost output Voltage (pin VOUTBOOST)	Voltage feedback mode (e.g. if used for IGBT driver)	4.5	4.8	5.25	V
		Current feedback mode; max. $V_{VOUTBOOSTMAX}$		VLED+0.4		V
f_{CLK}	Operating Frequency	All internal timings are derived from this oscillator; -30ºC - 85ºC	-7.5%	2.0	+7.5%	MHz
		T_J=0ºC - 75ºC	-5.0%		+5.0%	
AF LED Driver						
I_{VLED}	VLED current source output	Adjustable by AF_LED_current, limited to Max_LED_current	10.0		80.0	mA
$I_{VLED\Delta}$	VLED current source accuracy		-7.5		+7.5	%
V_{VLED}	VLED forward voltage		1.7		3.6	V
V_{VLED_COMP}	Current Source Compliance	VOUTBOOST-VLED current source voltage compliance		200	350	mV
Red privacy indicator LED (pin IND)						
I_{IND}	IND current source output	adjustable by IND_LED_current	2		16	mA
$I_{IND\Delta}$	IND current source accuracy	VBATINT > 2.7V, indicator LED forward voltage between 1.3V and 2.4V (e.g. use red LED)	-10		+10	%
IGBT Driver (pin IGBT_GATE)						
R_{IGBT_GATE}	Output driver series resistance	measured at IGBT_fall_speed2zero=50mA, V(IGBT_GATE)=0.8V	15	20	25	Ω
		all current settings and output voltages	15	20		Ω
I_{IGBT_RISE}	IGBT_GATE rise current	For a IGBT with 10nF gate capacitance results in 0.5V/µs(5mA)...8V/µs(80mA); adjustable by IGBT_rise_and_fall_speed, IGBT_fall_speed2zero, IGBT_fall2zero_slow Driving to $V_{VOUTBOOST}$ (typ. 5.0V, DCDC in voltage feedback mode)	10		80	mA
I_{IGBT_FALL}	IGBT_GATE fall current		5		80	mA
$I_{IGBT\Delta}$	IGBT_GATE current tolerance	parameter I_{IGBT_RISE} and I_{IGBT_FALL}; >10mA	-20		+20	%
		5mA and 10mA setting	-25		+25	%
Protection and Fault Detection Functions						
$V_{VOUTBOOSTMAX}$	DCDC Boost maximum voltage	in current feedback mode	4.5		5.5	V
I_{LIMIT}	Current Limit for coil L_{BOOST} (Pin SW_B) measured at 50% PWM duty cycle[2]	coil_peak_current= 00b		0.25		A
		01b		0.3		
		10b	-10%	0.35	+10%	
		11b		0.4		
$V_{VLEDSHORT}$	AF LED short circuit detection voltage	Voltage measured on pin VLED		1.2	1.65	V
$V_{VLEDOPEN}$	AF LED open circuit detection voltage	Voltage measured on pin VLED		4.4		V
$V_{INDSHORT}$	Indicator LED short circuit detection voltage	Voltage measured on pin IND		0.7	1.2	V

Table 3. Electrical Characteristics (Continued)

Symbol	Parameter	Condition	Min	Typ	Max	Unit
$I_{IND\_OUT\ OPEN}$	IND current open detection	Detection threshold for open indicator detection on pin IND		45		% of I_{IND_OUT}
Digital Interface						
V_{IH}	High Level Input Voltage	Pins SDA, SCL, TORCH	1.26		VBAT	V
V_{IL}	Low Level Input Voltage	Pins SDA, SCL, TORCH	0.0		0.54	V
$V_{IHSTROBE}$	High Level Input Voltage	Pin STROBE	0.74		VBAT	V
$V_{ILSTROBE}$	Low Level Input Voltage	Pin STROBE	0.0		0.54	V
V_{OL}	Low Level Output Voltage	Pins $\overline{INT}$ and SDA; with pullup >1kΩ to digital supply <2V, VBAT>2.7V			0.3	V
I_{LEAK}	Leakage current	Pins SDA, SCL, $\overline{INT}$	-10		+10	µA
$R_{PULLDOWN}$	Pulldown resistor to GND	Pins TORCH and STROBE, at 1.8V	30	48	65	kΩ
		Pins TORCH and STROBE, at 1.2V		37.5		kΩ
$t_{DEBTORCH}$	TORCH debounce time		6.3	9	11.7	ms
t_{STROBE_MIN}	STROBE minimum timing			200		ns
I²C mode timings - see Figure 3 on page 7						
$t_{TIMEOUT}$	SCL timeout	In active mode, if SCL is low for this time, the device enters shutdown mode - see Figure 21, "AS3636 operating mode," on page 12	35		100	ms
f_{SCLK}	SCL Clock Frequency		30		400k	Hz
t_{BUF}	Bus Free Time Between a STOP and START Condition		1.3			µs
$t_{HD:STA}$	Hold Time (Repeated) START Condition[3]		0.6			µs
t_{LOW}	LOW Period of SCL Clock		1.3			µs
t_{HIGH}	HIGH Period of SCL Clock		0.6			µs
$t_{SU:STA}$	Setup Time for a Repeated START Condition		0.6			µs
$t_{HD:DAT}$	Data Hold Time[4]		0		0.9	µs
$t_{SU:DAT}$	Data Setup Time[5]		100			ns
t_R	Rise Time of Both SDA and SCL Signals		20 + $0.1C_B$		300	ns
t_F	Fall Time of Both SDA and SCL Signals		20 + $0.1C_B$		300	ns
$t_{SU:STO}$	Setup Time for STOP Condition		0.6			µs
C_B	Capacitive Load for Each Bus Line	C_B — total capacitance of one bus line in pF			400	pF

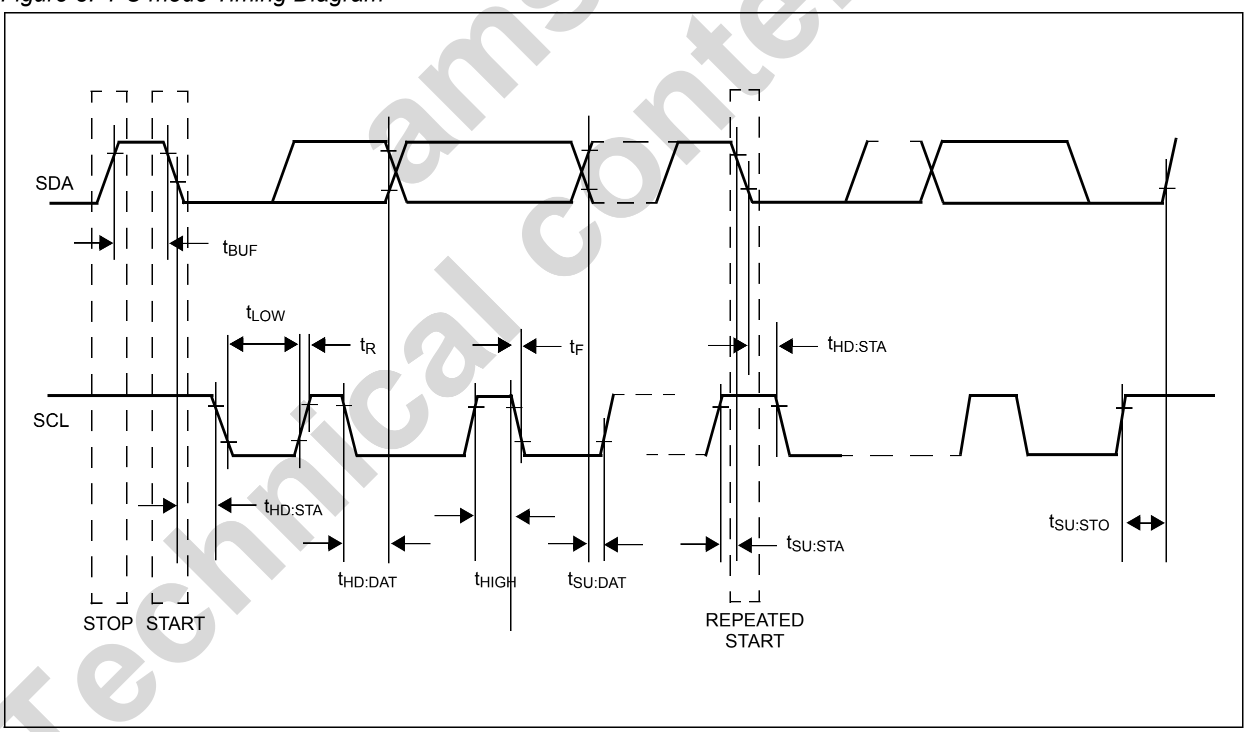
Table 3. Electrical Characteristics (Continued)

Symbol	Parameter	Condition	Min	Typ	Max	Unit
$C_{I/O}$	I/O Capacitance (SDA, SCL)				10	pF
Transformer Parameters - only use transformers approved by austriamicrosystems, see Approved Transformers on page 38						
$L_{PRIMARY}$	Primary Inductance			7		µH
N	Turns Ratio	for V_{FLASH}=330V (final charged voltage on C_{FLASH})		10.2		
$V_{ISOLATION}$	Isolation Voltage		500			V

1. $I_{SHUTDOWN}$ or I_{STANBY} includes leakage current for SW_B and SW_F.
2. Due to slope compensation of the current limit, I_{LIMIT} changes with duty cycle.
3. After this period, the first clock pulse is generated.
4. A device must internally provide a hold time of at least 300ns for the SDA signal (referred to the V_{IHMIN} of the SCL signal) to bridge the undefined region of the falling edge of SCL.
5. A fast-mode device can be used in a standard-mode system, but the requirement $t_{SU:DAT}$ = to 250ns must then be met. This is automatically the case if the device does not stretch the LOW period of the SCL signal. If such a device does stretch the LOW period of the SCL signal, it must output the next data bit to the SDA line t_R max + $t_{SU:DAT}$ = 1000 + 250 = 1250ns before the SCL line is released.

Timing Diagrams

Figure 3. I²C mode Timing Diagram



7 Typical Operating Characteristics

VBAT = 3.7V, CFLASH=25µF, Xenon transformer=TTRN3822H, switch_current_selection=900mA, TAMB=+25ºC, IGBT=RJP4003ANS, IGBT_rise_and_fall_speed=IGBT_fall_speed2zero=000b, (unless otherwise specified)

Figure 4. Charging Waveform

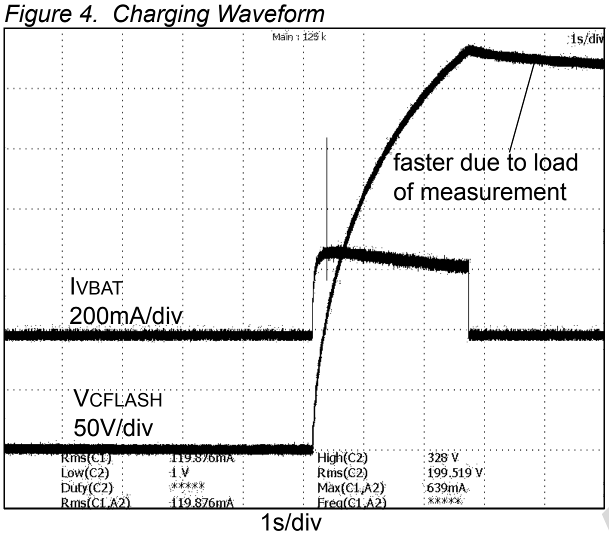


Figure 5. Charging Waveform VBAT=2.7V

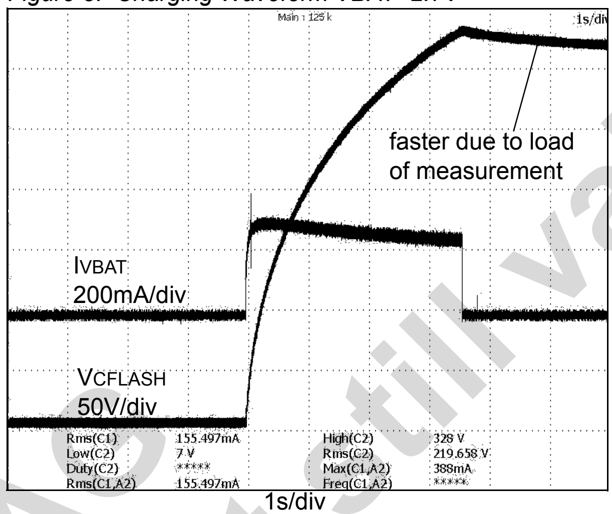


Figure 6. Charging Waveform VBAT=4.4V

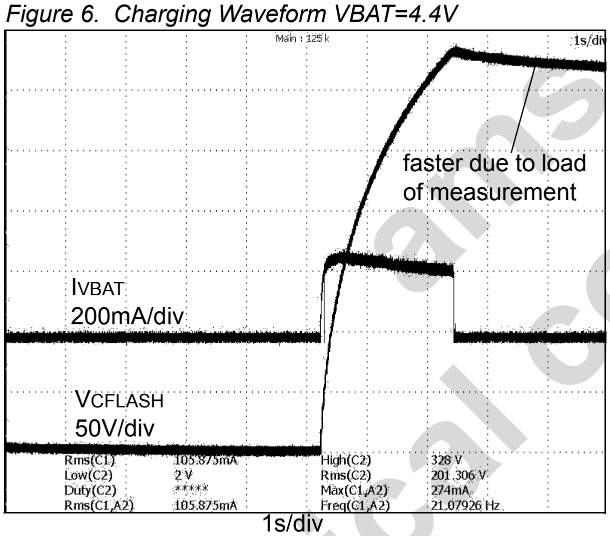


Figure 7. Xenon Charge Primary Current

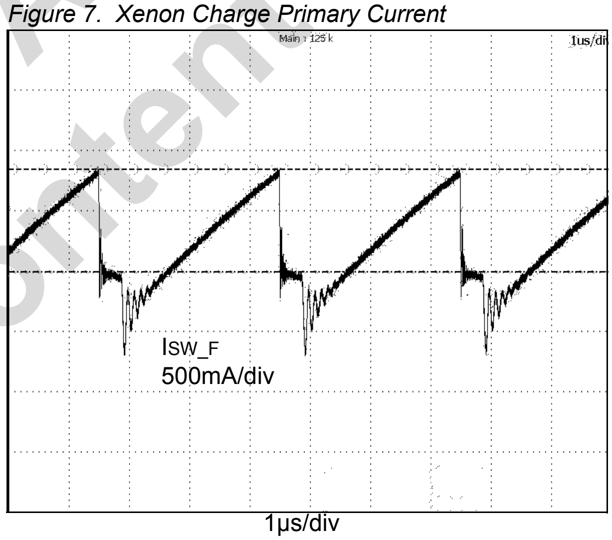


Figure 8. Xenon EOC vs. charge_voltage_selection

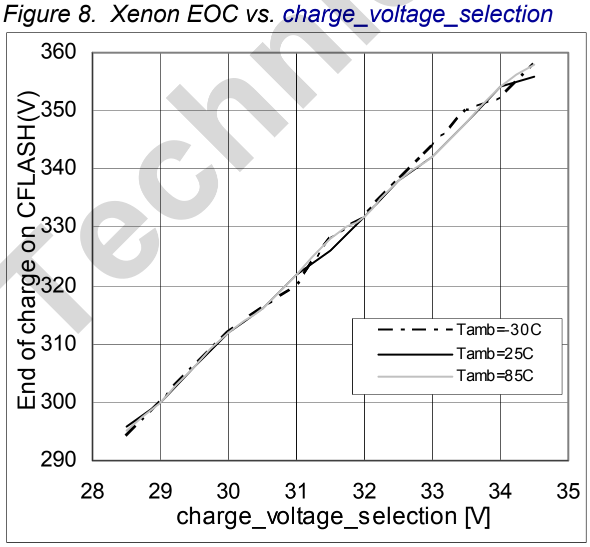


Figure 9. Xenon EOC vs. VBAT

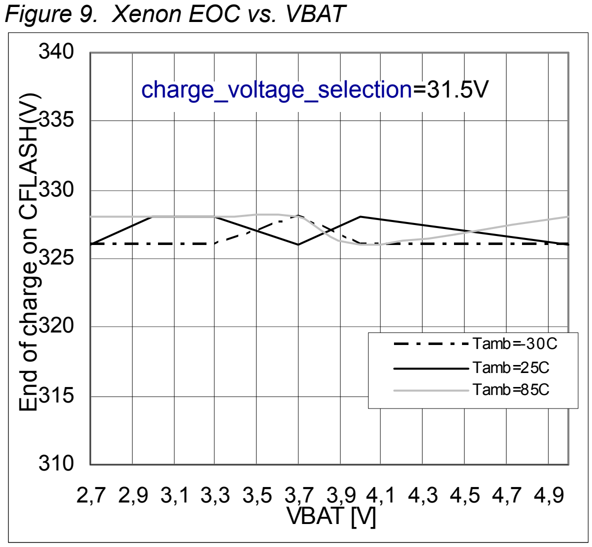


Figure 10. SW_F switching waveform

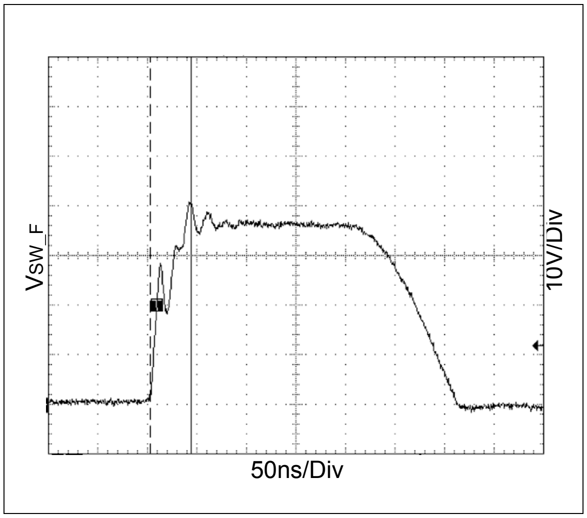


Figure 11. Oscillator frequency vs. VBAT

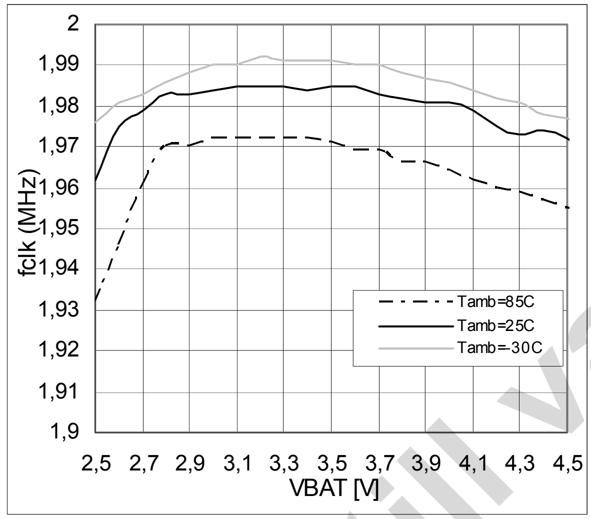


Figure 12. IGBT Drive waveforms

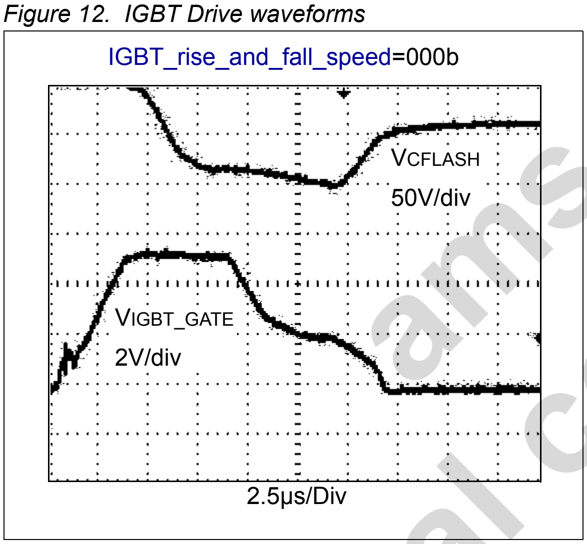


Figure 13. IGBT Drive waveforms

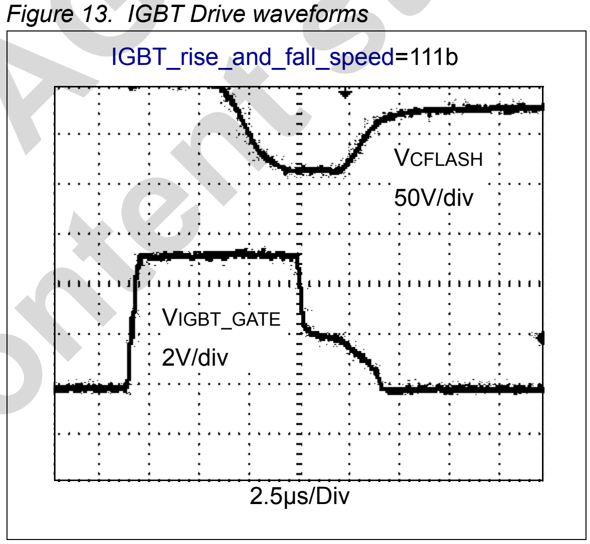


Figure 14. IGBT Drive waveforms SST Pulses

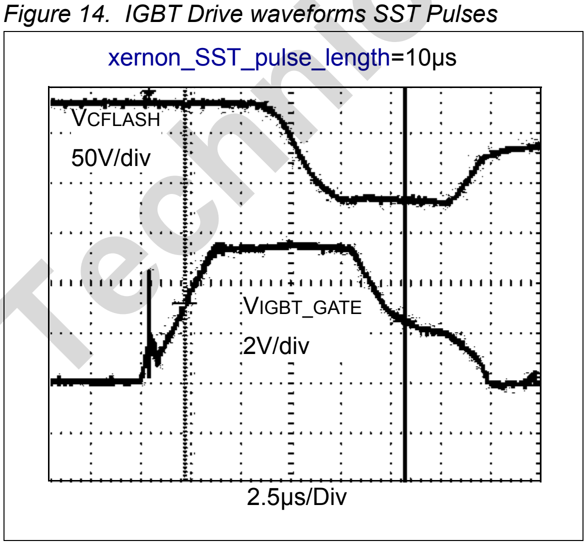


Figure 15. IGBT Drive waveforms SST Pulses

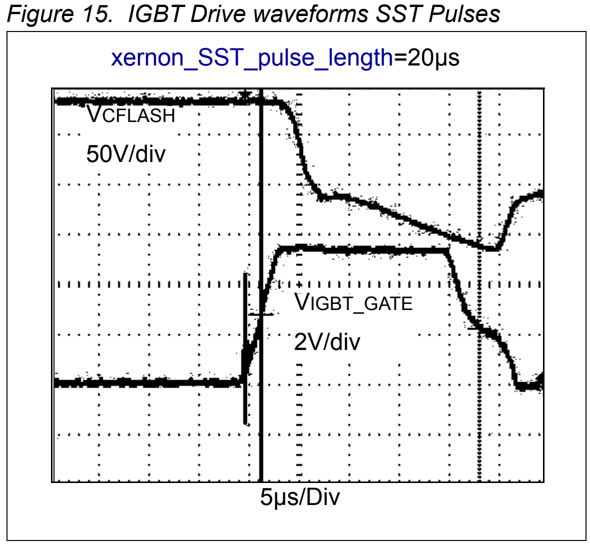


Figure 16. IGBT Drive waveforms SST Pulses

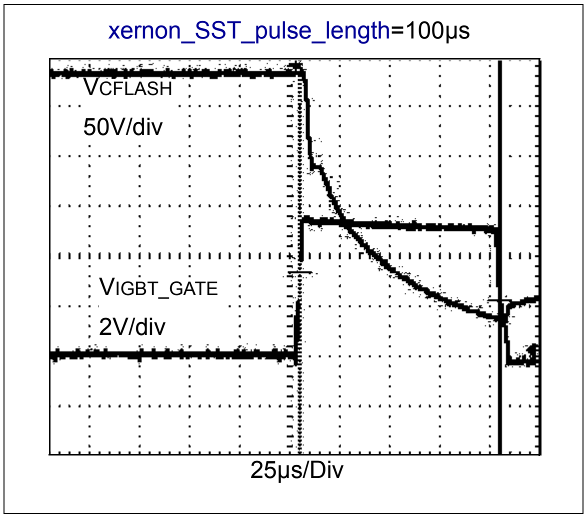


Figure 17. DCDC Boost Efficiency vs. V_{VBAT}

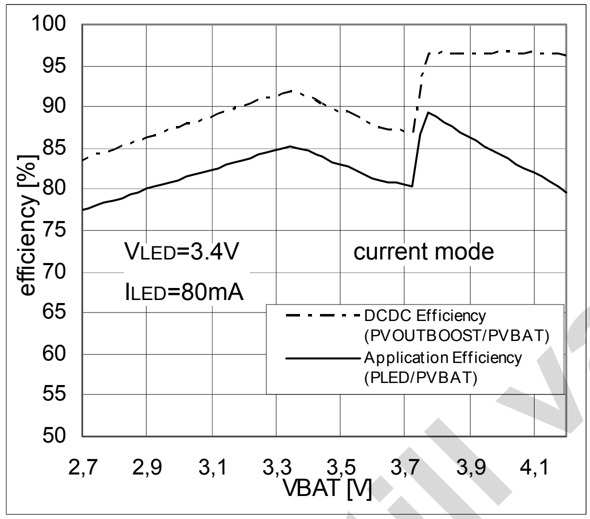


Figure 18. I_{VLED} vs. V_{VBAT} at 10mA

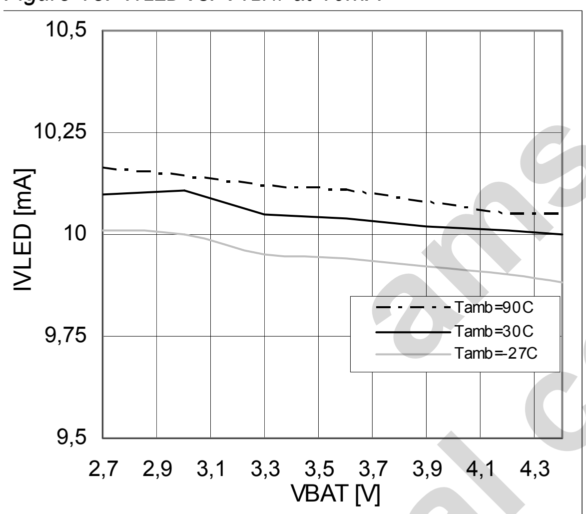
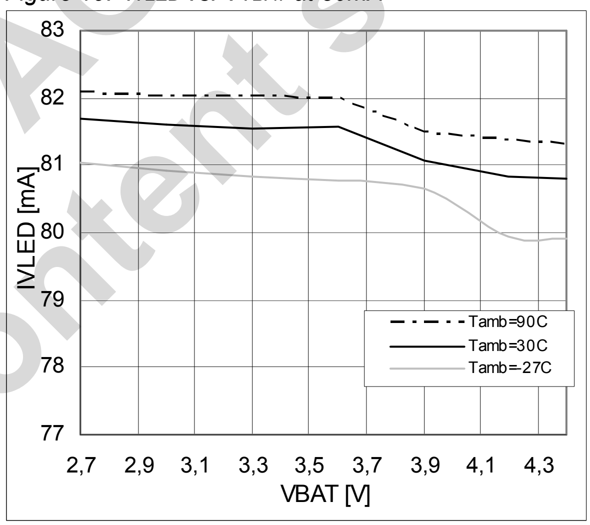


Figure 19. I_{VLED} vs. V_{VBAT} at 80mA



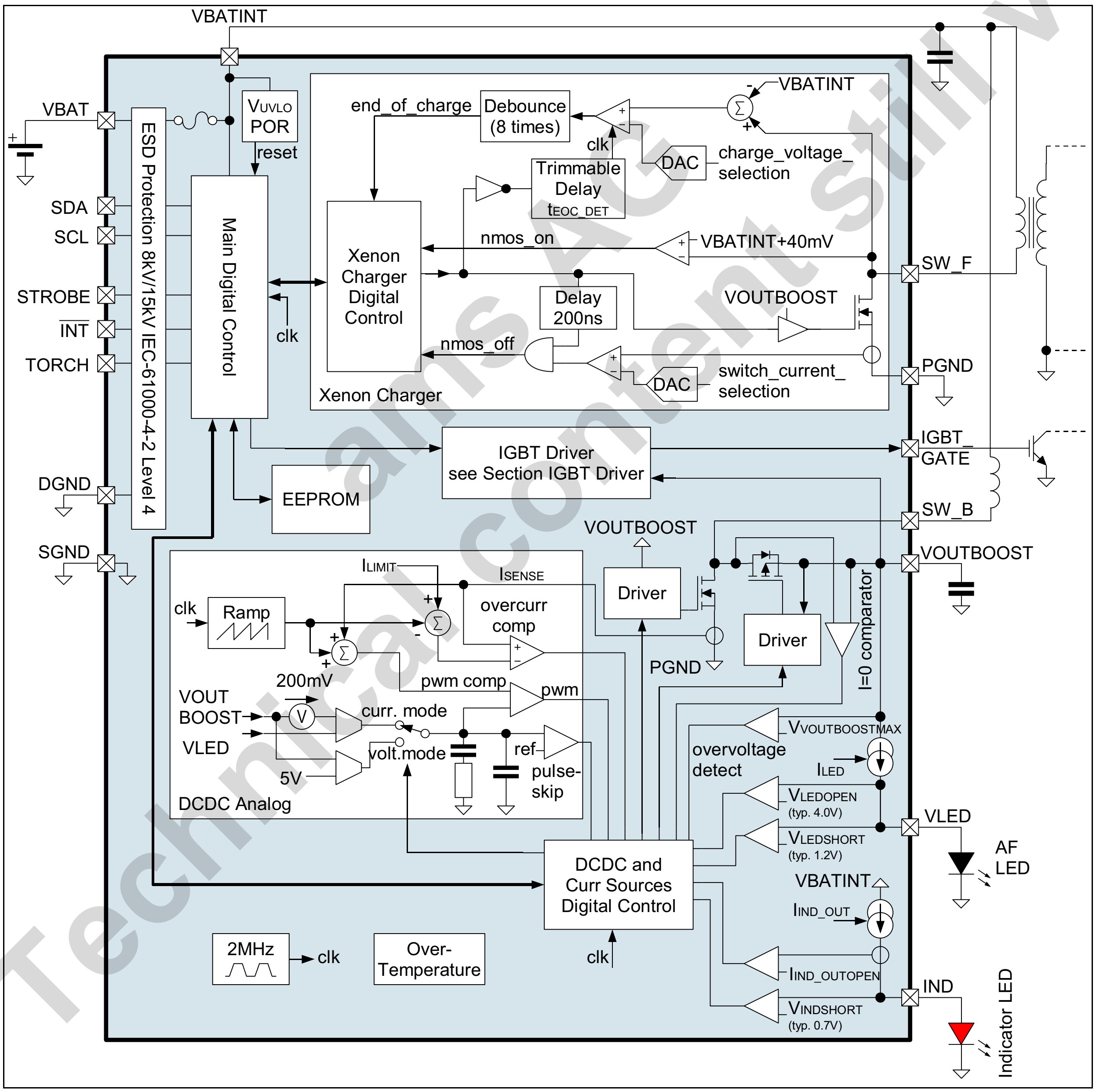
8 Detailed Description

The AS3636 is a highly integrated photoflash charger with build in IGBT driver, inductive DCDC boost autofocus/video LED driver, an indicator LED driver and it includes system level ESD protection and a breakable fuse. The integrated fuse will be blown if there is short circuitry in the module[1]. It is not reversible.

Note: The AS3636 uses a WL-CSP (wafer level chip scale package) to optimize the PCB area required and minimize the module size. Therefore the actual DIE is visible (and it is not molded in plastic as for other packages like QFN or DFN) and the AS3636 is sensitive to external light. It has to be protected from direct light from the Xenon tube.

Internal Circuit

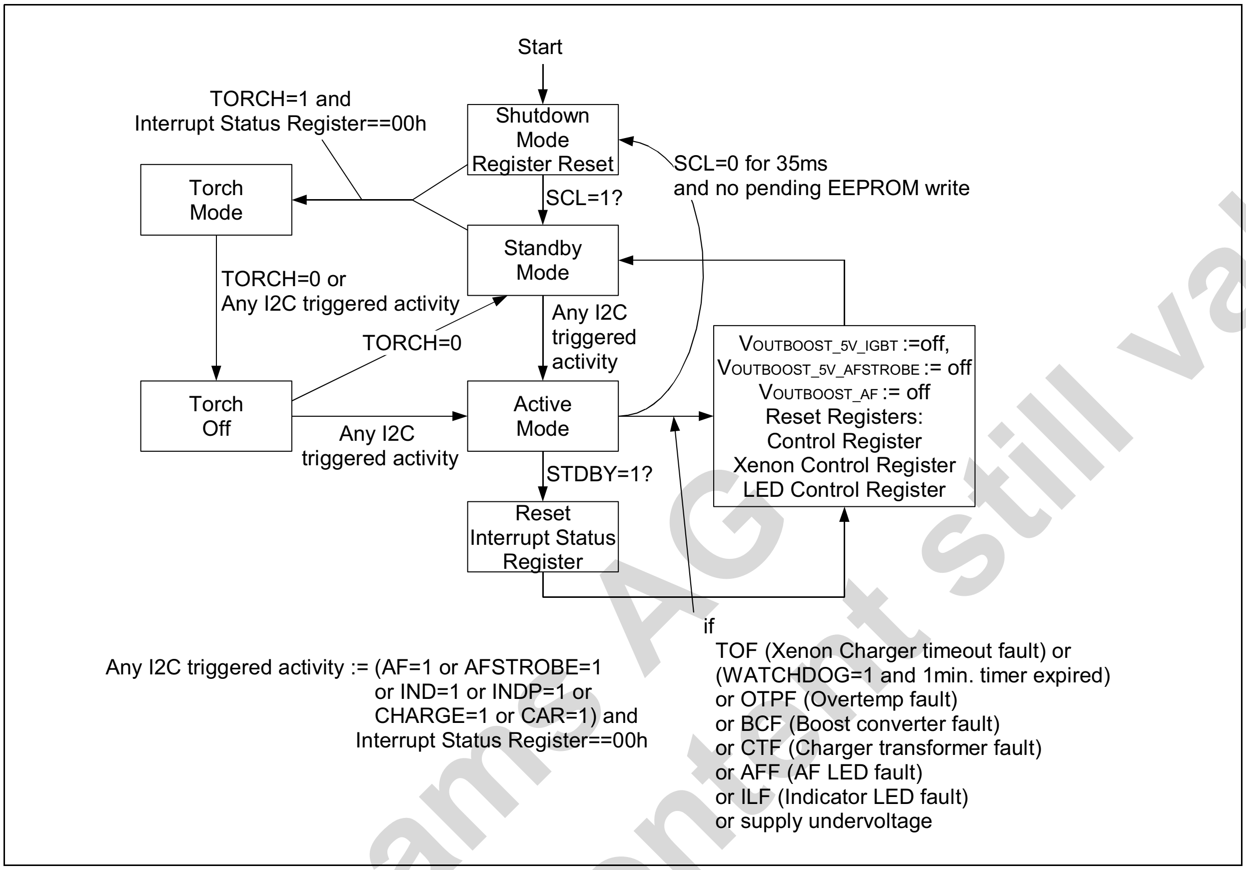
Figure 20. AS3636 Internal Circuit



1. The purpose is to fulfill the IEC60065 safety requirements (see section 14.5.4).

Operating modes

Figure 21. AS3636 operating mode



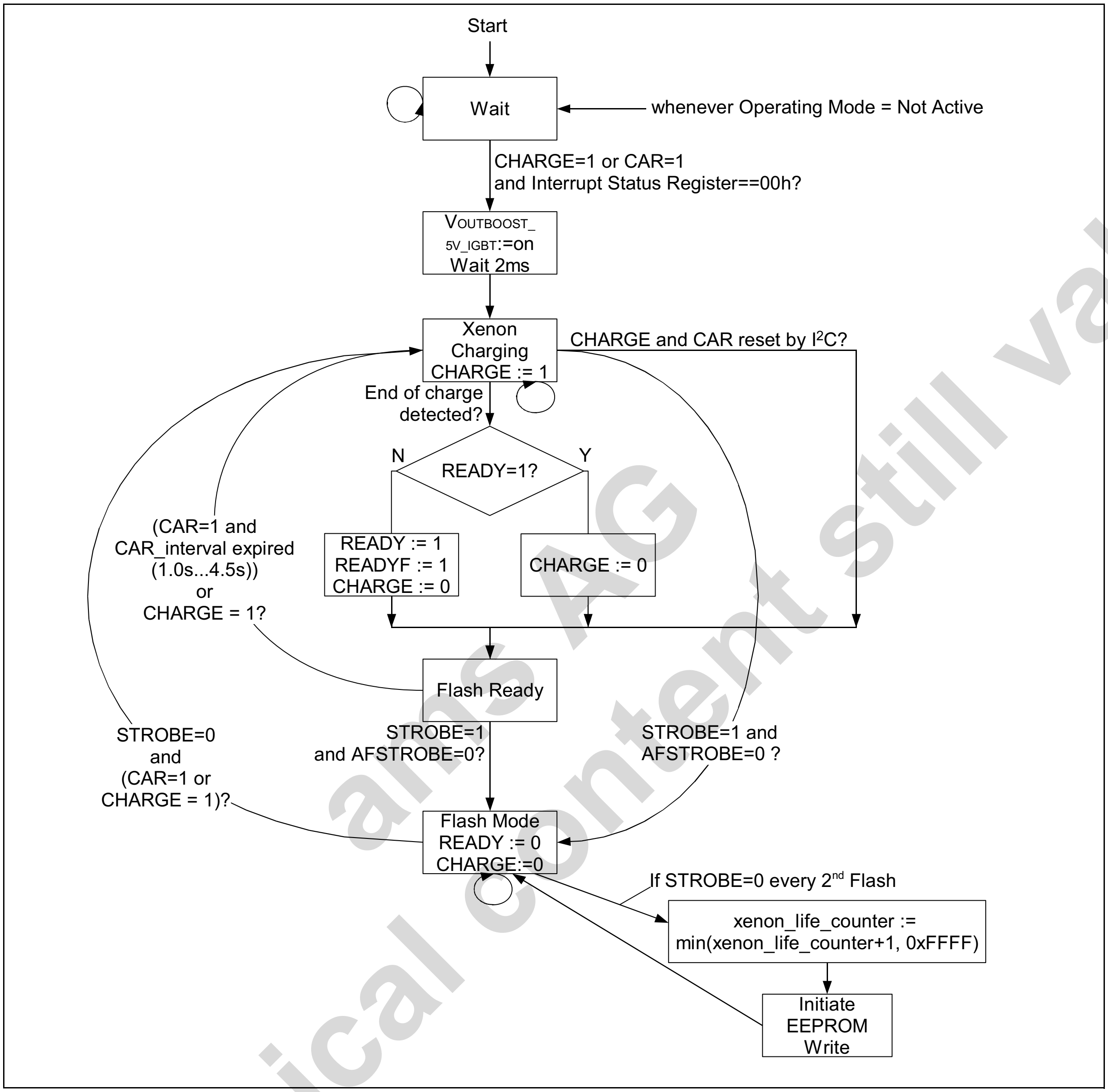
The internal operating modes are chosen according to the flowchart in Figure 21. The xenon charging procedure is described in Figure 22.

The AS3636 wakes up from shutdown mode by sensing its bus. If SCL rises, the AS3636 enters standby modes and the I^2C interface is operating. If any activity is sensed (any of the register bits AF, AFSTROBE, IND, INDP, CAR or CHARGE is set), the AS3636 enters active mode.

Note: If a previous fault has been detected (Interrupt Status Register (see page 36) not 00h - see Protection and Fault Detection Functions on page 21), the fault has to be cleared by reading of Interrupt Status Register before external Torch Mode or Active Mode can be used.

Note: Watchdog can be triggered (if WATCHDOG (see page 26)=1 and 1min. watchdog timer expired) only in active mode. There is no watchdog for Torch Mode (TORCH=1) - see Figure 21.

Figure 22. Xenon Charging Flowchart



Upon setting of CHARGE (see page 28) or CAR, VOUTBOOST is boosted to 5V[2], the Xenon capacitor charging is started. Once finished, charging is stopped (CHARGE is reset), READY and READYF s set and the interrupt line $\overline{INT}$ is pulled low (if not disabled by READYFI). Upon STROBE[3] a flash is started.

Upon release of STROBE and if the register bit CAR[4]=1 an automatic recharge cycle is started.

Every second flash cycle, the internal life time counter(xenon_life_counter_MSB and xenon_life_counter_LSB) inside the EEPROM (see EEPROM Writing Cycle on page 16) is updated to count the number of flash for the attached Xenon tube.

2. Using the internal signal VOUTBOOST_5V_IGBT - see DCDC Boost Converter VOUTBOOST on page 15
3. Using the register bit STROBE or the input signal STROBE
4. Capacitor Automatic Recharge

If no flash is triggered for CAR_interval time (can be set between 1.0s to 4.5s) and CAR = 1, the capacitor is automatically recharged.

Standby mode is entered upon following conditions and Xenon Control Register, LED Control Register and Control Register are reset to their default:

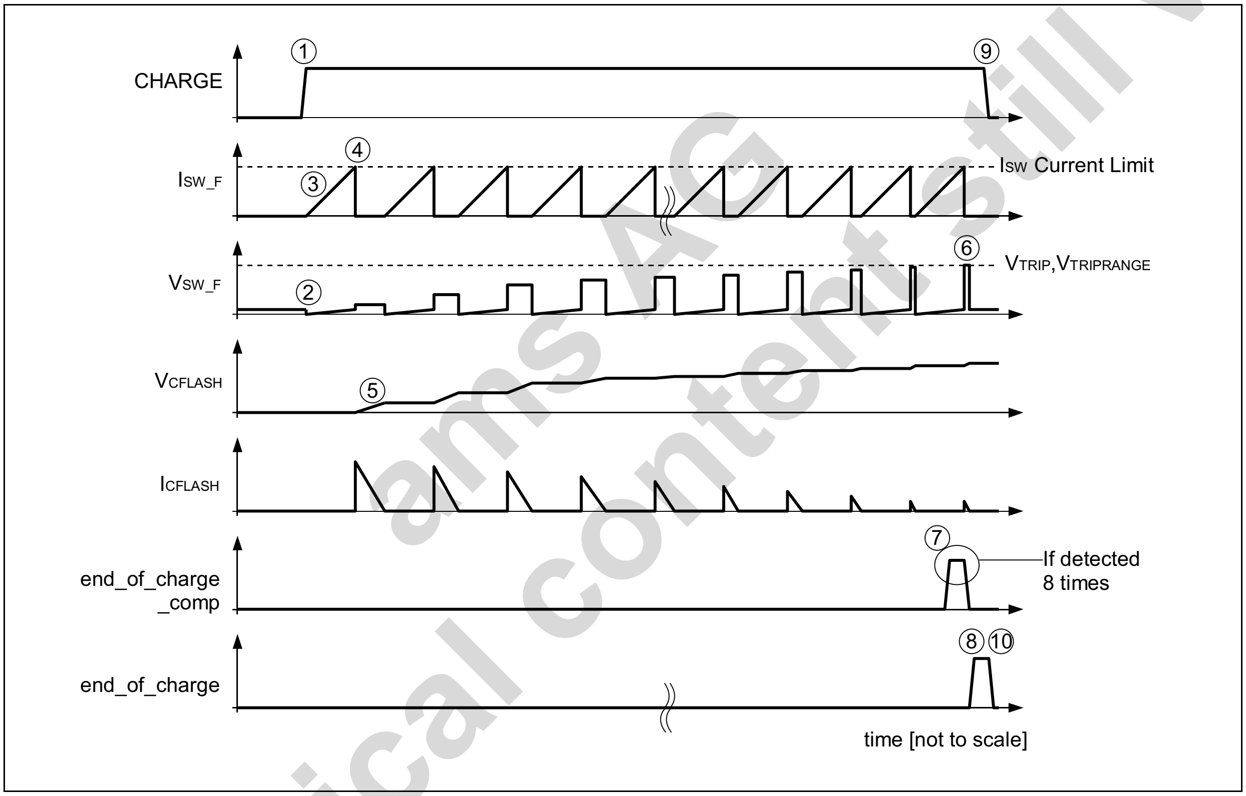
1. STDBY is set to 1 - additionally reset Interrupt Status Register
2. Any fault condition (TOF, CTF, BCF, OTPF, AFF or ILF)
3. No flash is triggered within one minute and WATCHDOG=1

By writing ‘1’ into register RESET, all registers can be reset to their default.

In active mode, if SCL = 0 for 35ms and an EEPROM write is not pending, all registers are reset to their default values and shutdown mode is entered reducing current consumption to a minimum.

Xenon Charging Waveform

Figure 23. Xenon Charging Waveform



The register CHARGE is set to high and charging begins (1).

During a single cycle, the internal NMOS transistor connects the pin SW_F to PGND (2). Therefore the current I_{SW_F} rises (3) until it reaches I_{SW} current limit (4) defined by switch_current_selection. Then the energy is transferred to the secondary side of the transformer and the voltage V_{CFLASH} on the flash capacitor C_{FLASH} rises (5).

The output voltage V_{CFLASH} gradually increases and once it hits the end of charge detection threshold defined by charge_voltage_selection (6) (detected on V_{SW_F} during the off time of the NMOS transistor between SW_F and PGND) 8 times (7)[5], end_of_charge[6] is set high (8). This automatically sets READY:=1 and CHARGE:=0 (9) finishing a full charging cycle (10) - see Figure 22.

Note: For simplicity the number of actual charging cycles (NMOS SW on/off) are reduced in Figure 23.

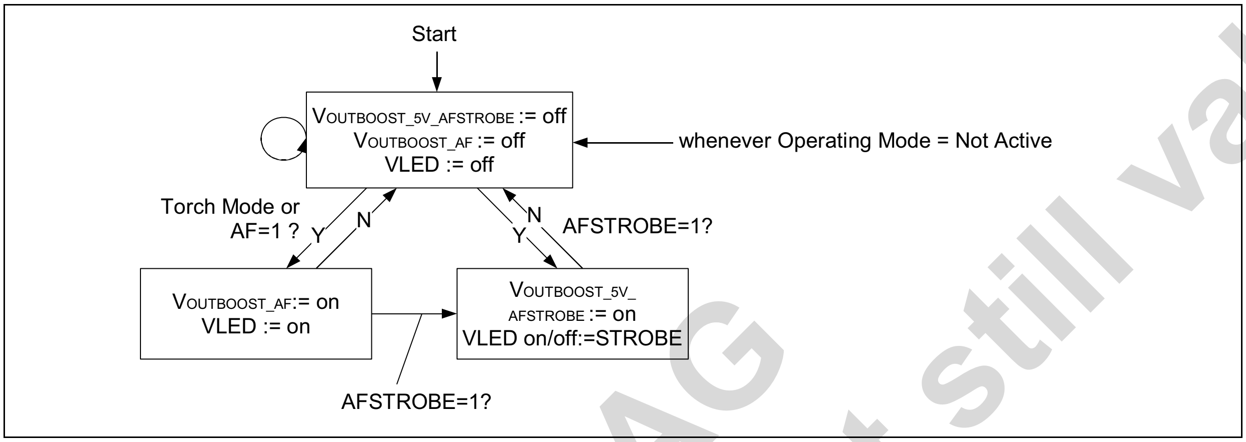
5. The 8 cycles required for actual detection of the end of charge conditions are not shown in Figure 23.
6. Internal signal - see Figure 20

Autofocus (AF) LED on pin VLED operating modes

The AF LED can be enabled with the TORCH input or the AF register bit or gated by the STROBE input if AFSTROBE is set. If AFSTROBE is used, the DCDC converter is always run at 5V[7] to allow for immediate reaction to the STROBE input signal (within µs). The AFSTROBE register bit has priority over AF signal or TORCH input.

If AF or AFSTROBE is used and WATCHDOG=1, the AF LED and DCDC boost converter is automatically disabled after one minute. Any read or write access to any AS3636 register resets this watchdog timer.

Figure 24. Autofocus LED operating modes



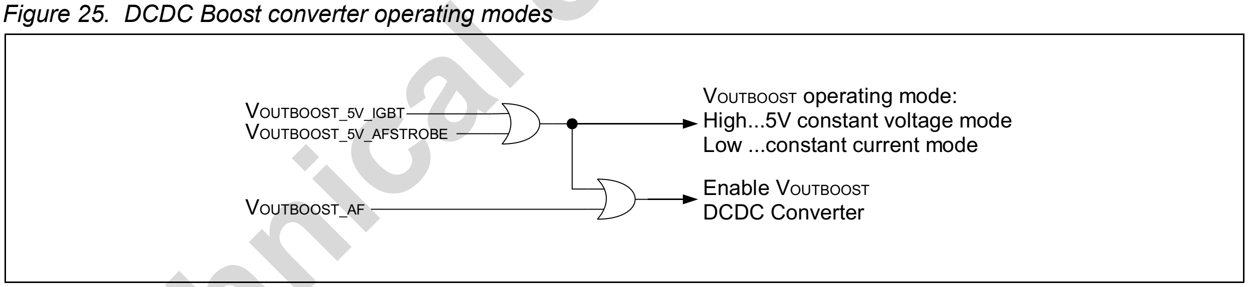
The LED current on pin VLED is defined by:

1. If in torch mode (see Figure 21, "AS3636 operating mode," on page 12) and the pin TORCH=H, the LED current is defined by Max_LED_current (AF_LED_PWM is not used). Do not use this operating mode if the battery voltage VBATINT is below V_{UVLO}[8].
2. If AF or AFSTROBE is set, the current is defined by AF_LED_current (limited to Max_LED_current). If PWM=1, then the AF_LED_current current is PWM modulated with a duty cycle defined by AF_LED_PWM.

DCDC Boost Converter VOUTBOOST

VOUTBOOST is used for the IGBT driver and for the autofocus (AF) LED. Therefore it supports 5V constant voltage output and a constant current mode (where the 5V voltage output has priority) as shown in Figure 25:

Figure 25. DCDC Boost converter operating modes



Note: If the input/output voltage ratio is too small or the output current is too low to allow continuous operation of the DCDC step-up converter (e.g. in constant current mode when the battery voltage is close or slightly below the LED forward voltage), the DCDC will use pulseskip operation for high efficiency. This can cause increased input current ripple on the battery supply. To avoid this condition, setting AFSTROBE=1 forces 5V operation of

7. Using the internal signal VOUTBOOST_5V_AFSTROBE - see DCDC Boost Converter VOUTBOOST
8. If operated below V_{UVLO}, the AS3636 will run in an infinite loop following procedure: startup, enable the LED and check for V_{UVLO} detecting a too low voltage and therefore stop again.

the DCDC and increase the input/output voltage ratio, but will reduce efficiency for the AF LED operation.

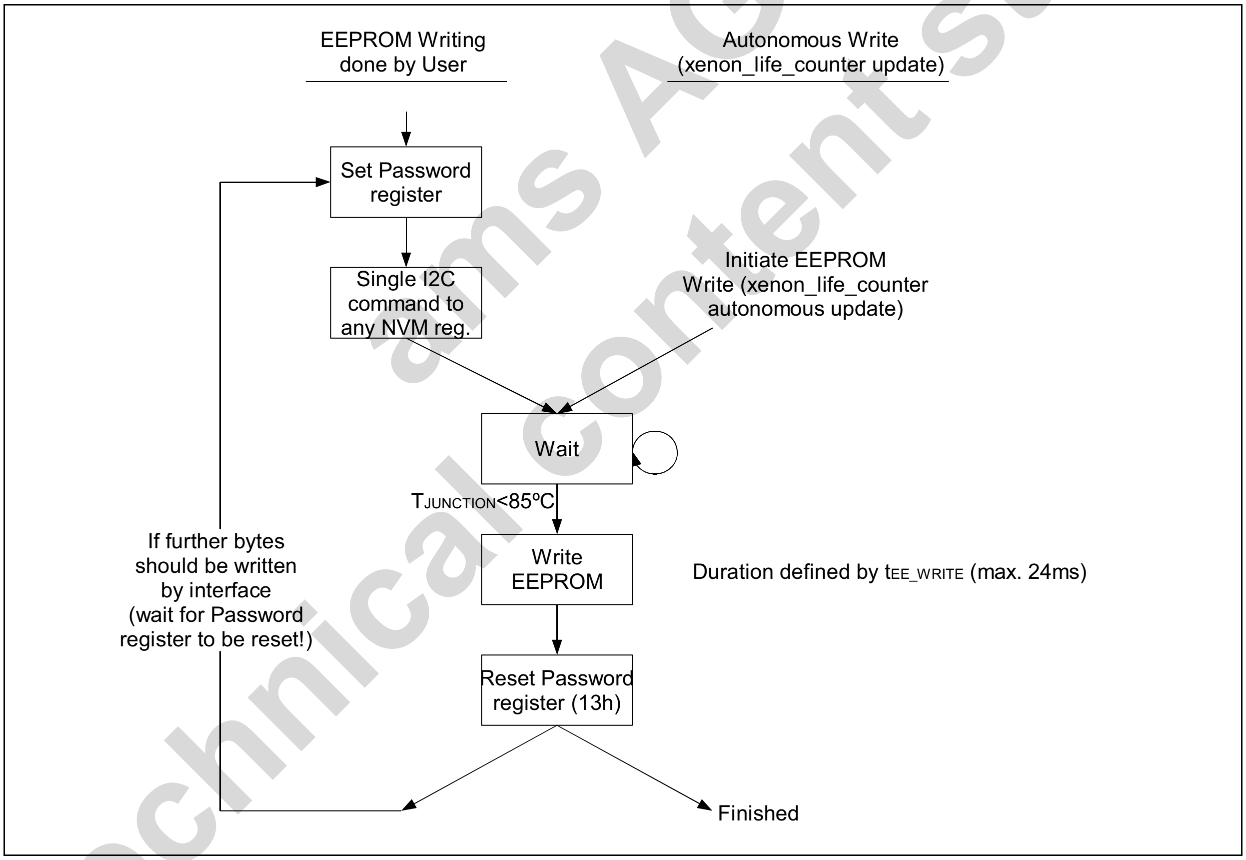
If the output voltage is set for 5V and there is no external load (5V generation for the IGBT driver only using VOUTBOOST_5V_IGBT=1 but no AF LED operation - see Figure 25), pulseskip operation will be used by the DCDC converter. In this case the current through the DCDC converter is very small and therefore the battery supply current ripple is increased only by a minimal amount.

EEPROM Writing Cycle

The internal EEPROM is updated under the following two conditions:

1. Life Time Counter: The automatic procedure for update of the internal life time counter is shown in Figure 26; the update of the xenon_life_counter_MSB (see page 30) and xenon_life_counter_LSB is done every 2nd flash cycle (see Figure 21 on page 12) increasing the value by one[9]. The counter does not run over 0xFFFFh.
2. NVM Register update: Any update to a NVM register[10] (See Register Map on page 36) through the interface has to be started by writing the password number[11] to the Password_register. Then the NVM can be written. Do not read or write NVM register during the life time counter is updated.
   If further bytes should be written, the user shall wait until the Password_register is reset by the AS3636 as shown in Figure 26[12].

Figure 26. EEPROM Writing Cycle



9. Allow minimum 48ms between updates of the xenon life time counter. Updates happen every 2nd flash pulse.
10. The xenon life time counter (xenon_life_counter_MSB and xenon_life_counter_LSB) cannot be changed.
11. Consult austriamicrosystems for the exact value to write into the Password_register
12. Do not initiate an EEPROM writing cycle during flash as this might collide with the xenon life time counter update.

If the junction temperature exceeds 85ºC, the EEPROM writing is postponed until the internal temperature drops (An I^2C read to this register will return the old value during this time). Then the writing cycle is automatically executed.

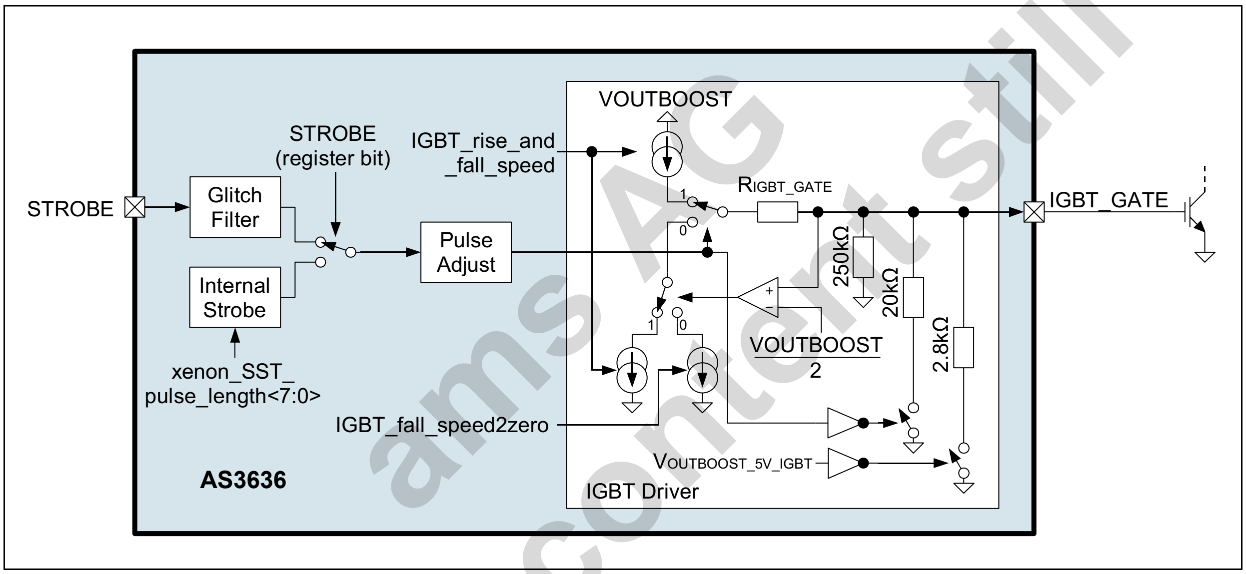
See austriamicrosystems application note 'AN3636_In-Production_Trimming_xvx.pdf' for a detailed description of the trimming parameters and procedure.

IGBT Driver

The IGBT Driver shown in Figure 27 has an internal glitch filter to filter out short spikes with a length of up to t_{STROBE_MIN}. After this filter, the strobe pulse can be adjusted in timing (see IGBT Pulse Timing adjustment on page 17). The actual IGBT driver consists of three current source. One is connected to VOUTBOOST to driver the IGBT_GATE high. The two other current sources drive the IGBT_GATE low, where the falling edge is divided into two sections:

1. IGBT_rise_and_fall_speed control the edge from VOUTBOOST to VOUTBOOST/2
2. IGBT_fall_speed2zero control the remaining part from VOUTBOOST/2 to GND.

Figure 27. IGBT Driver internal circuit



If the STROBE pulse is longer than 2ms, a timeout timer fault is raised and the strobe pulse is stopped - see Xenon charger and strobe timeout fault (TOF) on page 21.

IGBT Pulse Timing adjustment

The IGBT pulse timing can be extended by a programmable duration to allow the fine adjustment of the light output from the Xenon tube during flash especially for light pulses with very short time typically used for pre-flash pulses (typically about 5µs). This adjustment can be performed on a module by module basis thus accurately trimming the light output energy over production for pre-flash pulses.

The internal circuit for this pulse adjustment is shown in Figure 28:

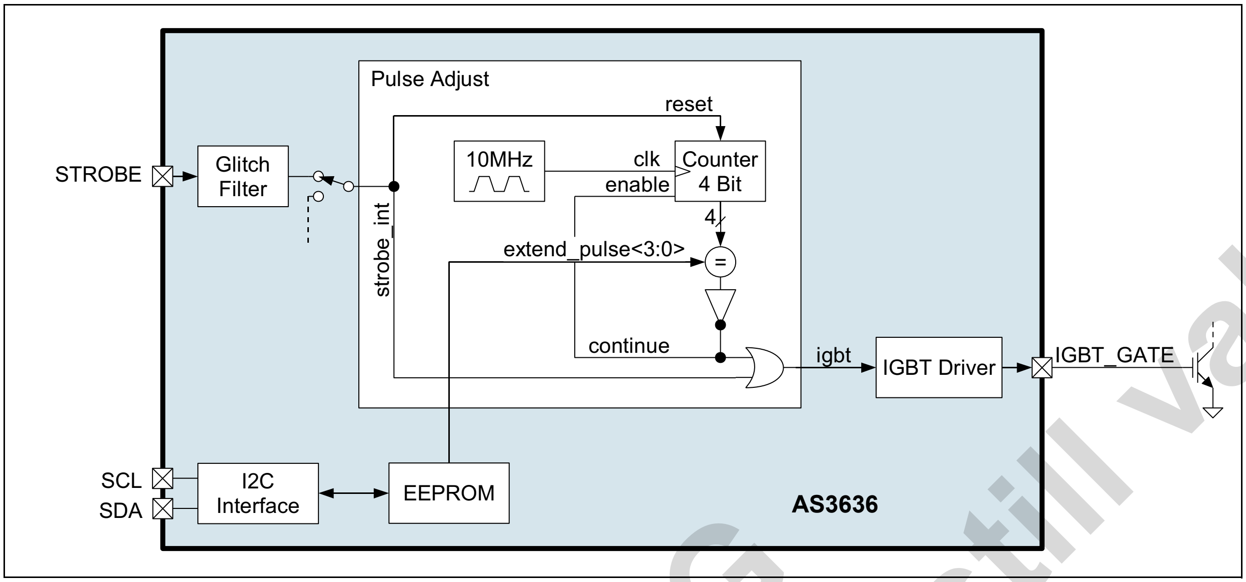


Figure 28. Strobe Pulse adjustment internal circuit

The circuit operates as shown in Figure 29:

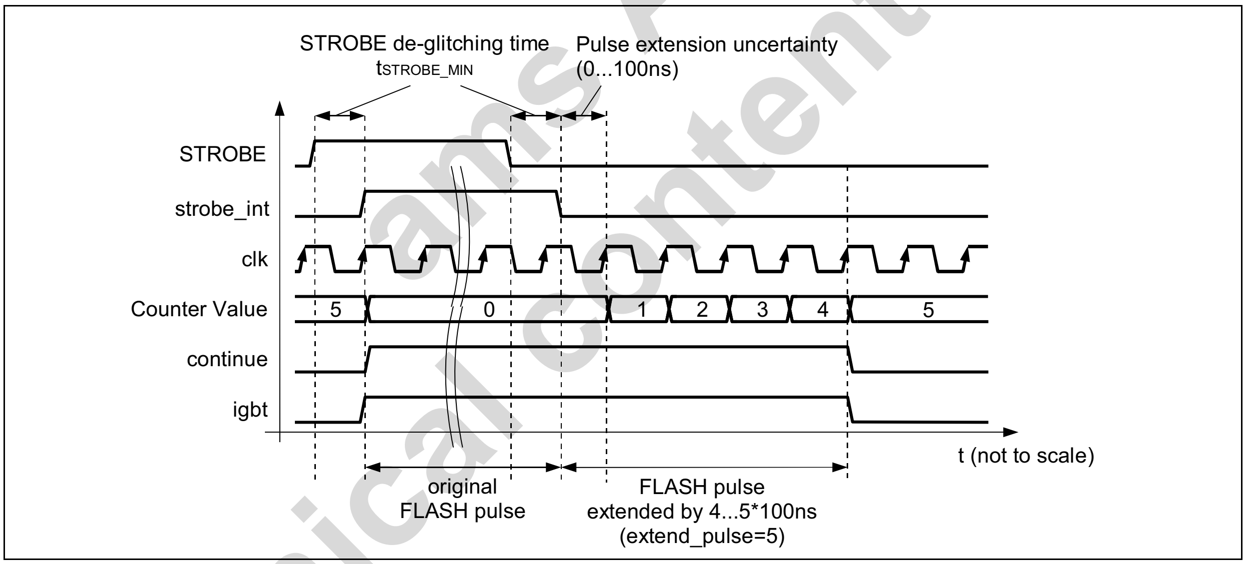


Figure 29. Strobe Pulse adjustment operating waveforms

Note: As the internal oscillator is used for pulse adjustment, which is asynchronous to the external signal from STROBE, there is an uncertainty of one clock period in the actual timing extension.

If extend_pulse (see page 31)=0, the pulse adjust circuit is disabled.

Self Testing

The AS3636 supports internal self testing to allow the verification of the device together with all its external components in a completed system.

Self testing is initiated in active mode[13] by setting the register bit MST (see page 26) and it executes the flow described in Figure 30[14]. After the $\overline{INT}$ signal is low, the test equipment can readout the fault register - for a properly working module, it will read 40h (only register bit READYF set in this register).

Note: After the self-test is finished, the register bit READY is set.

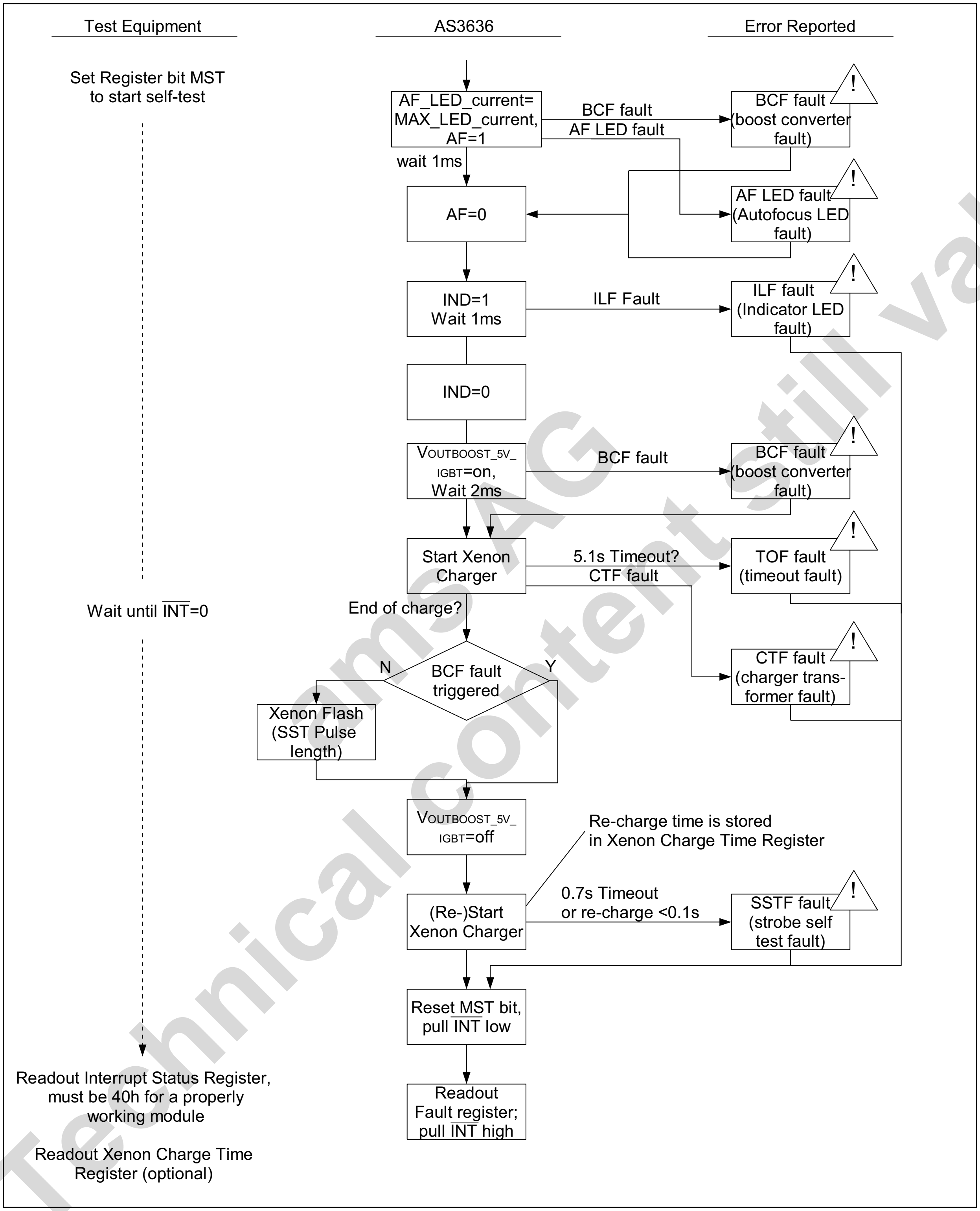
It is recommended to start the self-test with following commands (works under all operating conditions):

1. `write 40h to register 04h` (Control Register) - reset the AS3636
2. `Wait 4ms` - the reset command needs up to 4ms for processing
3. `write 08h to register 11h` (LED Control Register) - enable AF LED to force AS3636 into active mode
4. `write 00h to register 11h` (LED Control Register) - disable AF LED
5. `write 04h to register 04h` (Control Register) - start the self testing procedure by setting MST=1
6. wait for $\overline{INT}$=0 (or MST=0)
7. Readout Interrupt Status Register - it shall return 0x40h for a properly working module.

Note: During the self test do not readout the Interrupt Status Register, only after self test has been finished.
If waiting for $\overline{INT}$=0 is not possible, only check MST bit by polling register Control Register. If MST bit is equal '0' the self test is finished and then Interrupt Status Register can be readout.

13. For entering active mode see Figure 21, "AS3636 operating mode," on page 12 (e.g. after charging)
14. A running self test can only be stopped by writing MST=0 and afterwards STDBY=0; the last step in the procedure is still executed.

Figure 30. Self Testing procedure



Protection and Fault Detection Functions

The protection functions protect the AS3636 and the external devices against physical damage. In case of a failure a register bit is set. The fault bits are cleared[15] by a readout of the Interrupt Status Register (see page 36). If enabled by the Interrupt Mask Register (see page 36), any fault condition will raise an interrupt by pulling $\overline{INT}$ low. The interrupt output $\overline{INT}$ return to open drain, once the fault condition is cleared.

If a fault is detected, the DCDC converter and the Xenon charger is disabled, the current sources are switched off and the device enters standby mode (see Figure 21, "AS3636 operating mode," on page 12). The AS3636 cannot be re-enabled before all fault registers are cleared by readout of Interrupt Status Register (applies for active mode triggered by I^2C and for external torch operation).

Interrupt Output $\overline{INT}$

The interrupt output $\overline{INT}$ is used to indicate a fault or status changes.

If any bit in register Interrupt Status Register (see page 36) is set, which is not masked by Interrupt Mask Register (see page 36), $\overline{INT}$ is set to 0. Upon readout of the register Interrupt Status Register, this register is automatically cleared and $\overline{INT}$returns to high ohmic - an external pullup resistor (or other device which are connected in parallel to the interrupt line) control the voltage on pin $\overline{INT}$.

Note: It is recommended to monitor the status of the $\overline{INT}$ line and only when $\overline{INT}$=0 readout the Interrupt Status Register. Therefore a polling of Interrupt Status Register is not required and the bus traffic on the I^2C bus is automatically reduced.

Indicator LED fault (ILF)

If the indicator LED is enabled, an indicator LED fault is triggered under the following conditions:

1. In case of no or a broken LED and the current through pin IND is below $I_{IND\_OUTOPEN}$.
2. If the LED is shorted and the voltage on IND does not reach $V_{INDSHORT}$.

If one of these conditions is detected the bit ILF is set but the current source is not disabled[16].

Charge transformer fault (CTF)

If the Xenon charger is started and the AS3636 detects a too low inductance[17] of the transformer, the Xenon is stopped and the bit CTF is set.

Boost converter fault (BCF)

The boost converter fault is triggered under the following conditions:

1. To limit the maximum current from the battery, the DCDC converter limits its current through the coil to I_{LIMIT}. If within a single cycle I_{LIMIT} is reached and afterwards (still in the same cycle) the current through the coil reaches zero, a shorted coil is assumed.
2. If the voltage on VOUTBOOST is below 4.0V and a flash strobe command is triggered. The boost converter fault is triggered to protect the IGBT from operating below a minimum voltage.

If any of the above conditions is detected, the DCDC is stopped, the current source is disabled (if enabled) and the bit BCF is set.

Xenon charger and strobe timeout fault (TOF)

During every charging of the Xenon capacitor, the register charge_time monitor the charge time. If the register reaches FFh, the Xenon charger is stopped and the bit TOF is set.

The register TOF is also set, if the strobe length (from pin STROBE) exceeds 2ms[18]. In this case, the IGBT_GATE is switched off automatically.

15.Except overtemperature protection fault OTPF.
16.To avoid erroneously disabling of the indicator current source due to short voltage drops on the supply.
17.An inductance below 0.5µH will be detected as a fault. Above 3.5µH, a valid transformer is detected.
18.The exact duration can vary between 930µs to 2.15ms.

Overtemperature fault (OTPF)

If the AS3636 junction temperature exceeds T_{OVTEMP} the register bit OTPF is set. The AS3636 can be re-enabled once the temperature drops below T_{OVTEMP}-$T_{OVTEMPHYST}$ and register bit OTPF is cleared by reading of the Interrupt Status Register.

Autofocus LED fault (AFF)

If the autofocus LED (pin VLED) is enabled, an autofocus LED fault is triggered under the following conditions:

1. If the LED is shorted and the voltage on VLED does not reach $V_{VLEDSHORT}$[19].
2. If the voltage on VLED is above $V_{VLEDOPEN}$.

If one of these conditions is detected, the DCDC converter is stopped, the current source is disabled and the bit AFF is set.

Xenon strobe self test fault (SSTF)

The xenon strobe is only used upon self testing - for details see section Self Testing on page 18. The fault bit is set if the re-charge time for the Xenon charger is above 0.7s or below 0.1s.

Supply undervoltage Protection

If the voltage on the pin VBATINT (=battery voltage) is or falls below V_{UVLO}, the AS3636 is kept in shutdown state and all registers are set to their default state.

I²C Serial Data Bus

The AS3636 supports the I²C bus protocol. A device that sends data onto the bus is defined as a transmitter and a device receiving data as a receiver. The device that controls the message is called a master. The devices that are controlled by the master are referred to as slaves. A master device that generates the serial clock (SCL), controls the bus access, and generates the START and STOP conditions must control the bus. The AS3636 operates as a slave on the I²C bus. Within the bus specifications a standard mode (100kHz maximum clock rate) and a fast mode (400kHz maximum clock rate) are defined. The AS3636 works in both modes. Connections to the bus are made through the open-drain I/O lines SDA and SCL.

The following bus protocol has been defined (Figure 31):

- Data transfer may be initiated only when the bus is not busy.
- During data transfer, the data line must remain stable whenever the clock line is HIGH. Changes in the data line while the clock line is HIGH are interpreted as control signals.

Accordingly, the following bus conditions have been defined:

Bus Not Busy

Both data and clock lines remain HIGH.

Start Data Transfer

A change in the state of the data line, from HIGH to LOW, while the clock is HIGH, defines a START condition.

Stop Data Transfer

A change in the state of the data line, from LOW to HIGH, while the clock line is HIGH, defines the STOP condition.

Data Valid

The state of the data line represents valid data when, after a START condition, the data line is stable for the duration of the HIGH period of the clock signal. The data on the line must be changed during the LOW period of the clock signal. There is one clock pulse per bit of data.

19.Short LED detection is disabled in PWM mode set by PWM (see page 34)=1 or (INDP (see page 34)=1 and ILP (see page 35)=1).

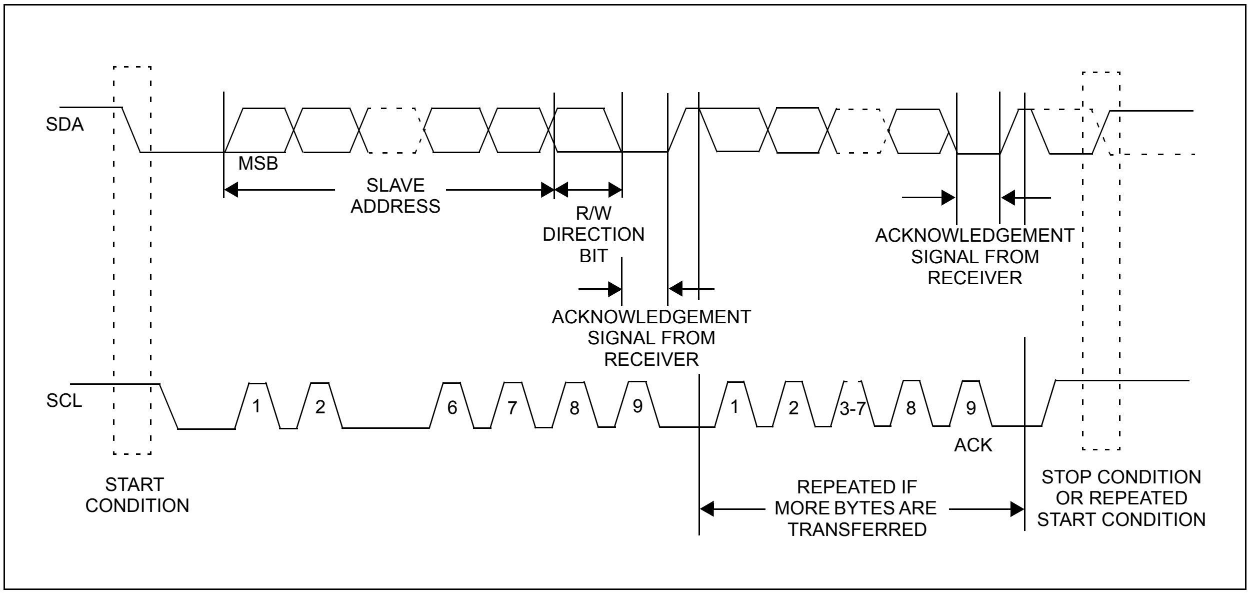
Each data transfer is initiated with a START condition and terminated with a STOP condition. The number of data bytes transferred between START and STOP conditions are not limited, and are determined by the master device. The information is transferred byte-wise and each receiver acknowledges with a ninth bit.

Acknowledge

Each receiving device, when addressed, is obliged to generate an acknowledge after the reception of each byte. The master device must generate an extra clock pulse that is associated with this acknowledge bit.

A device that acknowledges must pull down the SDA line during the acknowledge clock pulse in such a way that the SDA line is stable LOW during the HIGH period of the acknowledge-related clock pulse. Of course, setup and hold times must be taken into account. A master must signal an end of data to the slave by not generating an acknowledge bit on the last byte that has been clocked out of the slave. In this case, the slave must leave the data line HIGH to enable the master to generate the STOP condition.

Figure 31. Data Transfer on I^2C Serial Bus



Depending upon the state of the R/W bit, two types of data transfer are possible:

1. **Data transfer from a master transmitter to a slave receiver.** The first byte transmitted by the master is the slave address. Next follows a number of data bytes. The slave returns an acknowledge bit after each received byte. Data is transferred with the most significant bit (MSB) first.
2. **Data transfer from a slave transmitter to a master receiver.** The master transmits the first byte (the slave address). The slave then returns an acknowledge bit, followed by the slave transmitting a number of data bytes. The master returns an acknowledge bit after all received bytes other than the last byte. At the end of the last received byte, a “not acknowledge” is returned. The master device generates all of the serial clock pulses and the START and STOP conditions. A transfer is ended with a STOP condition or with a repeated START condition. Since a repeated START condition is also the beginning of the next serial transfer, the bus is not released. Data is transferred with the most significant bit (MSB) first.

The AS3636 can operate in the following two modes:

1. **Slave Receiver Mode (Write Mode):** Serial data and clock are received through SDA and SCL. After each byte is received an acknowledge bit is transmitted. START and STOP conditions are recognized as the beginning and end of a serial transfer. Address recognition is performed by hardware after reception of the slave address and direction bit (see Figure 32). The slave address byte is the first byte received after the master generates the START condition. The slave address byte contains the 7-bit AS3636 address, which is 0101000, followed by the direction bit (R/W), which, for a write, is 0.[20] After receiving and decoding the slave address byte the device outputs an acknowledge on the SDA line. After the AS3636 acknowledges the slave address +

20.The address for writing to the AS3636 is 50h = 01010000b write bit, the master transmits a register address to the AS3636. This sets the register pointer on the AS3636. The master may then transmit zero or more bytes of data, with the AS3636 acknowledging each byte received. The address pointer will increment after each data byte is transferred. The master generates a STOP condition to terminate the data write.

2. **Slave Transmitter Mode (Read Mode):** The first byte is received and handled as in the slave receiver mode. However, in this mode, the direction bit indicates that the transfer direction is reversed. Serial data is transmitted on SDA by the AS3636 while the serial clock is input on SCL. START and STOP conditions are recognized as the beginning and end of a serial transfer (Figure 33 and Figure 34). The slave address byte is the first byte received after the master generates a START condition. The slave address byte contains the 7-bit AS3636 address, which is 0101000, followed by the direction bit (R/W), which, for a read, is 1.[21] After receiving and decoding the slave address byte the device outputs an acknowledge on the SDA line. The AS3636 then begins to transmit data starting with the register address pointed to by the register pointer. If the register pointer is not written to before the initiation of a read mode the first address that is read is the last one stored in the register pointer. The AS3636 must receive a "not acknowledge" to end a read.

Figure 32. Data Write - Slave Receiver Mode

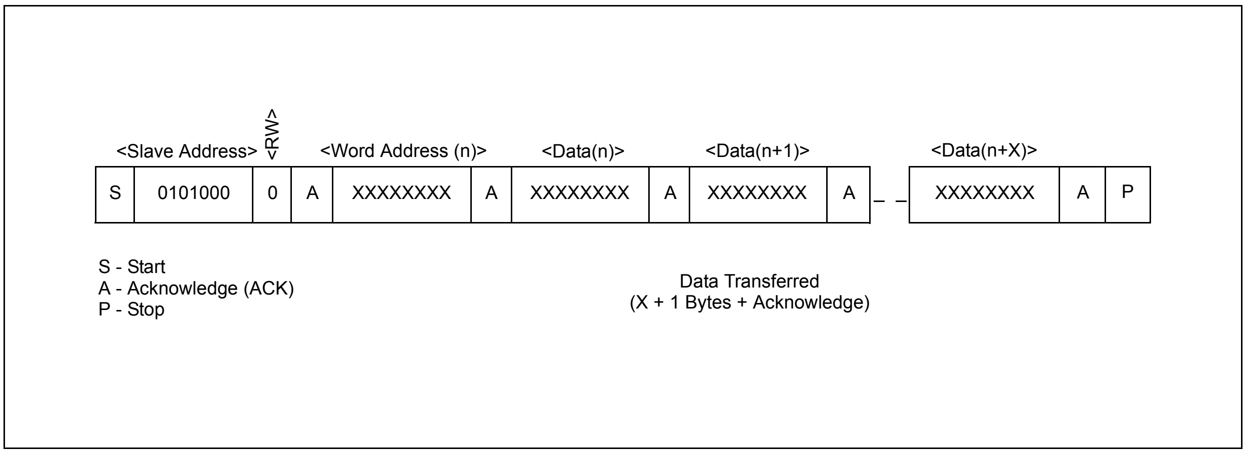
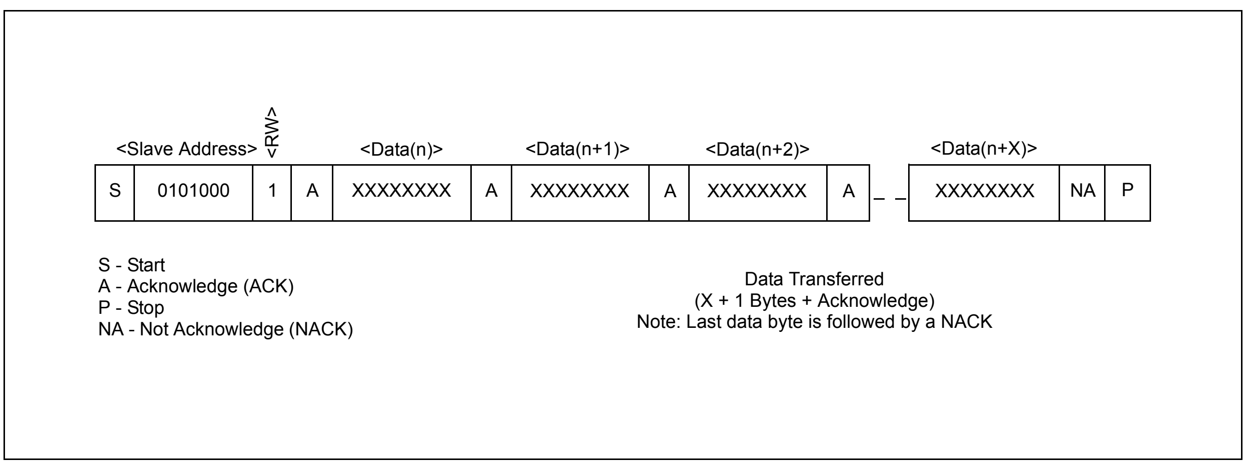
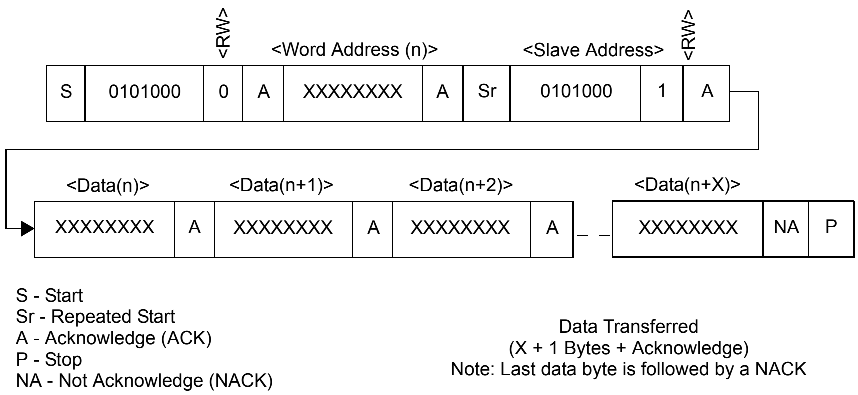


Figure 33. Data Read (from Current Pointer Location) - Slave Transmitter Mode



21.The address for read mode from the AS3636 is 51h = 01010001b

Figure 34. Data Read (Write Pointer, Then Read) - Slave Receive and Transmit



Register Description

Table 4. IC Info Register

Addr: 00h		IC Info Register		
		This register has a fixed content and can be used to verify the I^2C communication		
Bit	**Bit Name**	**Default**	**Access**	**Description**
3:0	IC_model	0010b	R	Fixed ID
7:4	IC_manufacturer_ID	0001b	R	Fixed Manufacturer ID

Table 5. IC Version Control Register

Addr: 01h		IC Version Control Register		
		Design Round Identification		
Bit	**Bit Name**	**Default**	**Access**	**Description**
3:0	Design_round	NA	R	Internal number; don’t use in software
7:4		0h	R	always 0, don’t use

Table 6. Module Info Reg.A

Addr: 02h		Module Info Reg.A			
		Module identification - written by module manufacturer			
Bit	**Bit Name**	**Default**	**Access**	**Description**	
1:0	Module_Type	NVM	R	Module Sample Type	
				00	Technology Sample
				01	Engineering Sample
				10	Commercial Sample, Mass Production
				11	Reserved for future use

Table 6. Module Info Reg.A (Continued)

Addr: 02h		Module Info Reg.A Module identification - written by module manufacturer		
Bit	**Bit Name**	**Default**	**Access**	**Description**
4:2	Module_Generation	NVM	R	Module Generation
7:5	Module_Manufacturer_ID	NVM	R	Module Manufacturer

Table 8. Control Register

Addr: 04h		Control Register Operating mode of AS3636			
Bit	**Bit Name**	**Default**	**Access**	**Description**	
0	WATCHDOG	1	R/W	Watchdog timer enable	
				0	No watchdog timer
				1	After one minute after charging is finished the AS3636 automatically enters standby mode; any read or write access to any AS3636 register resets this one minute watchdog timer
1	AFSTROBE	0	R/W	Strobe input usage (level sensitive)	
				0	STROBE input is used for Xenon flash
				1	STROBE input is used for AF LED on/off; LED current is defined by LED Current Register with no PWM
2	MST	0	R/W	Module Self Testing	
				0	Read: No module test running Write: Writing ‘0’ stops a running self test
				1	Writing ‘1’ to this register starts the module self test procedure; when the test is finished MST is automatically cleared - see Self Testing on page 18
3	TORCH_S	0	R	TORCH pin status (used for module testing)	
				0	low
				1	high
5:4		00b	R	always 0, don’t use	
6	RESET[1]	0		Reset of all registers	
			R	always reads back ‘0’	
			W	0	no action
				1	all registers are reset to their default
7	STDBY[2]	0	R/W	Standby mode	
				0	normal operation (all modes are possible)
				1	Writing ‘1’ writes defaults to Xenon Control Register, LED Control Register and eventually to the Control Register. The AS3636 enters standby mode and clears the bit STDBY

1. The AS3636 needs up to 4ms to process a reset command. Wait at least 4ms before sending the next command.
2. After setting STDBY=1 and if a reset shall be done afterwards, wait at least 3ms before setting RESET=1.

Table 9. Interrupt Mask Register

Addr: 05h		Interrupt Mask Register			
		Mask Interrupts (interrupt output $\overline{INT}$, open drain, active low)			
Bit	**Bit Name**	**Default**	**Access**	**Description**	
0	ILFI	1	R/W	Indicator LED fault interrupt	
				0	Disabled
				1	Enabled
1	CTFI	1	R/W	Xenon Charger Transformer fault interrupt	
				0	Disabled
				1	Enabled
2	BCFI	1	R/W	DCDC Boost converter (VOUTBOOST) fault interrupt	
				0	Disabled
				1	Enabled
3	TOFI	1	R/W	Xenon Charger Timeout fault interrupt	
				0	Disabled
				1	Enabled
4	OTPFI	1	R/W	Over Temperature protection fault interrupt	
				0	Disabled
				1	Enabled
5	AFFI	1	R/W	Autofocus LED (VLED) fault interrupt	
				0	Disabled
				1	Enabled
6	READYFI	1	R/W	Xenon charger ready interrupt	
				0	Disabled
				1	Enabled
7	SSTFI	1	R/W	Xenon Strobe Self test fault interrupt	
				0	Disabled
				1	Enabled

Table 10. Interrupt Status Register

Addr: 06h		Interrupt Status Register			
		Interrupts status (interrupt output $\overline{INT}$, open drain, active low); reading this register automatically clears the interrupt; see Protection and Fault Detection Functions on page 21			
Bit	**Bit Name**	**Default**	**Access**	**Description**	
0	ILF	0	R/SC[1]	Indicator LED fault interrupt	
				0	no interrupt
				1	interrupt occurred
1	CTF	0	R/SC[1]	Xenon Charger Transformer fault interrupt	
				0	no interrupt
				1	interrupt occurred

Table 10. Interrupt Status Register (Continued)

Addr: 06h		Interrupt Status Register		
		Interrupts status (interrupt output $\overline{INT}$, open drain, active low); reading this register automatically clears the interrupt; see Protection and Fault Detection Functions on page 21		
Bit	**Bit Name**	**Default**	**Access**	**Description**
2	BCF	0	R/SC[1]	DCDC Boost converter (VOUTBOOST) fault interrupt 0: no interrupt 1: interrupt occurred
3	TOF	0	R/SC[1]	Xenon Charger or Strobe Timeout fault interrupt 0: no interrupt 1: interrupt occurred
4	OTPF	0	R/SC[1]	Over Temperature protection fault interrupt 0: no interrupt 1: interrupt occurred
5	AFF	0	R/SC[1]	Autofocus LED (VLED) fault interrupt 0: no interrupt 1: interrupt occurred
6	READYF	0	R/SC[1]	Xenon charger ready interrupt flag 0: no interrupt 1: interrupt occurred
7	SSTF	0	R/SC[1]	Xenon Strobe Self test fault interrupt 0: no interrupt 1: interrupt occurred

1. R/SC = Read, self clear: Upon readout, the register bit is automatically cleared.

Table 11. Xenon Control Register

Addr: 07h		Xenon Control Register		
		Control Xenon Charger and Re-charging		
Bit	**Bit Name**	**Default**	**Access**	**Description**
0	CHARGE	0	R/W	Xenon charging 0: Read: no charging; Write: writing '0' to CHARGE stops charging 1: Read: Xenon charger running; Write: writing '1' to CHARGE starts charging
1	READY	0	R	Xenon Charger Finished charging 0: not ready for flash 1: ready for flash; a flash strobe automatically resets READY

Table 11. Xenon Control Register (Continued)

Addr: 07h		Xenon Control Register Control Xenon Charger and Re-charging			
Bit	**Bit Name**	**Default**	**Access**	**Description**	
2	STROBE	0		Strobe test pulse enable	
			R	0	Input pin STROBE[1]=0
				1	Input pin STROBE[1]=1
			W	0	IGBT strobe flash is controlled by STROBE pin
				1	A Xenon flash test pulse of length Xenon SST Pulse Length Register is generated
3	CAR	0	R/W	Xenon Charger automatic recharge	
				0	no automatic recharge
				1	automatic recharge enabled - see Figure 21 on page 12
7:4		0000b	R	always 0, don't use	

1. Reading register bit STROBE only returns valid results, if VOUTBOOST_5V_IGBT or VOUTBOOST_5V_AFSTROBE is set. VOUTBOOST_5V_IGBT is set during or after Xenon charging (see Figure 22 on page 13), VOUTBOOST_5V_AFSTROBE is set if AFSTROBE is set (see Figure 24 on page 15).

Table 12. Xenon CAR Interval Register

Addr: 08h		Xenon CAR Interval Register Xenon automatic Re-charging Timer			
Bit	**Bit Name**	**Default**	**Access**	**Description**	
2:0	CAR_interval[1]	001b	R/W	Xenon Re-charging Timer - - see Figure 21 on page 12	
				000	1.0s
				001	default 1.5s
				010	2.0s
				011	2.5s
				100	3.0s
				101	3.5s
				110	4.0s
				111	4.5s
7:3		00h	R	always 0, don't use	

1. The first recharge interval can be shorter than selected due to an synchronization to an internal timer. The recharge time is always measured from start of recharge to the next start of recharge.

Table 13. Xenon Charge Time Register

Addr: 09h		Xenon Charge Time Register Measure last xenon charging time			
Bit	**Bit Name**	**Default**	**Access**	**Description**	
7:0	charge_time[1]	00h	R	Xenon charging time; register content is valid if READY=1	
				00h	timer has not been started
				01h	0-20ms
				02h	20-40ms
				03h	40ms-60ms
				04h	60ms-80ms
				...	...
				FEh	5060-5080ms
				FFh	>5080ms Xenon charger time out fault was triggered - see TOF

1. Reading register Interrupt Status Register (see page 36) resets charge_time, therefore read charge_time before reading Interrupt Status Register.

Table 14. Xenon SST Pulse Length Register

Addr: 0Ah		Xenon SST Pulse Length Register Xenon strobe test pulse length			
Bit	**Bit Name**	**Default**	**Access**	**Description**	
7:0	xernon_SST_pulse_length[1]	NVM	R	define Xenon strobe pulse length for register bit STROBE=1 and for Xenon module self testing - see Self Testing on page 18	
				00h	don't use
				01h	1µs
				02h	2µs
				...	
				FFh	255µs

1. The resulting timing can vary by +1µs/-0µs (excluding the variation of the internal oscillator), therefore use this internal pulse generator only for self testing.

Table 15. Xenon Life Time Register MSB

Addr: 0Bh		Xenon Life Time Register MSB xenon_life_counter_MSB		
Bit	**Bit Name**	**Default**	**Access**	**Description**
7:0	xenon_life_counter_MSB	NVM	R	Count the number of flash double-pulses performed and store in NVM - see AS3636 operating mode on page 12 counter stops at FFFFh

Table 16. Xenon Life Time Register LSB

Addr: 0Ch		Xenon Life Time Register LSB		
		xenon_life_counter_LSB		
Bit	**Bit Name**	**Default**	**Access**	**Description**
7:0	xenon_life_counter_LSB	NVM	R	Count the number of flash double-pulses performed and store in NVM - see AS3636 operating mode on page 12 counter stops at FFFFh

Table 17. Xenon Config Register A

Addr: 0Dh		Xenon Config Register A			
		Define the end of charge detection voltage			
Bit	**Bit Name**	**Default**	**Access**	**Description**	
5:0	charge_voltage_selection	NVM	R	Define the Xenon end of charge detection voltage (measured on pin SW_F)	
				00h	28.5V
				01h	28.6V
				02h	28.7V
				...	
				3Fh	34.8V
7:6		00b	R	always 0, don't use	

Table 18. Xenon Config Register B

Addr: 0Eh		Xenon Config Register B			
		Define the peak current limit for the Xenon charger			
Bit	**Bit Name**	**Default**	**Access**	**Description**	
2:0	switch_current_selection[1]	NVM	R	Peak current limit measured on pin SW_F	
				000	375mA
				001	450mA
				010	525mA
				011	600mA
				100	675mA
				101	750mA
				110	825mA
				111	900mA
6:3	extend_pulse	NVM	R	Extend the timing for the IGBT strobe pulse - see IGBT Pulse Timing adjustment	
				0h	no pulse extension
				1h	100ns
				2h	200ns
				3h	300ns
				...	...
				Eh	1400ns
				Fh	1500ns

Table 18. Xenon Config Register B (Continued)

Addr: 0Eh		Xenon Config Register B Define the peak current limit for the Xenon charger			
Bit	**Bit Name**	**Default**	**Access**	**Description**	
7	IGBT_fall2zero_slow	NVM	R/W	Define together with IGBT_fall_speed2zero IGBT driver fall speed for final switch-off (VOUTBOOST/2 to 0V)	
				0	full current - see IGBT_fall_speed2zero
				1	half current - see IGBT_fall_speed2zero

1. Take care to set the peak current limit to fit to the Xenon charger transformer used - if the peak current limit is set too low, efficiency will drop and eventually end of charge will not be reached anymore.

Table 19. Xenon Config Register C

Addr: 0Fh		Xenon Config Register C Define IGBT driver parameters and SW_B switch current limits				
Bit	**Bit Name**	**Default**	**Access**	**Description**		
2:0	IGBT_fall_speed2zero[1]	NVM	R	Define IGBT driver fall speed for final switch-off (VOUTBOOST/2 to 0V)		
					IGBT_fall2zero_slow = 0	1
				000	1V/µs (10mA)	0.5V/µs (5mA)
				001	2V/µs (20mA)	1V/µs (10mA)
				010	3V/µs (30mA)	1.5V/µs (15mA)
				011	4V/µs (40mA)	2V/µs (20mA)
				100	5V/µs (50mA)	2.5V/µs (25mA)
				101	6V/µs (60mA)	3V/µs (30mA)
				110	7V/µs (70mA)	3.5V/µs (35mA)
				111	8V/µs (80mA)	4V/µs (40mA)
5:3	IGBT_rise_and_fall_speed[2]	NVM	R	Define IGBT switch-on speed and switch-off down to VOUTBOOST/2		
				000	1V/µs (10mA)	
				001	2V/µs (20mA)	
				010	3V/µs (30mA)	
				011	4V/µs (40mA)	
				100	5V/µs (50mA)	
				101	6V/µs (60mA)	
				110	7V/µs (70mA)	
				111	8V/µs (80mA)	
7:6	coil_peak_current	NVM	R	DCDC Boost Coil Peak current setting (pin SW_B)		
				00	250mA	
				01	300mA	
				10	350mA	
				11	400mA	

1. Assuming a 10nF capacitance. The timings scale by the gate capacitance of the IGBT
2. Assuming a 10nF capacitance. The timings scale by the gate capacitance of the IGBT

Table 20. LED Current Register

Addr: 10h		LED Current Register			
		AF LED and indicator LED current and PWM settings			
Bit	**Bit Name**	**Default**	**Access**	**Description**	
2:0	AF_LED_current[1]	000b	R/W	AF LED Current settings	
				000	10mA
				001	15mA
				010	20mA
				011	28mA
				100	37mA
				101	50mA
				110	65mA
				111	80mA
5:3	AF_LED_PWM[2]	000b	R/W	AF LED PWM setting	
				000	1/32
				001	2/32
				010	3/32
				011	5/32
				100	8/32
				101	12/32
				110	20/32
				111	32/32
7:6	IND_LED_current	00b	R/W	Indicator LED current setting	
				00	2mA
				01	4mA
				10	8mA
				11	16mA

1. AF_LED_current setting is automatically limited to Max_LED_current (see page 34)
2. The internal PWM generator output frequency is 31.25kHz (to avoid audible noise)

Table 21. LED Control Register

Addr: 11h		LED Control Register Control AF LED and indicator LED operating mode			
Bit	**Bit Name**	**Default**	**Access**	**Description**	
0	IND[1]	0	R/W	Indicator LED on/off	
				0	off
				1	if ILP=0: use VLED output with AF_LED_current and AF_LED_PWM duty cycle if ILP=1: use IND output with IND_LED_current
1	INDP[2]	0	R/W	100ms Indicator LED pulse	
				0	no pulse
				1	if ILP=0: 100ms pulse on VLED output with AF_LED_current and AF_LED_PWM duty cycle if ILP=1: 100ms pulse on IND output with IND_LED_current
2	PWM	0	R/W	AF LED PWM enable if AF=1(pin VLED)	
				0	no PWM
				1	AF LED PWM with AF_LED_PWM
3	AF[3]	0	R/W	AF LED on/off (pin VLED)	
				0	off
				1	enabled AF LED with AF_LED_current; if PWM=1 use AF_LED_PWM duty cycle
7:4		0000b	R	always 0, don't use	

1. If IND=1 and INDP=1, IND=1 has priority
2. After the 100ms pulse, the register INDP is automatically reset
3. Do not operate AF=1 and (IND or INDP=1) at the same time

Table 22. LED Configuration Register

Addr: 12h		LED Configuration Register Set maxim AF LED current and configure indicator type			
Bit	**Bit Name**	**Default**	**Access**	**Description**	
2:0	Max_LED_current	NVM	R	AF LED Maximum current limit	
				000	10mA
				001	15mA
				010	20mA
				011	28mA
				100	37mA
				101	50mA
				110	65mA
				111	80mA
6:3		0h	R	always 0, don't use	

Table 22. LED Configuration Register (Continued)

Addr: 12h		LED Configuration Register Set maxim AF LED current and configure indicator type			
Bit	**Bit Name**	**Default**	**Access**	**Description**	
7	ILP	NVM	R/W	Indicator LED present; applies when indicator is switched on (IND=1)	
				0	use VLED output with AF_LED_current and AF_LED_PWM duty cycle
				1	use IND output with IND_LED_current; ILF (indicator LED fault) detection is enabled

Table 23. Password Register

Addr: 13h		Password Register EEPROM writing password lock register			
Bit	**Bit Name**	**Default**	**Access**	**Description**	
7:0	Password_register	00h	R/W	Un-lock register for EEPROM writing - see EEPROM Writing Cycle on page 16	
				password code[1]	Read: EEPROM writing pending Write: Unlock EEPROM writing for next I^2C command
				wrong code	EEPROM writing locked

1. Consult austriamicrosystems for the exact value.

9 Register Map

Table 26. Register Map

Register Definition	Addr	Default	Content							
Name			**b7**	**b6**	**b5**	**b4**	**b3**	**b2**	**b1**	**b0**
IC Info Register	00h	12h	0	0	0	1	0	0	1	0
IC Version Control Register	01h	0Xh	0	0	0	0	Design_round			
Module Info Reg.A	02h	NVM	Module_Manufacturer_ID			Module_Generation			Module_Type	
User NVM 1	03h	NVM	User defined							
Control Register	04h	01h	STDBY	RESET	0	0	TORCH_S	MST	AFSTROBE	WATCHDOG
Interrupt Mask Register	05h	FFh	SSTFI	READYFI	AFFI	OTPFI	TOFI	BCFI	CTFI	ILFI
Interrupt Status Register[1]	06h	00h	SSTF	READYF	AFF	OTPF	TOF	BCF	CTF	ILF
Xenon Control Register	07h	00h	0	0	0	0	CAR	STROBE	READY	CHARGE
Xenon CAR Interval Register	08h	01h	0	0	0	0	0	CAR_interval		
Xenon Charge Time Register	09h	00h	charge_time							
Xenon SST Pulse Length Register	0Ah	NVM	xernon_SST_pulse_length							
Xenon Life Time Register MSB	0Bh	NVM	xenon_life_counter_MSB							
Xenon Life Time Register LSB	0Ch	NVM	xenon_life_counter_LSB							
Xenon Config Register A	0Dh	NVM	0	0	charge_voltage_selection					
Xenon Config Register B	0Eh	NVM	IGBT_fall2zero_slow	extend_pulse				switch_current_selection		
Xenon Config Register C	0Fh	NVM	coil_peak_current		IGBT_rise_and_fall_speed			IGBT_fall_speed2zero		
LED Current Register	10h	00h	IND_LED_current		AF_LED_PWM			AF_LED_current		
LED Control Register	11h	00h	0	0	0	0	AF	PWM	INDP	IND
LED Configuration Register	12h	NVM	ILP					Max_LED_current		
Password Register	13h	00h	Password_register							
User NVM 2	14h	NVM	User defined							
User NVM 3	15h	NVM	User defined							
User NVM 4	16h	NVM	User defined							
User NVM 5	17h	NVM	User defined							
User NVM Area	27h-7Fh	NVM	User defined							

1. Reading register Interrupt Status Register resets charge_time, therefore read charge_time before reading Interrupt Status Register.

NVM...Non Volatile Memory using internal EEPROM; for programming see EEPROM Writing Cycle on page 16, don't read or write during life time counter updates

Note: When writing to read-only register (in mixed read only / read/write register like Xenon Control Register) write 0 to read-only register bits. For undefined register bits always write '0'. Do never write to undefined register addresses (above 15h).

Upon delivery the EEPROM default value are set according to Table 27:

Table 27. EEPROM default settings

Register Definition	Addr	Default	Content							
Name			**b7**	**b6**	**b5**	**b4**	**b3**	**b2**	**b1**	**b0**
Module Info Reg.A	02h	05h	Module_Manufacturer_ID			Module_Generation			Module_Type	
User NVM 1	03h	00h	Module_Project_Number				Module_Major_Version			
Xenon SST Pulse Length Register	0Ah	08h	xernon_SST_pulse_length							
Xenon Life Time Register MSB	0Bh	00h	xenon_life_counter_MSB							
Xenon Life Time Register LSB	0Ch	00h	xenon_life_counter_LSB							
Xenon Config Register A	0Dh	1Fh	0	0	charge_voltage_selection					
Xenon Config Register B	0Eh	86h	IGBT_fall2 zero_slow	extend_pulse				switch_current_selection		
Xenon Config Register C	0Fh	80h	coil_peak_current	IGBT_rise_and_fall_speed				IGBT_fall_speed2zero		
LED Configuration Register	12h	07h	ILP					Max_LED_current		
User NVM 2	14h	00h	User defined							
User NVM 3	15h	00h	User defined							

10 Application Information

External Components

Transformers TCHARGE and TTRIG

Following transformers are approved for the AS3636 (due to the programming features the output voltage VFLASH can be programmed):

Table 28. Approved Transformers

Component	Part Number	N	L	Size (mm)	Manufacturer
TCHARGE	TTRN-3825H	10.2	7µH	3.8x3.8x2.5	Tokyo Coil www.tokyo-coil.co.jp
	TTRN-3822H	10.2	7µH	3.8x3.8x2.2	
	TTRN2518[1]	10.2	7µH	3.2x2.5x1.8 (H is max)	
	TTRN2516[2]	10.2	7µH	3.2x2.5x1.6 (H is max)	
	C3-T2.5R	10.2	7µH	3.4x3.4x2.5	Mitsumi www.mitsumi.co.jp
	C2-T1.8D[3]	10.2	7µH	3.2x2.4x1.8 (H is max)	
	C2-T1.6D[4]	10.2	7µH	3.2x2.4x1.6 (H is max)	
	LDT4520T-01	10.2	10µH	4.7x4.5x2.0	TDK www.tdk.com
	ATB322515[5]	10.2	7µH	3.2x2.5x1.55 (H is max)	
TTRIG	BO-02			7.3x2.5(3.5)x2.2	Tokyo Coil www.tokyo-coil.co.jp

1. Use only for switch_current_selection=825mA or 900mA.
2. Use only for switch_current_selection=825mA or 900mA.
3. Use only for switch_current_selection=825mA or 900mA.
4. Use only for switch_current_selection=825mA. Contact Mitsumi to use for switch_current_selection=900mA.
5. Use only for switch_current_selection=825mA or 900mA.

Always check if the voltage on the pin SW_F does never exceed the AS3636 maximum VSW (see Table 3 on page 4) specification during charging.

IGBT

As the AS3636 has an internal DCDC step up included, 2.5V and 4V IGBT can be used without limit on the supply VVBAT. The IGBT is used for two purposes:

1. Powering of the Xenon tube and generating together with the oscillation circuit consisting of TTRIG, CTRIG, RTRIG a sufficiently high trigger pulse to ignite the Xenon tube (about 3.5kV) - this is accomplished by a fast rising edge of the gate of the IGBT
2. Switching off the current through the Xenon tube at the end of the flash pulse to accurately control the light emitted by the flash. To protect the IGBT the switching off falling edge voltage should be less than 400V/µs (measured on the emitter of the IGBT)

Both requirements are achieved with the internal driving circuit of the AS3636. Trimming allows to adopt to different trigger coils and IGBTs.

Table 29. Recommended IGBTs

Component	Part Number	min. Drive Voltage	Size	Manufacturer
Q_{IGBT}	RJP4002ANS	2.5V	VSON-8 3 x 4.8mm	Renesas www.renesas.com
	RJP4003ANS	4.0V		
	RJP4006ANS[1]	2.5V	2.85x2.95mm	
	GT8G133	4.0V	TSSOP-8 3.3 x 6.4mm	Toshiba www.semicon.toshiba.co.jp
	TIG058E8[1]	4.0V	ECH8 2.8 x 2.9mm	Sanyo www.sanyo.com

1. Requires additional resistor in series with gate. See datasheet of IGBT.

Note: The non-volatile registers IGBT_fall_speed2zero, IGBT_rise_and_fall_speed and IGBT_fall2zero_slow have to be set to fit to the used IGBT. Failing to do so might cause permanent damage to the IGBT.

Photoflash Capacitor C_{FLASH}

The photoflash capacitor stores the energy for the flash. Its capacitance define the maximum available energy. Using higher value capacitors as shown in Table 30 is possible, but will increase the charging time.

It is recommended to use low ESR capacitors to avoid loosing power during flash (it is also possible to connect two capacitors in parallel to reduce ESR):

Table 30. Recommended Photoflash Capacitors

Component	Part Number	Capacitor	Voltage rating	Size	Manufacturer
C_{FLASH}	330FW13A6.3X20	2x13.5µF[1]	330V	Cylinder 2 x l=24mm, d=7mm	Rubycon www.rubycon.co.jp

1. Different capacitor values are possible to be used together with the AS3636. Lower capacitor value will reduce charging time, lower ESR capacitor will improve light output energy and reduce losses in the capacitor during the flash pulse.

Photoflash Charger rectification diode D_{CHARGE}

The rectification diode should have very low parasitic capacitance[22] and has to withstand the operating current and reverse voltages.

Table 31. Recommended Rectification Diodes

Component	Part Number	Parasitic Capacitor	Voltage rating	Size	Manufacturer
D_{CHARGE}	FVO2R80	5pF	800V	1.25x2.5mm	Origin www.origin.co.jp
	GSD2004S	5pF / 2	2x240V	SOT-23 2.4x3.0mm	Vishay www.vishay.com
	BAS21	5pF / 2	2x250V	SC-70 2.0x2.1mm	OnSemi www.onsemi.com
	DA2SF650EL	0.7pF	600V	1.2x0.8mm	Panasonic www.panasonic.com
	RFU01SM4S	1.5pF	450V	1.0x0.6mm	Rohm www.rohm.com

Supply Capacitor C_{VBAT} and DCDC Boost capacitor $C_{VOUTBOOST}$

Low ESR capacitors should be used to minimize VBAT ripple. Multi-layer ceramic capacitors are recommended since they have extremely low ESR and are available in small footprints. The capacitor should be located as close to the device as possible.

X5R dielectric material is recommended due to their ability to maintain capacitance over wide voltage and temperature range.

Table 32. Recommended C_{VBAT} and $C_{VOUTBOOST}$ Capacitor

Component	Part Number	C	TC Code	Rated Voltage	Size	Manufacturer
C_{VBAT},$C_{VOUTBOOST}$	GRM188R60J106	10µF >5.5µF @1.8V >4µF @5V	X5R	6.3V	0603	Murata www.murata.com
$C_{VOUTBOOST}$	C1608X5R 0J106M	10µF	X5R	6.3V	0603	TDK www.tdk.com

If a different output capacitor is chosen, ensure low ESR values and voltage ratings.

Inductor L_{DCDC}

The fast switching frequency (2MHz) of the AS3636 allows for the use of small SMDs for the external inductor. The inductor should have low DC resistance (DCR) to reduce the I^2R power losses - high DCR values will reduce efficiency.

Table 33. Recommended Inductor

Part Number	L	DCR	L @ 0.5A	Size	Manufacturer
LQM21PN2R2NGC	2.2µH	240mΩ	>1.5µH	2x1.25x0.9mm (0805)	Murata www.murata.com
BRC1608T2R2M[1]	2.2µH	550mΩ	>1.5µH @ 0.4A	1.6x0.8x0.8mm (0603)	Taiyo Yuden www.t-yuden.com
GLCR1608T2R2M	2.2µH	400mΩ	>1.5µH	1.6x0.8x0.9mm (0603)	TDK www.tdk.com

22.A low parasitic capacitance improves charging efficiency.

1. Use only at 250mA coil_peak_current (see page 32)=00b unless T_{AMB} can be limited. This coil has a temperature rise maximum current of 280mA. If T_{AMB} can be limited coil_peak_current can be increased to 350mA.

If a different inductor is chosen, ensure similar DCR values and at least 1.5µH inductance at 0.5A input current.

Resistor R_{TRIG}

This resistor has to withstand the high voltage on the photoflash capacitor C_{FLASH}. As there is a safety time for the IGBT driver (see IGBT Driver on page 17) the high voltage on this resistor is limited to 2ms. Therefore a smaller resistor size can be used (0402 sized surge or thick film resistor instead of 0805).

PCB Layout Guideline

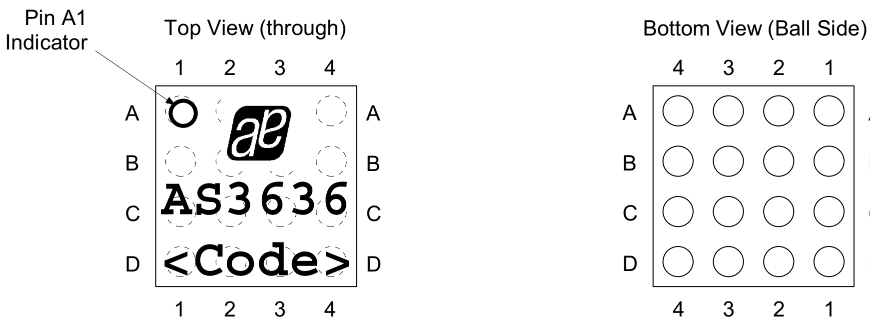
Following layout recommendations apply:

1. Keep the path (and area) of GND (SGND directly connected to DGND below the WL-CSP) - C_{VBAT} - VBATINT - T_{CHARGE}(primary) - SW_F - GND as short as possible to minimize the leakage inductance of T_{CHARGE} and ensure a proper supply connection for the AS3636
2. Keep the path (and area) of GND - C_{VBAT} - L_{BOOST} - SW_B - VOUTBOOST - $C_{VOUTBOOST}$ - GND as short as possible.
3. Place C_{VBAT} as close as possible to the AS3636.
4. Ensure wide and short PCB paths for the path GND - C_{FLASH} - X_{FLASH} - Q_{IGBT} - GND to allow 150A to flow during the flash pulse. Connect this GND only at a single place to the main GND plane.
5. The IGBT has two ground connections: One ground for the driving input and one ground for the power path.
6. Ensure larger spacings for all high voltage paths; check with the PCB manufacturer to ensure proper minimum spacing for 320V paths and 4kV (Xenon tube trigger pin) paths.
7. Minimize the parasitic capacitance of the PCB on the anode of D_{CHARGE} especially to GND and V_{FLASH}
8. See austriamicrosystems "WLP-CSP-Handling-Guidelines_1V0.pdf" for proper handling, PCB layout and soldering of the WL-CSP AS3636 device.
9. In order to meet system level ESD protection careful routing of the ground lines, supply capacitor C_{VBAT} and supply lines is required.

See austriamicrosystems demoboard layout (described in application note 'AN3636').

11 Package Drawings and Markings

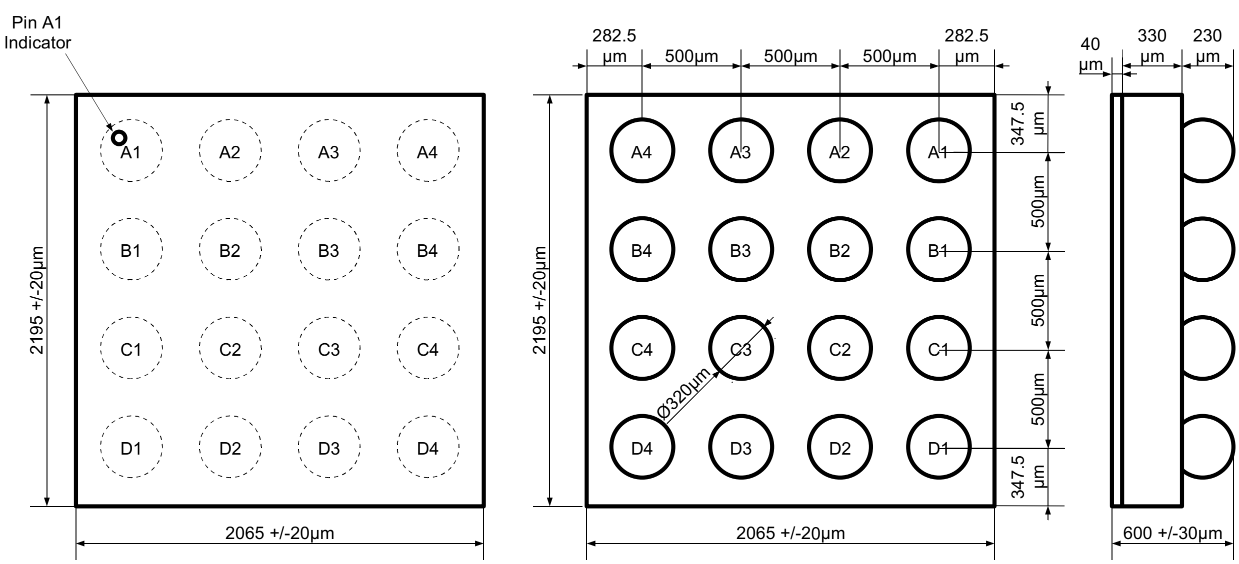
Figure 35. 16pin WL-CSP 2x2.15mm Marking



Note:

Line 1: austriamicrosystems logo
Line 2: AS3636
Line 3: <Code>
Encoded Datecode (4 characters)

Figure 36. 16pin WL-CSP 2x2.15mm Package Dimensions



The coplanarity of the balls is 40µm.

12 Ordering Information

The devices are available as the standard products shown in Table 34.

Table 34. Ordering Information

Model	Description	Delivery Form	Package
AS3636-ZWLT	Xenon Driver IC with LED Driver and Life Time Counter	Tape & Reel	16-pin WL-CSP (2mm x 2.15mm) RoHS compliant / Pb-Free / Green

Note: All products are RoHS compliant and austriamicrosystems green.
Buy our products or get free samples online at ICdirect: http://www.austriamicrosystems.com/ICdirect

Technical support is found at http://www.austriamicrosystems.com/Technical-Support

For further information and requests, please contact us mailto:sales@austriamicrosystems.com
or find your local distributor at http://www.austriamicrosystems.com/distributor

Note: AS3636-ZWLT

AS3636
Z Temperature Range: -30ºC - 85ºC
WL Package: Wafer Level Chip Scale Package (WL-CSP) 2x2.15mm
T Delivery Form: Tape & Reel

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Contact Information

Headquarters
austriamicrosystems AG

Tobelbaderstrasse 30
Schloss Premstaetten
A-8141 Austria

Tel: +43 (0) 3136 500 0
Fax: +43 (0) 3136 525 01

For Sales Offices, Distributors and Representatives, please visit:

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Contact Information

Headquarters
austriamicrosystems AG

Tobelbaderstrasse 30
Schloss Premstaetten
A-8141 Austria

Tel: +43 (0) 3136 500 0
Fax: +43 (0) 3136 525 01

For Sales Offices, Distributors and Representatives, please visit:

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