

AS8650A

High-efficient Power Management Device with High-speed CAN Interface

1 General Description

The AS8650A is a companion IC which combines power management functions and a fully conforming high-speed CAN Transceiver in one high performance analog device for automotive applications. The AS8650A is powered by the battery, provides 4 output voltage levels of which 3 outputs can be individually programmed in the range of 1.8V to 3.3V with a maximum current consumption up to 120mA at the LDO voltage regulator outputs. An integrated DCDC converter with a very high efficiency for the 5V output supplies the 3 voltage regulators and ensures a voltage stability of $\pm 2.5\%$. The combination of DCDC converter with low-drop-out voltage regulators makes the AS8650A suitable for all Automotive Control Units where power efficiency is a must.

The AS8650A provides a high-speed CAN interface up to 1Mbps communication rate conforming to ISO 11898-5. The AS8650A provides wake-up via remote wake-up at CAN bus lines and a local wake pin. The watchdog unit provides three different timing functions: start-up, window- and time-out watchdog; configurable via the SPI and I²C interface.

Voltage monitoring is implemented for the battery supply, DCDC output and the 3 LDO regulator outputs. Undervoltage will be signalled on the INTN pin to the microcontroller. All diagnostics and status flags can be accessed with the SPI interface.

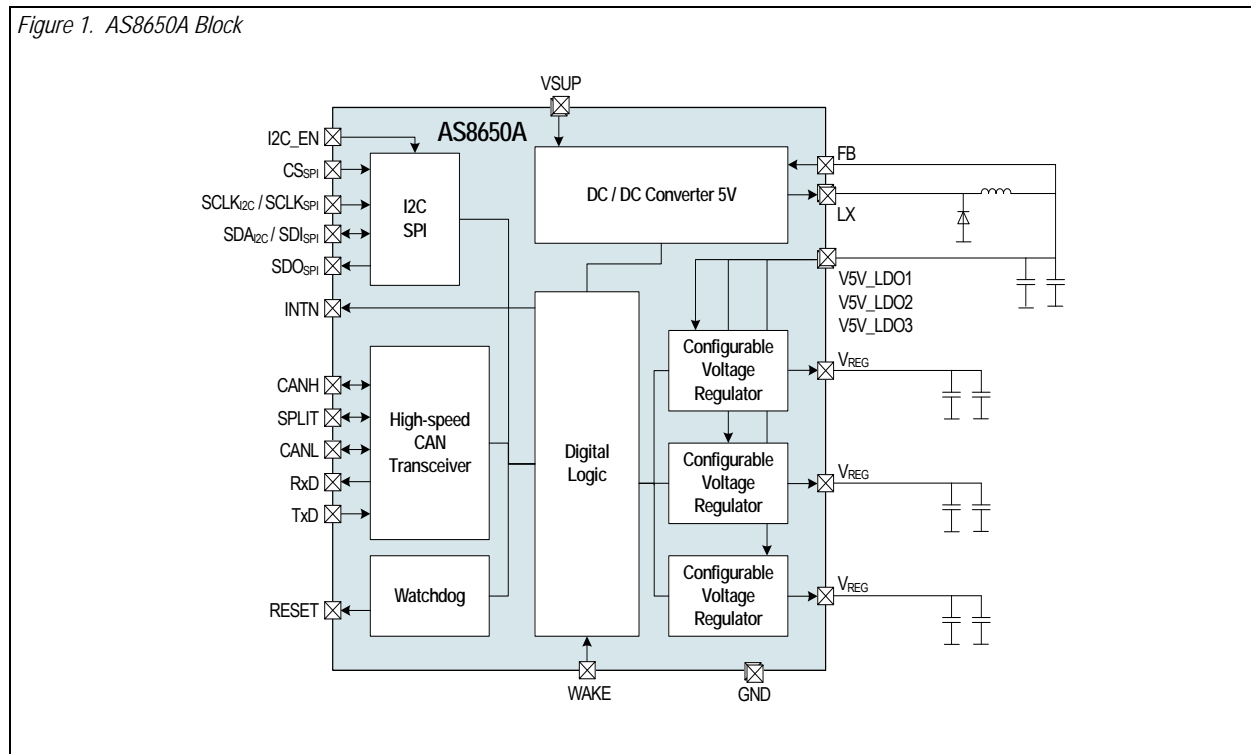
The product is available in a 36-pin QFN (6x6x0.9) package.

2 Key Features

- DCDC converter for 5V output with very high efficiency
- 2 programmable voltage regulators in the range of 1.8V to 3.3V
- High-speed CAN interface (ISO 11898-5) with remote wake-up
- Comprehensive voltage monitoring
- Configurable watchdog functions for start-up, operation, and standby
- Automatic thermal shutdown protection
- Excellent EMC performance with outstanding switching technology for the DCDC converter
- Ambient temperature range from -40°C to +105°C in maximum load conditions
- Lead-free 36-pin QFN (6x6x0.9) package

3 Applications

The AS8650A provides high efficient and flexible power supply together with state-of-the-art high-speed CAN Interface for automotive control units. The device is pin compatible with AS8550 (LIN interface) in order to change from CAN to LIN easy.



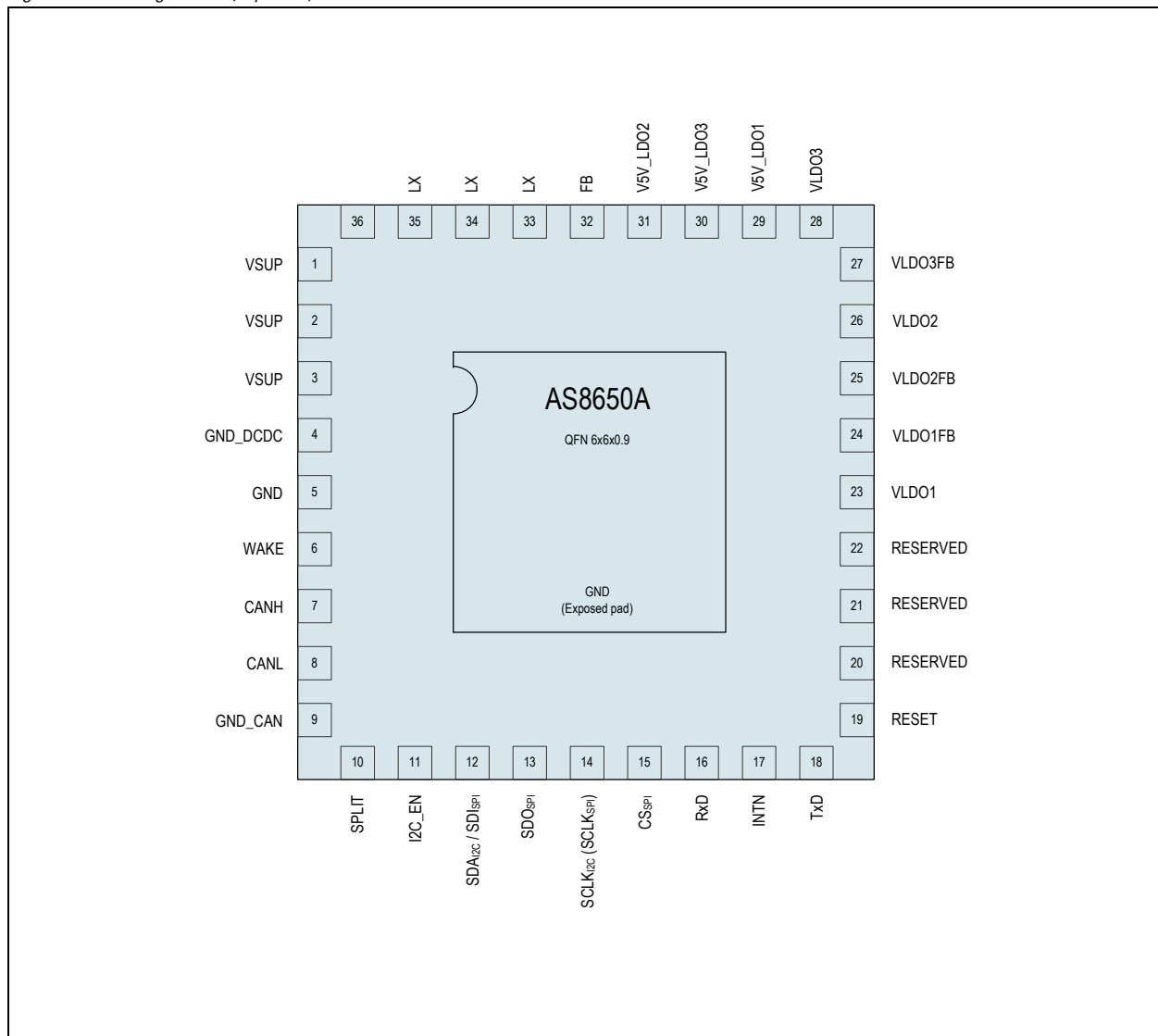
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4 Pin Assignments

Figure 2. Pin Assignments (Top View)



4.1 Pin Descriptions

Table 1. Pin Descriptions

| Pin | Pin Name | Pin Type | Description |
|---------|----------|------------------------------------|-----------------------------------------|
| 1, 2, 3 | VSUP | Power Supply Input | Power Supply |
| 4 | GND_DCDC | | |
| 5 | GND | | |
| 6 | WAKE | Analog Input / Output high-voltage | Local wake request (high-voltage input) |
| 7 | CANH | | High level CAN bus line |
| 8 | CANL | | Low level CAN bus line |
| 9 | GND_CAN | Power Supply Input | Power supply |
| 10 | SPLIT | Analog Input / Output high-voltage | Common-mode stabilization output |

Table 1. Pin Descriptions

| Pin | Pin Name | Pin Type | Description |
|------------|-------------------------------------------|-----------------------------------------------------|------------------------------------------------------------------------------|
| 11 | I2C_EN | Digital Input | I ² C/SPI select signal (High = I ² C, Low = SPI) |
| 12 | SDA _{I2C} / SDI _{SPI} | Digital Input/Output / Digital Input | Unidirectional for SPI, Bidirectional for I ² C |
| 13 | SDO _{SPI} | Digital Output | SPI data out |
| 14 | SCLK _{I2C} / SCLK _{SPI} | Digital Input | Serial clock (Multiplexed for I ² C and SPI) unidirectional |
| 15 | CS _{SPI} | Digital input with pull-up | SPI chip select |
| 16 | RxD | Digital output with pull-up | CAN Transceiver receive signal |
| 17 | INTN | Digital Output | Active low interrupt to μ C. Generated if status/ diagnostic is updated. |
| 18 | TxD | Digital input with pull-up | CAN Transceiver transmit signal |
| 19 | RESET | Digital Output | Digital Output referenced to VLDO1, active low |
| 20 | Reserved | Pin with Digital / Analog Input / Open-Drain-Output | Reserved |
| 21 | | Analog Input / Output | |
| 22 | | | |
| 23 | VLDO1 | Power Supply Input | Regulated voltage output |
| 24 | VLDO1FB | Pin with Digital / Analog Input / Open-Drain-Output | Regulated voltage feedback |
| 25 | VLDO2FB | Pin with Digital / Analog Input / Open-Drain-Output | Regulated voltage feedback |
| 26 | VLDO2 | Power Supply Input | Regulated voltage output |
| 27 | VLDO3FB | Pin with Digital / Analog Input / Open-Drain-Output | Regulated voltage feedback |
| 28 | VLDO3 | Power Supply Input | Regulated voltage output |
| 29 | V5V_LDO1 | | Step-down converter 5V output, supply for LDO1 |
| 30 | V5V_LDO3 | | Step-down converter 5V output, supply for LDO3 |
| 31 | V5V_LDO2 | | Step-down converter 5V output, supply for LDO2 |
| 32 | FB (DCDC) | Analog Input | DCDC output voltage feedback |
| 33, 34, 35 | LX (DCDC) | Power Supply Input | DCDC output |
| 0 | GND | | Exposed pad (GND) |

5 Absolute Maximum Ratings

Stresses beyond those listed in [Table 2](#) may cause permanent damage to the device. These are stress ratings only. Functional operation of the device at these or any other conditions beyond those indicated in [Electrical Characteristics on page 7](#) is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Table 2. Absolute Maximum Ratings¹

| Parameter | Min | Max | Units | Notes |
|-------------------------------------------------------------------------------------------------|---------|------------------|----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Electrical Parameters | | | | |
| Voltage at positive supply pin (V_{VSUP}) | -0.3 | 40 | V | |
| Voltage at pin V5V_LDO1, V5V_LDO2, V5V_LDO3, VLDO1, VLDO2, VLDO3, FB, VLDO1FB, VLDO2FB, VLDO3FB | -0.3 | 7 | V | |
| Voltage at pin CANH, CANL, SPLIT | -40 | +40 | V | |
| Voltage at pin LX, WAKE | -0.3 | $V_{VSUP} + 0.3$ | V | |
| Voltage at pin RESET, INTN, RxD, TxD, CS, SCLK, SDO, SDA/SDI, I2C_EN | -0.3 | 4.5 | V | |
| Input Supply slew-rate (V_{sup_slew}) | | 1 | V/ μ s | Input power supply ramp rate |
| Electrostatic Discharge | | | | |
| Electrostatic discharge voltage AEC-Q100-002 human body model standard (ESD) | ± 2 | | kV | All pins except VSUP, GND, CANH, CANL, WAKE, SPLIT |
| | ± 4 | | | VSUP, GND, WAKE, SPLIT |
| | ± 8 | | | CANH, CANL |
| Latch-Up Immunity | -100 | +100 | mA | AEC-Q100-004 |
| Continuous Power Dissipation | | | | |
| Maximum power dissipation (P_{tot}) | | 1.2 | W | |
| Temperature Ranges and Storage Conditions | | | | |
| Junction temperature (T_J) | | 170 | $^{\circ}$ C | |
| Storage temperature (T_{stg}) | -55 | +150 | $^{\circ}$ C | |
| Thermal resistance MLF package (R_{thj_36}) | | 30 | $^{\circ}$ C/W | SEMI G42-88 |
| Package body temperature (T_{BODY}) | | 260 | $^{\circ}$ C | <i>The reflow peak soldering temperature (body temperature) specified is in accordance with IPC/JEDEC J-STD-020 "Moisture/Reflow Sensitivity Classification for Non-Hermetic Solid State Surface Mount Devices".</i> The lead finish for Pb-free leaded packages is matte tin (100% Sn). |
| Moisture Sensitivity Level | | 3 | | Represents a maximum floor life time of 168h |

1. All voltages mentioned above are referred with respect to ground reference voltage V_{GND} .

6 Electrical Characteristics

Table 3. Electrical Characteristics

| Symbol | Parameter | Conditions | Min | Typ | Max | Units |
|-----------------------------|-----------------------------|----------------------------------------------------------------------------------------------|---------------|-----|---------------|-------|
| Operating Conditions | | | | | | |
| V _{SUP} | Positive supply voltage | Normal operating condition | 6 | | 18 | V |
| GND | Ground | In reference to all the voltages | 0 | | | V |
| T _{AMB} | Ambient temperature | Junction temperature (T _J) ≤ 150°C (at full-load) | -40 | | 105 | °C |
| I _{supp} | Supply current, normal mode | VSUP = 6V, LDOs at full load, DCDC load = 390mA, CAN dominant | | 425 | | mA |
| | | VSUP = 18V, LDOs at full load, DCDC load = 390mA, CAN dominant, not production tested. | | 150 | | |
| | | VSUP = 16V, LDOs at full load, CAN dominant | | 170 | | |
| CS | | | | | | |
| V _{t-} | Negative-Going Threshold | VLDO1 = 3.3V | 1.12 | | 1.52 | V |
| V _{t+} | Positive-Going Threshold | | 1.77 | | 2.23 | V |
| I _{il,cs} | Pull up current | In CS pad, Pulled up to VLDO1 | -60 | | -15 | μA |
| SDO | | | | | | |
| V _{OH} | High level output voltage | | 2.5 | | | V |
| V _{OL} | Low level output voltage | VSUP ≥ 6V | | | 0.4 | V |
| I _O | Output drive current | | | | 4 | mA |
| SDA / SDI | | | | | | |
| V _{IH} | High level input voltage | | 0.7* VLDO1 | | | V |
| V _{IL} | Low level input voltage | | | | 0.3* VLDO1 | V |
| V _{OL} | Low level output voltage | | | | 0.4 | V |
| SCLK | | | | | | |
| V _{IH} | High level input voltage | Open-drain, external 500Ω pull-up | 0.7* VLDO1 | | | V |
| V _{IL} | Low level input voltage | | | | 0.3* VLDO1 | V |
| RESET, INTN | | | | | | |
| V _{OH} | High level output voltage | | 2.5 | | | V |
| V _{OL} | Low level output voltage | VSUP ≥ 6V | | | 0.4 | V |
| I _O | Output drive current | | | | 4 | mA |
| TxD | | | | | | |
| V _{IH} | High level input voltage | | 2.0 | | | V |
| V _{IL} | Low level input voltage | | | | 0.8 | V |
| I _O | Output drive current | VSUP ≥ 6V | | | 1 | mA |

Table 3. Electrical Characteristics

| Symbol | Parameter | Conditions | Min | Typ | Max | Units |
|----------|---------------------------|---------------------------------------------------------------|-----|-----|-----|---------------|
| I_{ij} | Pull-up current | TxD pulled up to VLDO1 with control RxD pulled up to VLDO1 | -60 | | -15 | μA |
| RxD | | | | | | |
| V_{OH} | High level output voltage | | 2.5 | | | V |
| V_{OL} | Low level output voltage | | | | 0.4 | V |
| I_O | Output drive current | $V_{SUP} \geq 6\text{V}$ | | | 1 | mA |
| I_{ij} | Pull-up current | TxD pulled up to VLDO1 with control RxD pulled up to VLDO1 | -60 | | -15 | μA |

6.1 Electrical System Specification

$-40^\circ\text{C} < T_J < 150^\circ\text{C}$

Table 4. Electrical System Specification

| Symbol | Parameter | Conditions | Min | Typ | Max | Units |
|----------|---------------------------------------|-------------------------------------------------|-----|-----|-----|---------------|
| IDDnom | Current consumption normal mode | No load, $V_{SUP} = 12\text{V}$, CAN recessive | | 3.5 | 6 | mA |
| IDDrecv | Current consumption receive-only mode | No load, $V_{SUP} = 12\text{V}$, CAN recessive | | 1 | 2 | mA |
| IDDstby | Current consumption standby mode | No load, $V_{SUP} = 12\text{V}$ | | 135 | 270 | μA |
| IDDsleep | Current consumption sleep mode | No load, $V_{SUP} = 12\text{V}$ | | 75 | 150 | μA |

6.2 DCDC Converter

$-40^\circ\text{C} < T_J < 150^\circ\text{C}$; all voltages are with respect to ground, normal operating mode, unless otherwise mentioned.

Table 5. DCDC Converter

| Symbol | Parameter | Conditions | Min | Typ | Max | Units |
|----------------|----------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|-----|------|---------------|
| V_{SUP} | Battery Voltage Range | | 6 | 12 | 18 | V |
| V_{5V} | Output Voltage | | 4.75 | 5 | 5.25 | V |
| I_{LXS} | LX current limit | For inductor $22\mu\text{H}$ and capacitor $100\mu\text{F}$ | 0.8 | 1 | 1.25 | A |
| I_{V5V} | DCDC output current | | | | 500 | mA |
| R_{ON} | LX switch on-resistance | (bondwire resistance included) | | 0.8 | 1 | Ω |
| V_{FB} | Reference Voltage for FB | | 4.75 | 5 | 5.25 | V |
| Lireg_dc | Line regulation | Step from $V_{IN} = 6\text{V}$ to $V_{IN2} = 18\text{V}$, $I_{LOAD} = 100\text{mA}$ $\text{Lireg} = 100 \cdot (V_{OUT1} - V_{OUT2}) / [V_{OUT2} \cdot (V_{IN1} - V_{IN2})]$ | -0.1 | | +0.1 | % / V |
| Loreg_dc | Load regulation | I_{LOAD} step from 90mA to 10mA $V_{SUP} = 12\text{V}$ $\text{Loreg} = 100 \cdot (V_{90\text{mA}} - V_{10\text{mA}}) / V_{90\text{mA}}$ | -0.9 | | +0.9 | % |
| LX_ind | Output inductor | | 10 | | 22 | μH |
| V_{5V_cer1} | Output ceramic capacitor 1 | | 10 | | 100 | μF |
| V_{5V_esr1} | ESR of ceramic capacitor 1 | | 0 | | 0.05 | Ω |
| V_{5V_cer2} | Output ceramic capacitor 2 | X7R type | 100 | | 220 | nF |
| V_{5V_esr2} | ESR of ceramic capacitor 2 | | | | 0.01 | Ω |
| C_{sup} | Input capacitor (ceramic) | For EMC suppression | 22 | | 100 | μF |
| C_{sup_esr} | | | | | 1 | Ω |

6.3 Low Drop Out Regulators

-40°C < T_j < 150°C; all voltages are with respect to ground, normal operating mode, unless otherwise mentioned. The LDO block is a linear voltage regulator, which provides a regulated (band-gap stabilized) output voltage from the DCDC converter output voltage (V5V).

Table 6. VLDO1¹ Block Specifications

| Symbol | Parameter | Conditions | Min | Typ | Max | Units |
|----------------------|------------------------------|-----------------------------------------------------------------------------------------|-------|-----|-------|-------|
| V5V | Input Voltage Range | | 4.75 | 5 | 5.25 | V |
| I _{OUTLDO1} | Output current | Guaranteed by design. Not production tested. | 0 | | 100 | mA |
| VLDO1 | Output Voltage Range | | 3.217 | 3.3 | 3.383 | V |
| ICC_SH | Output Short Circuit Current | Normal mode | | | 300 | mA |
| dVLDO1 | Line Regulation | Δ VLDO1/ Δ V5V (static) for the input range, I _{LOAD} = 100mA | -8 | | 8 | mV/V |
| LOREG_NM | Load Regulation | Δ VLDO1 (for 100mA > I _{LOAD} > 1mA), V5V = 5V | -0.15 | | +0.15 | mV/mA |
| CL2 | Output Capacitor (Ceramic) | X7R type | 2 | | 5 | μF |
| ESR2 | | | 0.02 | | 0.1 | Ω |
| CL1 | | X7R type | 100 | | 220 | nF |
| ESR1 | | | | | 0.01 | Ω |

1. Please note that the VLDO1 is not programmable.

Table 7. VLDO2¹ Block Specifications

| Symbol | Parameter | Conditions | Min | Typ | Max | Units |
|----------------------|------------------------------|-----------------------------------------------------------------------------------------------------------|----------------------------|------------------|----------------------------|-------|
| V5V | Input Voltage Range | | 4.75 | 5 | 5.25 | V |
| I _{OUTLDO2} | Output current | Guaranteed by design. Not production tested. | 0 | | 120 | mA |
| VLDO2 | Output Voltage Range | V _{OUT} (typ) depends on the trim code as in OTP register mapping. Default code gives 2.8V | 0.975* V _{OUT} | V _{OUT} | 1.025* V _{OUT} | V |
| ICC_SH | Output Short Circuit Current | Normal mode | | | 300 | mA |
| dVLDO2 | Line Regulation | Δ VLDO2/ Δ V5V (static) for the input range, I _{LOAD} = 100mA | -8 | | 8 | mV/V |
| LOREG_NM | Load Regulation | Δ VLDO2 (for 120mA > I _{LOAD} > 1mA) | -0.15 | | +0.15 | mV/mA |
| CL2 | Output Capacitor (Ceramic) | X7R type | 2 | | 5 | μF |
| ESR2 | | | 0.02 | | 0.1 | Ω |
| CL1 | | X7R type | 100 | | 220 | nF |
| ESR1 | | | | | 0.01 | Ω |

1. V_{OUT} = 3.3V to 1.8V output.

Table 8. VLDO3¹ Block Specifications

| Symbol | Parameter | Conditions | Min | Typ | Max | Units |
|----------------------|------------------------------|-----------------------------------------------------------------------------------------------------------|----------------------------|------------------|----------------------------|-------|
| V5V | Input Voltage Range | | 4.75 | 5 | 5.25 | V |
| I _{OUTLDO3} | Output current | Guaranteed by design. Not production tested. | 0 | | 100 | mA |
| VLDO3 | Output Voltage Range | V _{OUT} (typ) depends on the trim code as in OTP register mapping. Default code gives 1.8V | 0.975* V _{OUT} | V _{OUT} | 1.025* V _{OUT} | V |
| ICC_SH | Output Short Circuit Current | Normal mode | | | 300 | mA |
| dVLDO3 | Line Regulation | ΔVLDO3/ΔV5V (static) for the input range, I _{LOAD} = 100mA | -8 | | 8 | mV/V |
| LOREG_NM | Load Regulation | ΔVLDO3 (for 100mA > I _{LOAD} > 1mA) | -0.15 | | +0.15 | mV/mA |
| CL2 | Output Capacitor (Ceramic) | X7R type | 2 | | 5 | μF |
| ESR2 | | | 0.02 | | 0.1 | Ω |
| CL1 | | X7R type | 100 | | 220 | nF |
| ESR1 | | | | | 0.01 | Ω |

1. V_{OUT} = 3.3V to 1.8V output.

6.4 CAN Transceiver

6V < V_{SUP} < 18V; -40°C < T_j < 150°C; all voltages are with respect to ground; 4.75V < V5V_LDO1 < 5.25V; R_L=60Ω.

Table 9. DC Electrical Characteristics

| Symbol | Parameter | Conditions | Min | Typ | Max | Units |
|-----------------|------------------------------------------------------------|---------------------------------------------------------------------------------|------|-----|------|-------|
| Driver | | | | | | |
| CANH_dom | Dominant Output Voltage | V _{TxD} = 0V | 3 | | 4.25 | V |
| CANL_dom | | | 0.5 | | 1.75 | V |
| VO_dom_m | Matching Dominant Output Voltage V5V_LDO1-V_CANH-V_CANL | | -0.1 | | 0.15 | V |
| VO_diff | Differential output voltage V_CANH-V_CANL | 45Ω < R _L < 60Ω, V _{TxD} = 0V (dominant) | 1.5 | | 3 | V |
| | | No load; V _{TxD} = VLDO1 (recessive) | -50 | | 50 | mV |
| VO_rec | Recessive output voltage V_CANH, V_CANL | V _{TxD} = VLDO1; No bus load, Normal mode | 2 | | 3 | V |
| | | No bus load, Standby mode | -0.1 | | 0.1 | V |
| IO_short | Short circuit output current | V _{TxD} = 0V, V_CANH = 0V | -160 | | -50 | mA |
| | | V _{TxD} = 0V, V_CANL = 40V | +50 | | +160 | mA |
| IO_rec | Recessive output current | -27V < V_CAN < 40V | -2.5 | | +2.5 | mA |
| Receiver | | | | | | |
| V_RxD_th | Differential receiver threshold voltage | -12V < V_CANH < 12V -12V < V_CANL < 12V Receive only mode (CAN receiver) | 0.5 | | 0.9 | V |
| | | -12V < V_CANH < 12V -12V < V_CANL < 12V Standby mode (low-power receiver) | 0.4 | | 1.15 | V |

Table 9. DC Electrical Characteristics

| Symbol | Parameter | Conditions | Min | Typ | Max | Units |
|------------|------------------------------------------|--------------------------------------------------------------------------------|------------------|-----|------------------|-------|
| V_RxD_hys | Differential receiver hysteresis voltage | -12V < V_CANH < 12V -12V < V_CANL < 12V Receive only mode (CAN receiver) | 20 | | 130 | mV |
| I_RxD_LEAK | Input leakage current | V5V_LDO1 = 0V; V_CANH = V_CANL = 5V | 100 | | 250 | μA |
| R_IN_cm | Common mode input resistance | Tested in Receive only mode | 15 | | 35 | kΩ |
| R_IN_cm_m | Common mode input resistance matching | V_CANH = V_CANL (Tested in Receive only mode) | -3 | | +3 | % |
| R_IN_diff | Differential input resistance | Tested in Receive only mode | 25 | | 75 | kΩ |
| VO_SPLIT | Output voltage on split pin | Normal mode -500μA < I_SPLIT < 500μA | 0.3* V5V_LDO1 | | 0.7* V5V_LDO1 | V |
| IL_SPLIT | Leakage current on split pin | Standby mode 0V < V_SPLIT < 35V (Not production tested) | -5 | | +5 | μA |
| | | Standby mode -22V < V_SPLIT < 0 (Not production tested) | -1 | | +1 | mA |

Table 10. AC Electrical Characteristics

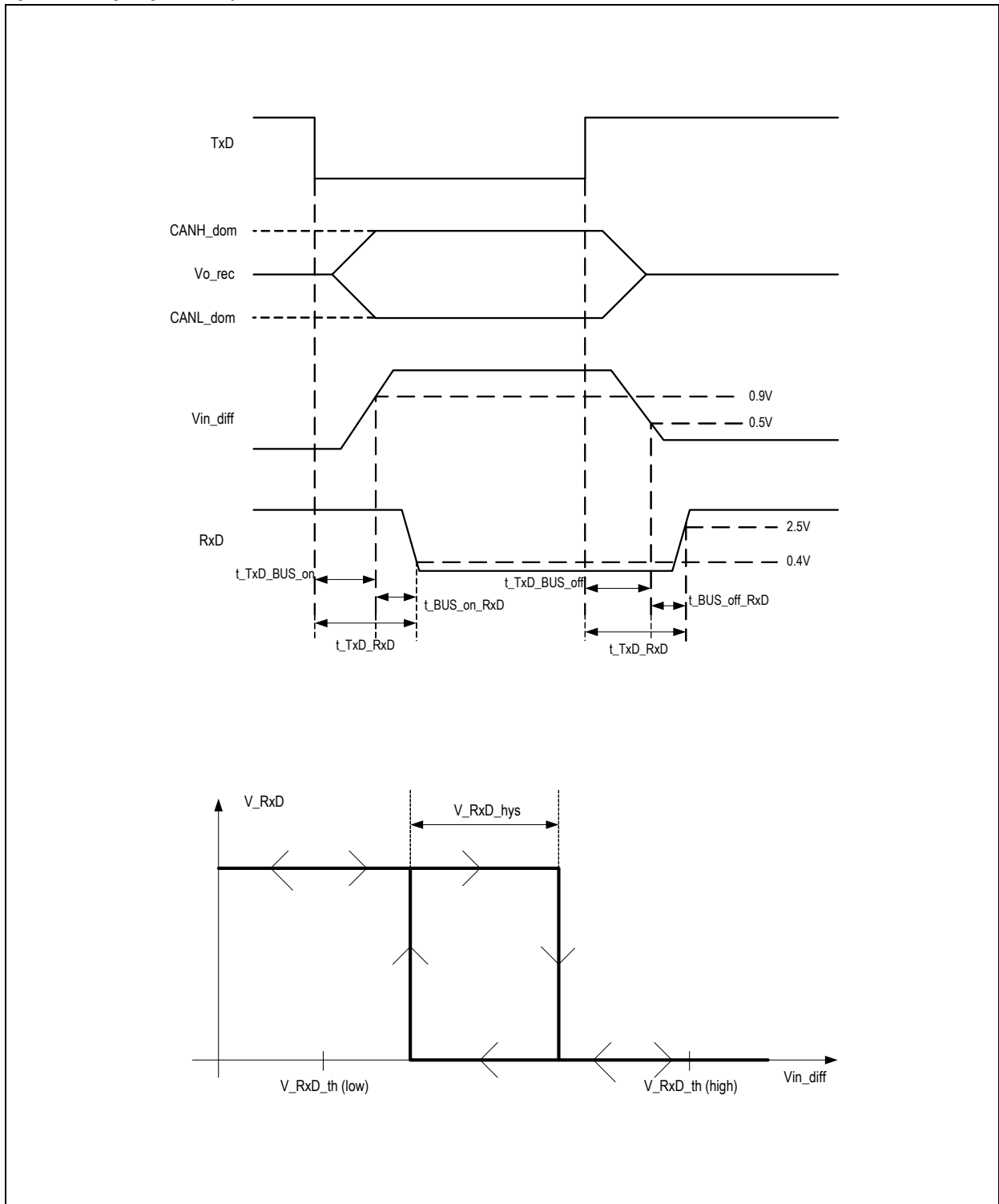
| Symbol | Parameter | Conditions | Min | Typ | Max | Units |
|------------------------|---------------------------------------------|-----------------------------------------------------|------|-----|-----|-------|
| t_TxD_BUS_on | Delay TxD to bus dominant | | 10 | | 110 | ns |
| t_TxD_BUS_off | Delay TxD to bus recessive | | 10 | | 140 | ns |
| t_BUS_on_RxD | Delay bus dominant to RxD | | 15 | | 115 | ns |
| t_BUS_off_RxD | Delay bus recessive to RxD | | 20 | | 160 | ns |
| t_TxD_RxD | Propagation Delay TxD to RxD | | 40 | | 255 | ns |
| WAKE UP via BUS | | | | | | |
| t_BUS_WR | Dominant time for wake-up detection via bus | | 0.75 | | 5 | μs |
| BUS Diagnostic | | | | | | |
| t_OC_CANH | Time to detect over current CANH | V_TxD = 0V, V_CANH = 0V (Not production tested) | 60 | | | μs |
| t_LC_CANH | Time to detect low current CANH | V_TxD = 0V, V_CANH = 40V (Not production tested) | 60 | | | μs |
| t_OC_CANL | Time to detect over current CANL | V_TxD = 0V, V_CANL = 40V (Not production tested) | 60 | | | μs |
| t_LC_CANL | Time to detect low current CANL | V_TxD = 0V, V_CANL = 0V (Not production tested) | 60 | | | μs |

Table 11. Temperature Limiter

| Symbol | Parameter | Conditions | Min | Typ | Max | Units |
|---------|-----------------------------------|------------------------------------------------------------------------------|-----|-----|-----|-------|
| T_jshut | Shut down temperature | Junction temperature when IC shuts down | 150 | 170 | 185 | °C |
| T_jrecv | Recovery temperature | Junction temperature below which state machine returns from shutdown/warning | 125 | 140 | 155 | °C |
| T_jwam | Over-temperature warning flag set | Junction temperature beyond which the warning flag is set | 140 | 157 | 175 | °C |

6.4.1 Timing Diagrams

Figure 3. Timing Diagram and Hysteresis of CAN Receiver



6.5 Undervoltage Detection

Table 12. Undervoltage Detection

| Symbol | Parameter | Conditions | Min | Typ | Max | Units |
|------------|----------------------------------------------------------------|---------------------------------------------------------------------|-------|------|-------|---------|
| VSUP_POR | VSUP Power on Reset threshold on | Rising edge of VSUP | 5.09 | 5.5 | 5.91 | V |
| VSUP_RESET | VSUP Power on Reset threshold off | (Master Reset for Device) | 4.49 | 4.85 | 5.21 | V |
| VSUP_POKTH | VSUP undervoltage threshold off | VSUP rising edge. (Brown out reset threshold) | 4.95 | 5.35 | 5.75 | V |
| VSUP_UVTH | VSUP undervoltage threshold on (CAN bus in recessive state) | VSUP falling edge. (Brown out reset threshold) | 4.625 | 5.0 | 5.375 | V |
| V5V_POKTH | V5V undervoltage threshold off | Rising edge of V5V | 4.16 | 4.5 | 4.84 | V |
| V5V_UVTH | V5V undervoltage threshold on | Falling edge of V5V | 3.8 | 4.1 | 4.4 | V |
| VLDO_POKTH | LDO undervoltage threshold off (VLDO1, VLDO2 and VLDO3) | Percent value is with respect to LDO output. Rising edge of LDO | 87 | 89 | 91 | % |
| VLDO_UVTH | LDO undervoltage threshold on (VLDO1, VLDO2 and VLDO3) | Percent value is with respect to LDO output. Falling edge of LDO | 78 | 80 | 82 | % |
| t_{rr} | Spike filter on VLDO1 | To remove disturbance | 2 | 4 | 8 | μ s |
| t_{Res} | Reset delay time | | 4 | 8 | 12 | ms |

6.6 Digital Timing Specification

SPI Protocol.

Table 13. SPI Timing Parameters

| Symbol | Parameter | Conditions | Min | Typ | Max | Units |
|-----------------------------------------------------------|------------------------------------|-------------------------------------------------------|-----|-----|-----|-------|
| General | | | | | | |
| BR _{SPI} | Bit rate | | | | 1 | Mbps |
| T _{SCLKH} | Clock high time | | 500 | | | ns |
| T _{SCLKL} | Clock low time | | 500 | | | ns |
| Write Operation Parameters | | | | | | |
| t _{DIS} | Data in setup time | | 20 | | | ns |
| t _{DIH} | Data in hold time | | 10 | | | ns |
| T _{CSH} | CS hold time | | 40 | | | ns |
| Read Operation Parameters | | | | | | |
| t _{DOD} | Data out delay | | | | 80 | ns |
| t _{DOHZ} | Data out to high impedance delay | Time for the SPI to release the SDO bus | | | 80 | ns |
| Timing Parameters for SCLK Polarity Identification | | | | | | |
| t _{CPS} | Clock setup time (CLK polarity) | Setup time of SCLK with respect to CS falling edge | 20 | | | ns |
| t _{CPHD} | Clock hold time (CLK polarity) | Hold time of SCLK with respect to CS falling edge | 20 | | | ns |

I²C Protocol. Electrical characteristics of SDA & SCLK bus lines for F/S mode

Table 14. I²C Electrical Parameters

| Symbol | Parameter | Standard | | Fast | | Units |
|------------------|----------------------------------------------------------------------------------------------------------------|------------|-------------------------|--------------------------------------------|-------------------------|---------------------------------|
| | | Min | Max | Min | Max | |
| V _{IL} | LOW level input voltage: VLDO1-related input levels | | 0.3V*VLDO1 | | 0.3V*VLDO1 | V |
| V _{IH} | HIGH level input voltage: VLDO1-related input levels | 0.7V*VLDO1 | | 0.7V*VLDO1 | | V |
| V _{hys} | Hysteresis of Schmitt trigger input | n/a | n/a | 0.05V*VLDO1 | | V |
| V _{OL1} | LOW level output voltage (open drain or open collector) at 3mA sink current | | 0.4 | | 0.4 | V |
| t _{of} | Output fall time from V _{IHmin} to V _{ILmax} with a bus capacitance from 10pF to 400pF | | 250 (see Footnote 2) | 20 + 0.1C _b (see Footnote 1) | 250 (see Footnote 2) | ns (lab tested only) |
| t _{SP} | Pulse width of spikes which must be suppressed by the input filter | n/a | n/a | | 50 | ns |
| I _i | Input current of each I/O pin with an input voltage between 0.1VLDO1 and 0.9VLDO1 maximum | -10 | 10 | -10 (see Footnote 3) | 10 (see Footnote 3) | μA |
| C _i | Capacitance for each I/O pin | | 10 | | 10 | pF (guaranteed by design) |

1. C_b = capacitance of one bus line in pF.
2. The maximum t_f for the SDA and SCLK bus lines quoted in Table 15 (300ns) is longer than the specified maximum t_{of} for the output stages (250ns). This allows for any series protection resistors to be connected between the SDA/SCLK pins and the SDA/SCLK bus lines without exceeding the maximum specified t_f.
3. I/O pins of Fast-mode devices must not obstruct the SDA and SCLK lines if VLDO1 is switched off.

Characteristics of the SDA and SCLK Bus Lines for F/S Mode I²C Bus.

Table 15. I²C Timing Parameters

| Symbol | Parameter | Standard | | Fast | | Units |
|---------------------|---------------------------------------------------------------------------------------------|-----------------------|--------------------------|----------------------------------------------|-------------------------|-------|
| | | Min | Max | Min | Max (see Footnote 1) | |
| f _{SCLK} | SCLK clock frequency | 0 | 100 | 0 | 400 | kHz |
| t _{HD_STA} | Hold time (repeated) START condition. After this period, the first clock pulse is generated | 4 | - | 0.6 | - | μs |
| t _{LOW} | LOW period of the SCLK clock | 4.7 | - | 1.3 | - | μs |
| t _{HIGH} | HIGH period of the SCLK clock | 4.0 | - | 0.6 | - | μs |
| t _{SU_STA} | Set-up time for a repeated START condition | 4.7 | - | 0.6 | - | μs |
| t _{SU_DAT} | Data set-up time | 250 | - | 100 (see Footnote 2) | - | ns |
| t _{HD_DAT} | Data hold-time | 0 (see Footnote 5) | 3450 (see Footnote 3) | 0 (see Footnote 5) | 900 (see Footnote 3) | ns |
| t _r | Rise time of SDA and SCLK signals | - | 1000 | 20+ 0.1C _b (see Footnote 4) | 300 | ns |
| t _f | Fall time of SDA and SCLK signals | - | 300 | 20+ 0.1C _b (see Footnote 4) | 300 | ns |
| t _{SU_STO} | Set-up time for STOP condition | 4.0 | - | 0.6 | - | μs |
| t _{BUF} | Bus free time between a STOP and START condition | 4.7 | - | 1.3 | - | μs |
| C _b | Capacitive load for each bus line | - | 400 | - | 400 | pF |
| V _{nL} | Noise margin at the LOW level for each connected device (including hysteresis) | 0.1V*LDO1 | - | 0.1V*LDO1 | - | |
| V _{nH} | Noise margin at the HIGH level for each connected device (including hysteresis) | 0.2V*LDO1 | - | 0.2V*LDO1 | - | |

1. All values referred to V_{IHmin} and V_{Ilmax} levels (see Table 14).
2. A fast mode I²C bus device can be used in Standard mode I²C bus system, but the requirement t_{SU_DAT} ≥ 250ns must then be met. This will automatically be the case if the device do not stretch the LOW period of the SCLK signal. If such a device does stretch the LOW period of the SCLK signal, it must output the next data bit to the SDA line t_{rmax}. T_{SU_DAT} = 1000 + 250 = 1250ns (according to standard mode I²C bus specification) before the SCLK line released.
3. The maximum t_{HD:DAT} has only to be met if the device does not stretch the LOW period (t_{LOW}) of the SCLK signal.
4. C_b = total capacitance of one bus line in pF. If mixed with Hs-mode devices, faster fall-times according to Table 14 allowed.
5. This device internally provides a hold time of at least 300ns for the SDA signal to bridge the undefined region of the falling edge of the SCLK.

6.6.1 System Specification and Timings

Table 16. System Timing Parameters

| Symbol | Parameter | Conditions | Min | Typ | Max | Units |
|---------------------------------------|-------------------------------------------------------------------------|--------------------------------------------------------|-------|------|-------|-------------------------|
| Mode Transition Related Timing | | | | | | |
| T _{POST} | Power-up to Standby mode | Reset time included, Start-up watchdog not included | | | 70 | ms |
| T _{STNO} | Standby to Normal mode | | | | 10 | ms |
| T _{SLST} | Sleep to Standby mode | Reset time included | | | 50 | ms |
| Wake-up Timing | | | | | | |
| T _{dom(wake)} | Minimum dominant pulse for CAN wake-up detection (remote wake) | | 5 | | | µs |
| T _{rec(wake)} | Minimum recessive pulse for CAN wake-up detection (remote wake) | | 5 | | | µs |
| TL _{wake} | Time between edge on WAKE pin to local wake detection | | | 32 | | µs |
| TLW _{filter} | Time between edge on WAKE pin to WAKE_LOCAL signal (Filter on WAKE pin) | | 0.75 | | 5 | µs |
| TR _{wake} | Remote wake detection time from the valid pattern detection | | | 24 | | µs |
| T _{INTN} | INTN pin high time | | 7 | | | µs |
| V _{LWUTH} | Local WAKE threshold input | | 2 | | 4 | V |
| Local Failure Related Timing | | | | | | |
| TT _{xDC(dom)} | TxD dominant time-out period | | 600 | 1000 | 1400 | µs |
| T _{BUSC(dom)} | BUS dominant clamping time-out period | | 600 | 1000 | 1400 | µs |
| Watchdog Timing & Timeouts | | | | | | |
| T _{WD(init)} | Start-up Watchdog time-out (initialization time) | | | 300 | | ms |
| T _{wd_trig} | Window watchdog Trigger window | T _{wwd_period} is defined in WWD register | 0.375 | 0.5 | 0.625 | T _{wwd_period} |

7 Detailed Description

The AS8650A consists of the following components on chip:

- DCDC converter with 5V outputs that supplies the three LDO voltage regulators and the CAN Transceiver
- One voltage regulator for 3.3V output voltage and two programmable voltage regulators in the range of 3.3V to 1.8V
- CAN bus Transceiver according to ISO 11898-5
- Integrated RESET unit with a power-on-reset delay and a programmable watchdog time

7.1 Operating Modes and States

The AS8650A provides four main operating modes normal, receive only, standby, and sleep. In normal mode, the CAN Transceiver can be disabled in case of over-temperature condition. The detailed transition table for each mode is shown in the subsequent pages.

7.1.1 Normal Mode

In normal mode DCDC converter, the three voltage regulators, BUS Transceiver, and Window Watchdog are turned on with full functionality. All the LDO regulators are capable of delivering maximum load current possible as per their respective ratings. The BUS Transceiver is capable of sending the TxD data from the microcontroller to the CANH at the maximum rate.

7.1.2 Receive-only Mode

In this mode, the CAN transmitter is disabled. The CAN receiver, the three voltage regulators, and over-temperature monitor circuit are enabled.

7.1.3 Standby Mode

This is the mode after power up. The Standby mode is a functional low-power mode where the CAN Transceiver is disabled. The bus wake-up (low power receiver) circuit, LDO1, and over-temperature monitor circuit are enabled. Both LDO2 and LDO3 can be enabled or disabled (default state) using the host command. The AS8650A can enter normal mode, sleep mode or receive only mode through host command.

7.1.4 Sleep Mode

Sleep mode is the current saving mode that is entered by host command or by over-temperature condition. The DCDC converter, the three voltage regulators, CAN Transceiver, the reset, and window watchdog unit are all switched off. The bus wake-up (low power receiver) circuit, oscillator, and over-temperature monitor circuit are active. The bus is in recessive state (high). The only wake-up possible is through remote wake-up (through the bus lines) or local wake up (through the WAKE pin) as described in the WAKE specification. In the case of entering sleep mode due to over-temperature condition ($T > T_{jshut}$), the device can come out of sleep only after the temperature falls back below the return temperature T_{jrecv} and any one of the wake up events mentioned above.

7.2 Power Management Strategy

The detailed block diagram and the power management strategy are shown in [Figure 4](#).

Internal Regulator. This module is powered externally by the VSUP. All the critical modules that needs to be kept always on, work on this supply. Some of the important modules among them are Over-temperature monitor, Local Wake block, Internal Power-on Reset module, Internal Oscillator, complete mode-control unit, Undervoltage comparators of three external LDOs.

DCDC Converter. This is the main supply regulator for all the internal blocks. A step-down hysteretic buck converter is used to generate 5V output from VSUP. This 5V output is then used to generate all the three LDOs. This high-efficiency step-down DCDC converter contains the following features:

- Current limited operation
- Thermal shutdown

LDO1. This is the main I/O supply. This is generated internally from the 5V DCDC converter output and gives a regulated 3.3V output to power-up the external micro-controller. All the I/Os that interface with the micro-controller work on this supply.

LDO2 and LDO3. These are two regulators that are generated from the 5V DCDC converter output. Both the LDOs can be programmed via I²C or SPI settings in the range from 3.3V to 1.8V.

Figure 4. Power Management Strategy

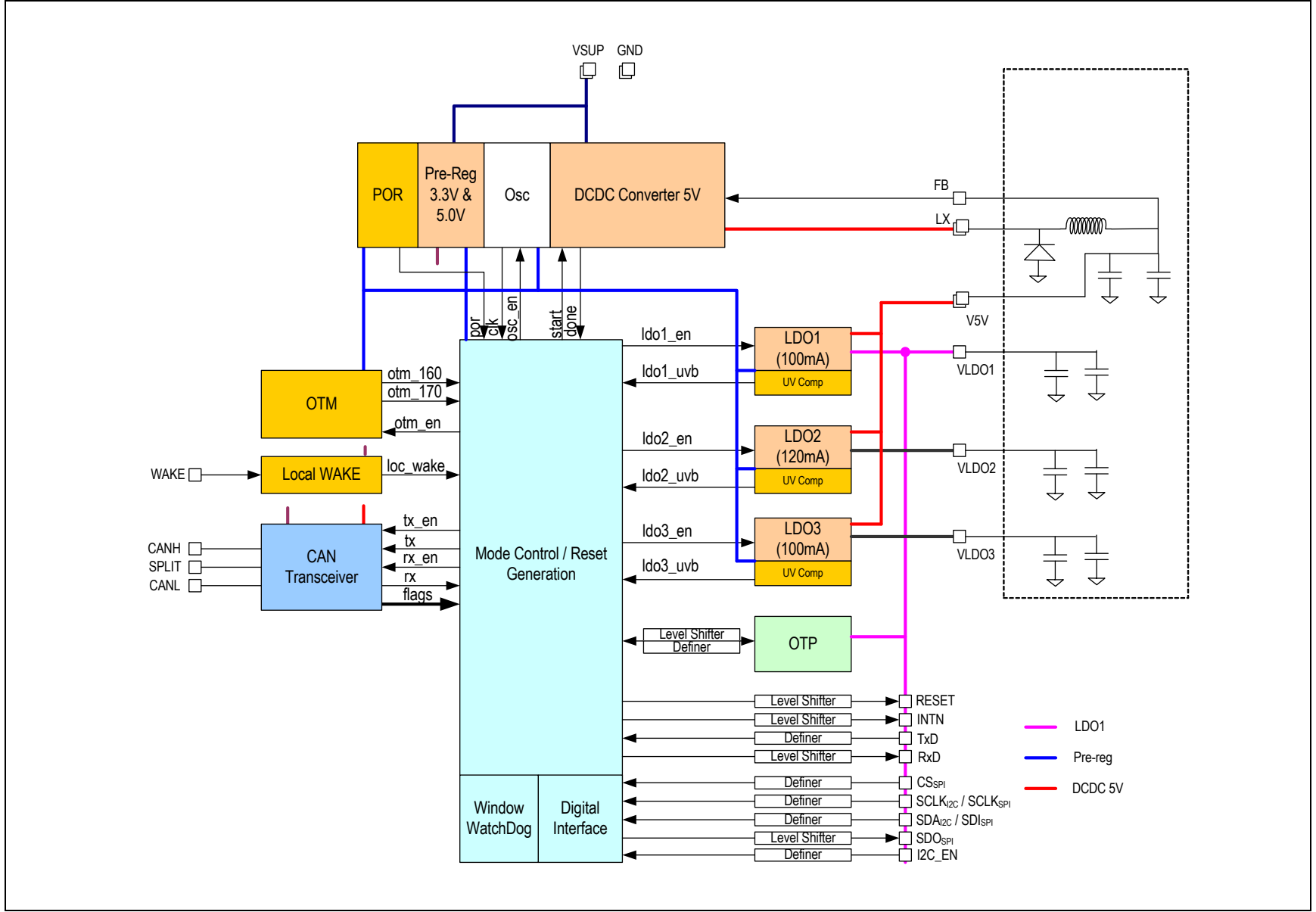


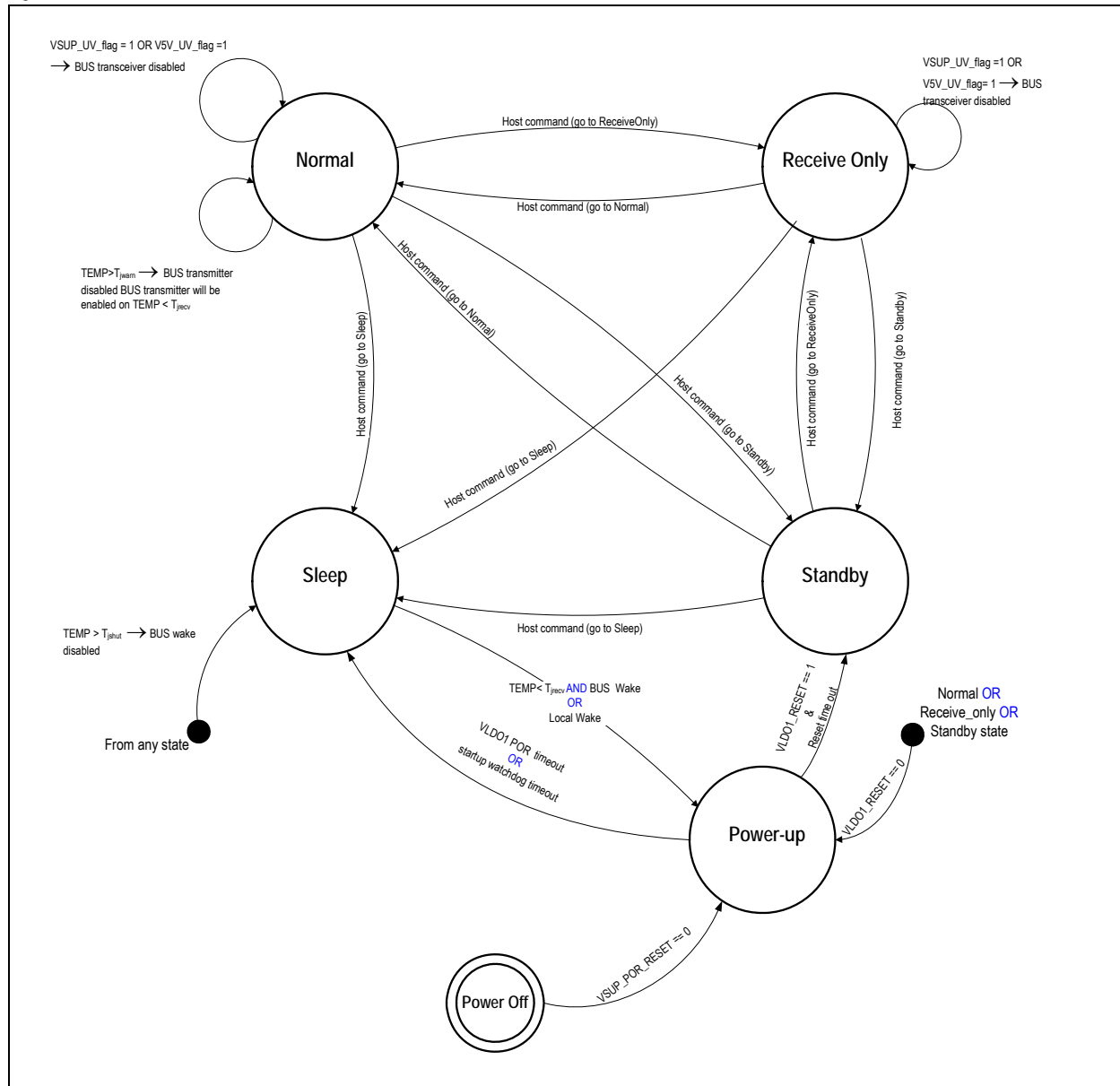
Table 17. Power Management Strategy for AS8650A

| Control States | Power-up | Normal | RX Only | Standby | Sleep |
|-----------------------|----------|-----------------|-----------------|------------------|------------------|
| Analog Blocks | | | | | |
| DCDC Converter | ON | ON | ON | ON | OFF ¹ |
| Oscillator | ON | ON | ON | ON | ON |
| Internal Regulator | ON | ON | ON | ON | ON |
| OTM | ON | ON | ON | ON | ON |
| LDO1 | ON | ON | ON | ON | OFF |
| LDO2 | OFF | ON ² | ON ² | OFF ¹ | OFF |
| LDO3 | OFF | ON ² | ON ² | OFF ¹ | OFF |
| CAN TX | OFF | ON | OFF | OFF | OFF |
| CAN RX | OFF | ON | ON | OFF | OFF |
| Low Power RX | OFF | OFF | OFF | ON | ON |
| LOCAL WAKE | OFF | OFF | OFF | ON | ON |
| SPLIT Generation | OFF | ON | ON | ON | ON |
| Digital Blocks | | | | | |
| WWD | OFF | ON | ON | ON | OFF |
| Digital Interface | OFF | ON | ON | ON | OFF |

1. Can be turned ON using Device configuration register
2. Can be turned OFF using Device Configuration register

7.3 State Diagram

Figure 5. State Machine Model



7.4 Initialization Sequence

The DCDC converter is switched 'ON'. Subsequently, on receiving power-good (PG) signal from the DCDC converter, the LDO1 regulator is switched 'ON'. During the initialization sequence, the VLDO1 is set to 2.5V if VLDO1 > VLDO1_POKTH threshold. VLDO1_RESET is released to 'high'. Then, active-low PORN_2_OTP is generated.

Initially the rising edge of PORN_2_OTP loads contents into the OTP latch. Next the LOAD_OTP_IN_PREREG signal loads the content of OTP latch into the pre-regulator domain register. Once the VLDO1_POKTH threshold is reached, the reset timeout timer also starts.

The RESET signal expires after Reset timeout period T_{Res} . After the RESET signal is 'high', the startup watchdog is launched. If the microcontroller generates a trigger within the startup window, then the device enters into Standby mode.

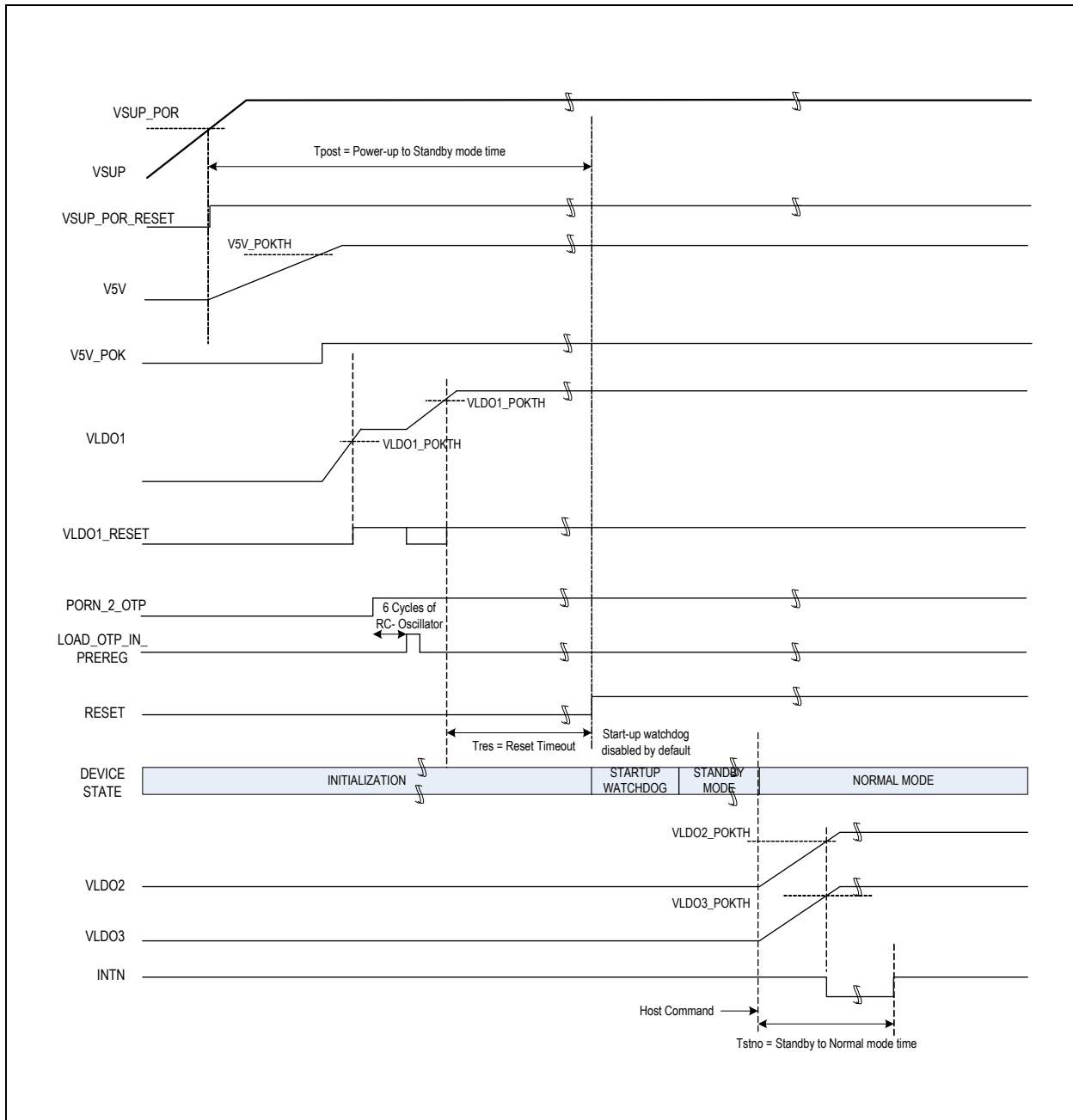
If the microcontroller fails to generate the trigger, then the RESET signal is generated and the Reset timeout will start.

If the microcontroller fails to generate the startup watchdog trigger for 3 consecutive times, then the device enters into Sleep mode. On receiving Normal mode command from the microcontroller, the LDO2 and LDO3 regulators are activated. By the time VLDO2 and VLDO3 reach their respective power-ok (POK) threshold values, an interrupt signal is generated. The AS8650A supports very slow VSUP ramp up of 0.5V/min.

The power initialization sequence diagram is shown in Figure 6.

- After activating the power supply on VSUP pin, the VSUP_POR_RESET flag becomes inactive (high) while the voltage exceeds the VSUP_POR threshold.
- The DCDC output voltage V5V exceeds the V5V_POKTH thresholds after the DCDC settling time and the first voltage regulator (LDO1) will be activated with the V5V_POK set.
- If the voltage output at LDO1 (set to 2.5V on power-up) reaches the VLDO1_POKTH threshold, the PORN_2_OTP flag is set and OTP register setting for the LDO1 is read. Consequently the output voltage will be regulated to the actual OTP settings.
- The initialization phase of the device is terminated after the preset output voltage level threshold is exceeded and the reset timeout is expired.
- After entering Standby mode the host controller can switch the device in any operation mode through the I²C or SPI interface.

Figure 6. Initialization Sequence



7.5 DCDC Converter

The high-efficiency, high-voltage, hysteretic step-down DCDC converter, operates in asynchronous mode and delivers 500mA of output load to drive the three internal LDOs and the CAN Transceiver. The low-power architecture extends hold-up time in battery-backed and critical applications where maximum up-time over a wide input supply voltage range is needed, while still providing for high efficiencies of up to 90% during peak current demands.

7.6 Voltage Regulator LDO1

The stability of the voltage output is below $\pm 2.5\%$ over the full input range and temperature for load current up to 100 mA at 3.3V. Power Input to this LDO is the V5V_LDO1 pin. This LDO is activated in Normal, Receive only or Standby mode. It is switched OFF in Sleep mode.

7.7 Voltage Regulator LDO2

The stability of the voltage output is below $\pm 2.5\%$ over input range and temperature for load current up to 100 mA. The voltage regulator is programmable between 3.3V and 1.8V via I²C or SPI interface. Power Input to this LDO is the V5V_LDO2 pin. LDO2 is activated in Normal and Receive Only mode.

7.8 Voltage Regulator LDO3

The stability of the voltage output is below $\pm 2.5\%$ over input range and temperature for load current up to 100 mA. The voltage regulator is programmable between 3.3V and 1.8V via I²C or SPI interface. Power Input to this LDO is the V5V_LDO3 pin. LDO3 is activated in Normal and Receive Only mode.

7.9 Over-Temperature Monitor

In Normal mode, if the junction temperature reaches the over-temperature threshold T_{jwarm} , a warning flag is set in the diagnostic register which can be accessed via the I²C and the SPI interface and an interrupt is signalled on INTN pin. The CAN transmitter is disabled and the device remains in Normal mode. If the junction temperature falls below T_{jrecv} , the CAN transmitter is enabled. The warning flag is cleared in the diagnostic register and an interrupt is signalled at the INTN pin. If the junction temperature exceeds the over-temperature threshold T_{jshut} , the device enters sleep mode irrespective of the current mode and bus wake receiver (Low power receiver) is disabled. As soon as the temperature falls below T_{jrecv} , the bus wake receiver (Low power receiver) is switched on.

7.10 Undervoltage Reset

Undervoltage on VSUP (Brown out Indication). If VSUP voltage falls below VSUP_UVTH threshold, the VSUP_UV_flag is set and an interrupt at INTN is generated. In this case the device enters into the Standby mode. The LDO1 voltage regulator remains activated. Two scenarios are possible at this stage:

- VSUP is recovering: If VSUP exceeds the VSUP_POKTH threshold, the VSUP_POK_flag is set and the device remains in Standby mode.
- VSUP is still falling: In this case the device continues to stay in Standby mode. If voltage falls below VSUP_RESET threshold, then the device enters Power-Off and the logic is reset.

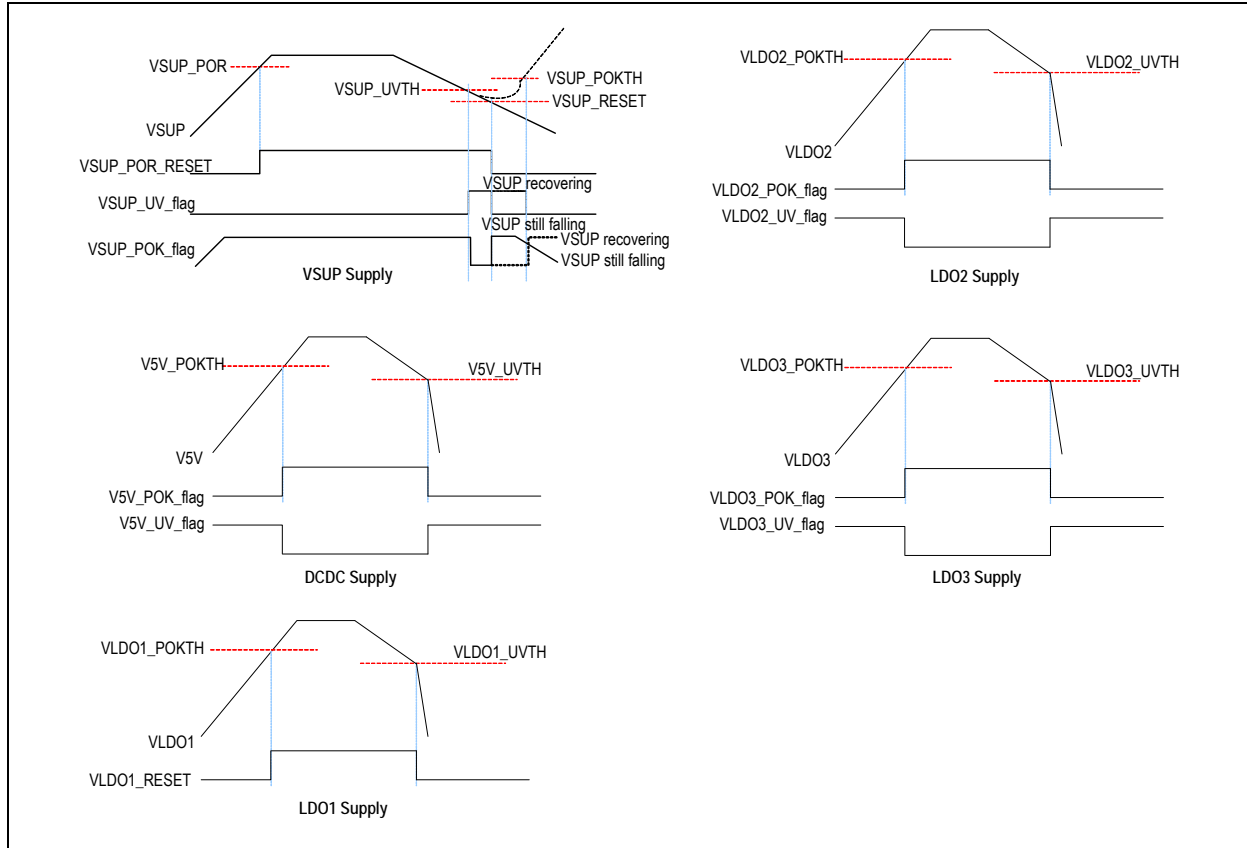
Undervoltage on V5V. If the V5V falls below V5V_UVTH threshold, the V5V_UV_flag is set. Once V5V returns to V5V_POKTH threshold value, V5V_POK_flag is set. In case a flag is set, an interrupt is generated at the INTN pin. If undervoltage on V5V occurs in Normal or Receive only modes then CAN Transceiver is disabled and the device remains in its operation mode.

Undervoltage on LDO1. If the voltage level of LDO1 falls below the VLDO1_UVTH threshold value and device is not in Sleep mode, the device enters into power-up state while RESET signal is asserted and the voltage regulator is still active. Once the VLDO1_POKTH threshold is reached, RESET signal is de-asserted after reset timeout period and device enters into Standby mode.

Undervoltage on LDO2. If the voltage level of the LDO2 falls below the VLDO2_UVTH threshold value a VLDO2_UV_flag is set. An indication is given to microcontroller by setting a bit in interrupt register and giving interrupt on INTN pin. Once VLDO2 returns to VLDO2_POKTH threshold value, VLDO2_POK_flag is set. An indication is given to microcontroller by setting a bit in interrupt register and giving interrupt on INTN pin.

Undervoltage on LDO3. If the voltage level of the LDO3 falls below the VLDO3_UVTH threshold value a VLDO3_UV_flag is set. An indication is given to microcontroller by setting a bit in interrupt register and giving interrupt on INTN pin. Once VLDO3 returns to VLDO3_POKTH threshold value, VLDO3_POK_flag is set. An indication is given to microcontroller by setting a bit in interrupt register and giving interrupt on INTN pin.

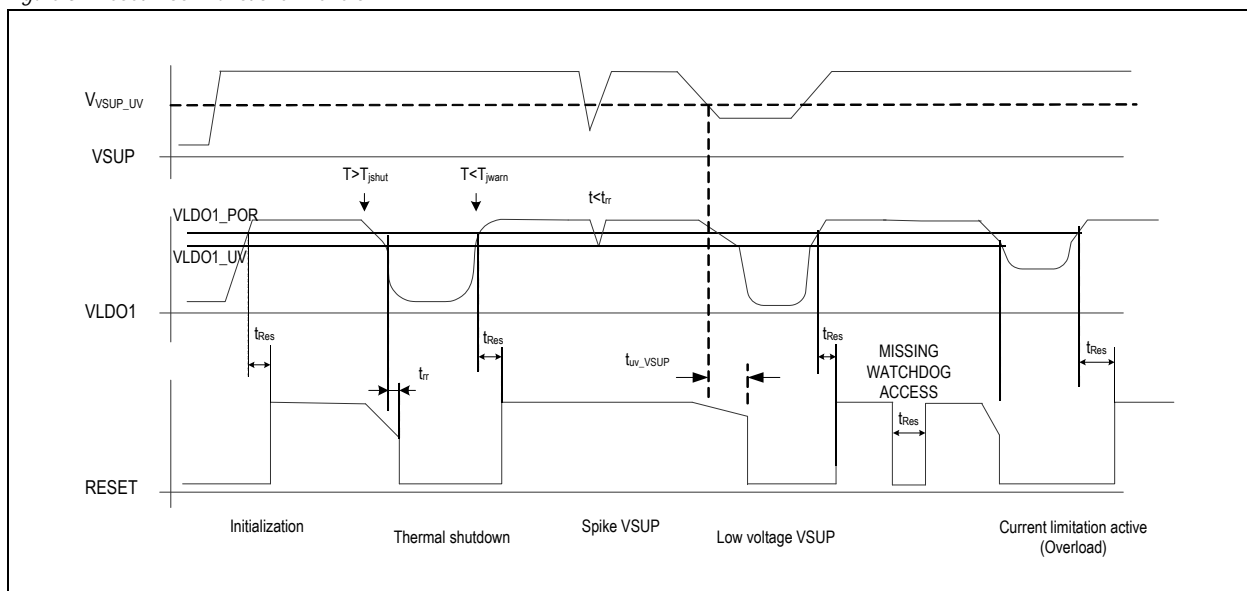
Figure 7. Power-up and Undervoltage Sequence



7.11 Reset Block

The reset block generates an external RESET signal to reset the microcontroller and all other external circuits. The reset functionality is explained in Figure 8. The reset block consists of a digital buffer at the output. The RESET signal is affected by VLDO1_RESET (during overload, reset on VLDO1) and watch dog output. All conditions which cause a drop of the VLDO1 voltage will be detected from the low voltage reset unit which in-turn generates a reset signal.

Figure 8. Reset Block Functional Waveform



7.12 CAN Transceiver

The AS8650A provides an advanced interface between the protocol controller and the physical bus in a Controller Area Network (CAN) node. This is intended for automotive high-speed CAN application (up to 1 Mbit/s), providing differential transmit capability to the bus and differential receive capability to the CAN controller. It is fully compatible to the ISO 11898-5 standard and offers excellent Electromagnetic Compatibility (EMC) performance. The CAN is a high-speed, low complexity protocol with improved EMI and EMC performance. The CAN is a serial communication protocol efficiently supporting the control of mechatronic nodes in a distributive automotive application. The basic blocks of the CAN Transceiver are described below:

7.12.1 BUS Driver

This driver has the basic functionality of relaying the data from the microcontroller on to the CAN bus. The data on the CAN needs to have a controlled slew to reduced EMI. A low side driver is used which has an inherent reverse polarity protection. It has a Short-Circuit current limitation.

7.12.2 Normal Receiver

It relays the data from the CAN bus to the microcontroller in Normal mode.

7.12.3 Low Power Receiver

It relays the data from the CAN bus to the microcontroller in low power mode state.

7.12.4 Operating Modes

The CAN Transceiver provides the following operating modes:

- NORMAL: Non low power mode
- RECEIVE ONLY: Non low power mode
- STANDBY: Low power mode
- SLEEP: Low power mode

Normal Mode. In this mode the Transceiver is able to send and receive data signals on the bus. RxD reflects the bus data.

Receive Only Mode. In this mode the Transceiver has the same behavior as in normal mode but the transmitter is disabled.

Standby Mode or Sleep Mode. In this mode the Transceiver is not able to send and receive data signals from the bus, but the wake up detector is active. The power consumption is significantly reduced respect the non low power operation modes. The WAKE_REMOTE reflects the remote wake up detector output; WAKE_LOCAL reflects the input signal on WAKE pin.

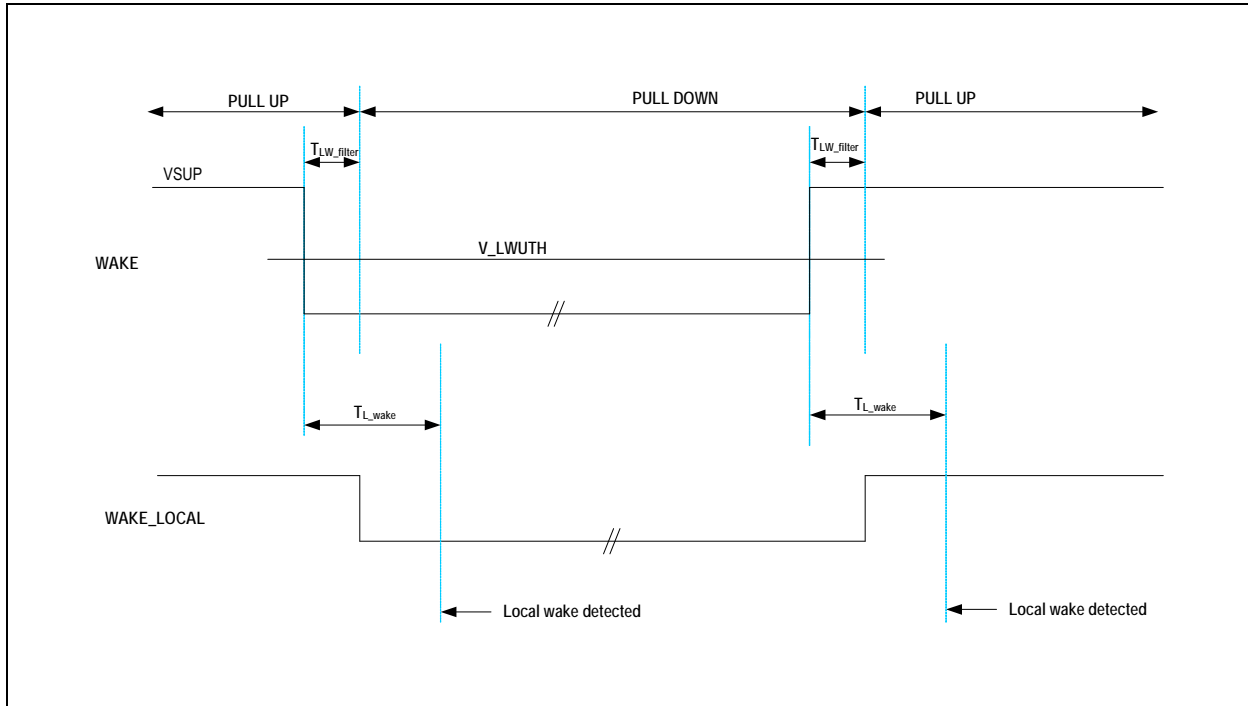
Table 18. Operating Modes

| State | TxD | Transmitter | Normal Receiver | Low Power Receiver | Bust State |
|----------|-----|-------------|-----------------|--------------------|-----------------------------|
| NORMAL | L | Enabled | Enabled | Disabled | Dominant |
| | H | Enabled | Enabled | Disabled | Recessive |
| REC ONLY | X | Disabled | Enabled | Disabled | (CANH, CANL are not driven) |
| STANDBY | X | Disabled | Disabled | Enabled | (CANH, CANL are not driven) |
| SLEEP | X | Disabled | Disabled | Enabled | (CANH, CANL are not driven) |

7.12.5 Local Wake-up Event

In all low power modes, if the voltage on the WAKE pin falls below V_{LWUTH} for longer than T_{LW_filter} , WAKE_LOCAL falls down. At the same time the biasing of the pin is switched to pull-down. If the voltage on the WAKE pin rises above V_{LWUTH} for longer than T_{LW_filter} , WAKE_LOCAL rises up. At the same time the biasing of the pin is switched to pull-up. In current application wake pin is initially pulled-down to ground using external resistor on power up. For valid wake-up, the WAKE pin needs a rising edge.

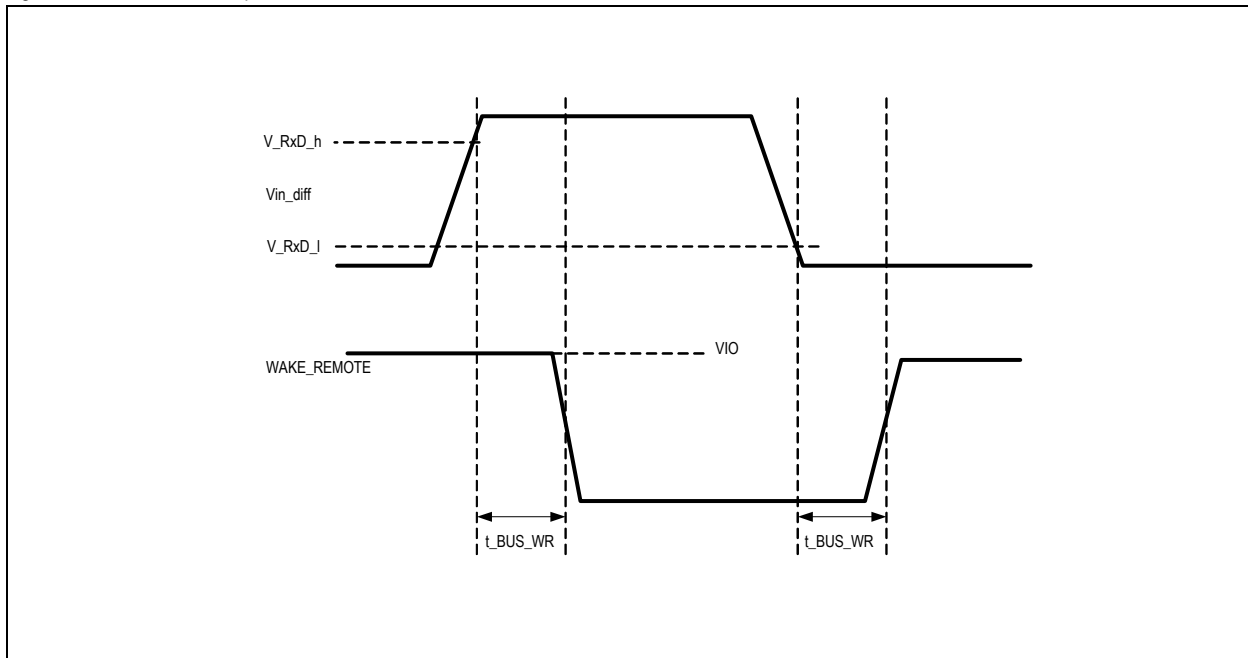
Figure 9. Wake Input Pin Behavior



7.12.6 Remote Wake-up

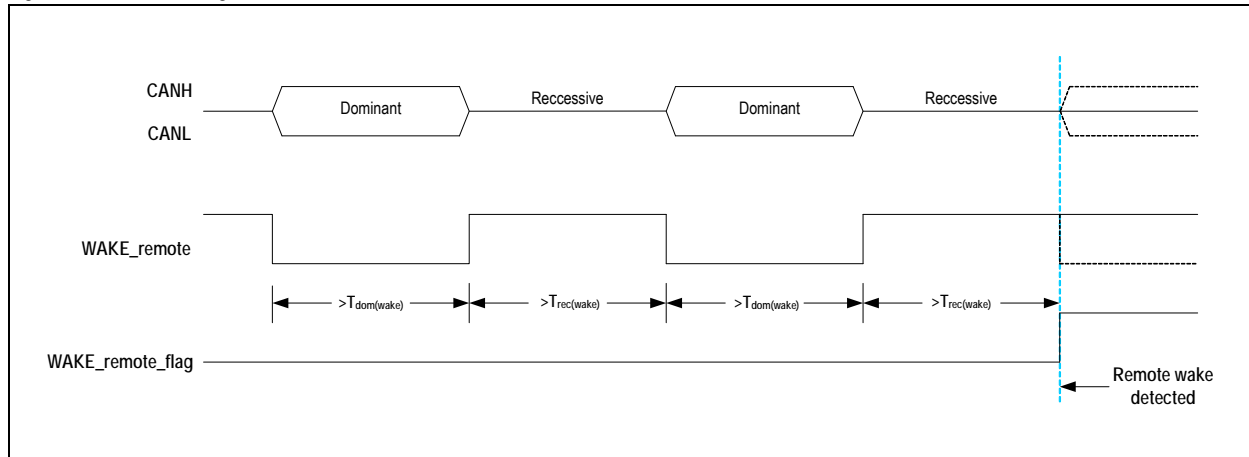
In all low power modes, if the differential voltage on the bus becomes recessive for longer than t_{BUS_WR} , WAKE_REMOTE rises up. If the differential voltage on the bus becomes dominant for longer than t_{BUS_WR} , WAKE_REMOTE falls down as shown in Figure 10.

Figure 10. Remote Wake-up Event



A remote wake request is detected after two dominant pulses with each pulse separated by a recessive pulse of at least $T_{rec(wake)}$. The remote wake detection circuit is active in sleep and standby modes. The wake message pattern is shown in Figure 11.

Figure 11. Wake Message Pattern



7.13 Internal Flags

The AS8650A supports internal flags to indicate the failures in the system. If any of these flag is set an interrupt is generated on INTN pin.

7.13.1 VSUP_UV_flag

This is a VSUP undervoltage flag. This flag is set when VSUP falls below the VSUP_UVTH threshold. When this flag is set the device enters into standby mode and BUS Transceiver is switched off to save power. When VSUP recovers and raises above VSUP_POKTH threshold the VSUP_UV_flag is reset.

7.13.2 VSUP_POK_flag

This is a VSUP power ok flag. This indicates the VSUP recovery from undervoltage condition. When the VSUP rises above VSUP_POKTH threshold, this flag is set. This indicates the microcontroller that undervoltage condition on battery is cleared.

7.13.3 V5V_UV_flag

This is a V5V undervoltage flag. This flag is set when V5V falls below the V5V_UVTH threshold. When this flag is set the device enters into Standby mode and BUS Transceiver is switched off to save power. When V5V recovers and raises above V5V_POKTH threshold the V5V_UV_flag is reset.

7.13.4 V5V_POK_flag

This is a V5V power ok flag. This indicates the V5V recovery from undervoltage condition. When the V5V rises above V5V_POKTH threshold, this flag is set. This indicates the microcontroller that undervoltage condition on DCDC converter is cleared.

7.13.5 VLDO2_UV_flag

This is a VLDO2 undervoltage flag. This flag is set when VLDO2 falls below the VLDO2_UVTH threshold. When VLDO2 recovers and raises above VLDO2_POKTH threshold the VLDO2_UV_flag is reset.

7.13.6 VLDO2_POK_flag

This is a VLDO2 power ok flag. This indicates the VLDO2 recovery from undervoltage condition. When the VLDO2 rises above VLDO2_POKTH threshold this flag is set. This indicates the microcontroller that undervoltage condition on LDO2 is cleared.

7.13.7 VLDO3_UV_flag

This is a VLDO3 undervoltage flag. This flag is set when VLDO3 falls below the VLDO3_UVTH threshold. When VLDO3 recovers and raises above VLDO3_POKTH threshold the VLDO3_UV_flag is reset.

7.13.8 VLDO3_POK_flag

This is a VLDO3 power ok flag. This indicates the VLDO3 recovery from undervoltage condition. When the VLDO3 rises above VLDO3_POKTH threshold this flag is set. This indicates the microcontroller that undervoltage condition on LDO3 is cleared.

7.13.9 BUS Wake_up Flag

The BUS Wake_up flag is set when the device detects a remote wake-up (BUS message) request. The remote wake-up request is detected when pattern shown in Figure 11 is found on wake_remote port of low power receiver. This indicates the microcontroller about the Bus wake event.

7.13.10 Local Wake_up Flag

The Local Wake_up flag is set when the device detects a local wake-up request on WAKE pin. A local wake-up request is detected when a logic state change on pin WAKE as shown in Figure 9. This indicates the microcontroller about the local wake event.

7.13.11 OVT_Warning Flag

The OVT_Warning flag is set when temperature exceeds $T_{j\text{warn}}$. This indicates the microcontroller about temperature exceeding warning levels.

7.13.12 OVT_Recover Flag

The OVT_Recover flag is set when temperature falls back below $T_{j\text{recv}}$. This indicates the microcontroller about temperature falling back below recovery levels.

7.13.13 Bus Failure Flags

The bus failure flag is set if the CAN Transceiver detects a bus line short-circuit condition to VSUP, V5V_LDO1 or GND. Such possible conditions are indicated to microcontroller through these flags. All these flags are cleared on microcontroller read. If the fault condition still exist after microcontroller read, the particular flag is set again. The device still be working in the current state. The microcontroller takes appropriate action on reading of these flags.

CANH_short_GND. This flag indicates Over Current condition on pin CANH. For example short to ground on pin CANH. When the output current on pin CANH exceeds the threshold OC_CANH_th then the output OC_CANH switches on high level after a filter time t_{OC_CANH} .

CANH_short_VSUP. This flag indicates Low Current on pin CANH. For example open load or short to VSUP on pin CANH. When the output current on pin CANH falls below the threshold LC_CANH_th then the output LC_CANH switches on high level after a filter time t_{LC_CANH} .

CANL_short_VSUP. This flag indicates Over Current on pin CANL. For example short to VSUP on pin CANL. When the output current on pin CANL exceeds the threshold OC_CANL_th , then the output OC_CANL switches on high level after a filter time t_{OC_CANL} .

CANL_short_GND. This flag indicates Low Current on pin CANL. For example open load or short to ground on pin CANL. When the output current on pin CANL falls the threshold LC_CANL_th then the output LC_CANL switches on high level after a filter time t_{LC_CANL} .

7.13.14 Local Failure Flags

The AS8650A prevents the system from four kinds of local failures without disturbing the BUS network. The four failures are TxD dominant clamping, RxD recessive clamping, TxD & RxD short, and bus dominant clamping. All these failures are indicated to microcontroller through flags.

TxD_Dom_Clamp flag. A permanent LOW-level on pin TxD (due to a hardware or software application failure) would drive the BUS into a permanent dominant state, blocking BUS network communication. If pin TxD remains at a LOW level for longer than the TxD dominant time-out period $T_{TxD\text{C}(\text{dom})}$, the device disables the transmitter of BUS Transceiver and TxD_Dom_Clamp flag is set. The device prevents such BUS network lock-up by disabling the transmitter of the transceiver. The device will not change the functional state. The transmitter remains disabled until the local failure persists. The flag is cleared with microcontroller read request.

RxD_Rec_Clamp flag. If pin RxD is shorted to VLDO1, the RxD pin is permanently clamped to recessive state. The BUS controller can't see the bus dominant state, and starts sending the message assuming that the bus is idle. This disturbs the BUS. This RxD recessive clamping is detected by the device when BUS is at dominant state. On detection of this failure, RxD_Rec_Clamp flag is set and the transmitter is disabled. The transmitter is enabled when a dominant is detected on the RxD pin, which means a dominant bit needs to be transmitted on the bus by other nodes. The flag is cleared with microcontroller read request.

TxD_RxD_Short flag. The TxD_RxD short circuit would result in a dead-lock situation clamping the bus dominant. For example the Transceiver receives a dominant signal, RxD outputs a dominant level. Because of the short circuit, TxD reflects a dominant signal, retaining the dominant bus state. As a result TxD and the bus are clamped continuously dominant. The resulting effect is the same as for the continuously clamped dominant TxD signal. The TxD dominant timeout interrupts the deadlock situation by disabling the transmitter and the TxD_RxD short condition is differentiated. The bus becomes recessive again and TxD will be recessive if it is not driven by microcontroller. However, the failure scenario may still exist and with the next dominant signal on the bus the described procedure will start again.

The device keeps the transmitter off after detection of TxD_RxD short fault and keeps updating this flag status. The microcontroller has to send 2 consecutive low pulses of duration 500ns with high period of 500ns in-between, in regular intervals to check short circuit recovery. This way a local TxD/RxD short circuit will not disturb the communication of the remaining bus system.

BUS_Dom_Clamp flag. In the case of a short circuit from BUS to GND, the circuit for the BUS receiver senses dominant signal continuously even if there is no dominant transmitting node. The result may be a permanently dominant clamped bus. The device detects and reports a Bus Dominant Clamping situation to microcontroller through BUS_Dom_Clamp flag. If the receiver detects a bus dominant phase of longer than the bus dominant time out $T_{BUS\text{C}(\text{dom})}$ BUS_Dom_Clamp flag is set. The flag is cleared on microcontroller read.

7.14 Watchdog (WD)

The WD has the following three monitory timing functions:

- Start-up watchdog: Gives opportunity to microcontroller to initialize the system.
- Window watchdog: Detects too early or too late microcontroller software response (loops and hangs).
- Time-out watchdog: Detects too very long response from microcontroller.

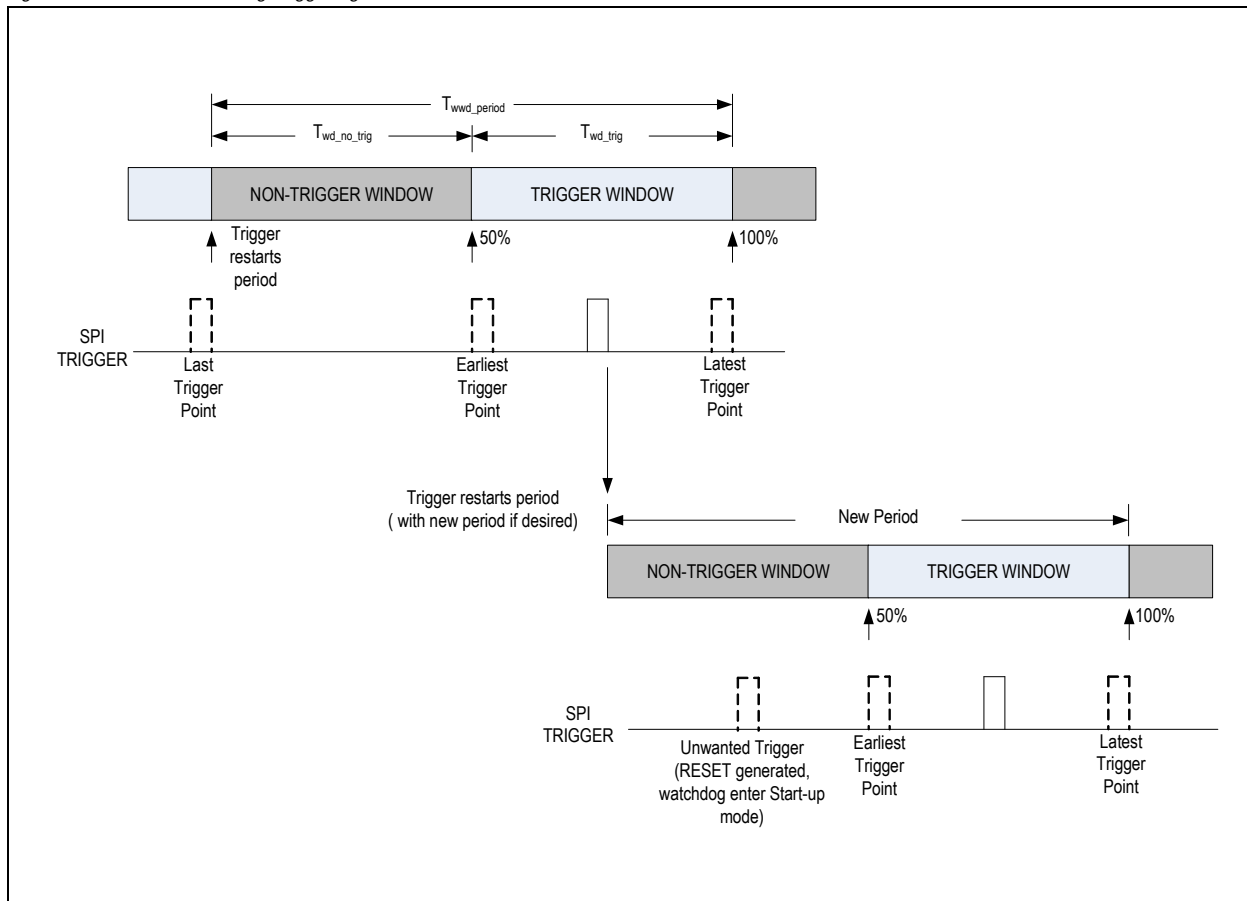
7.14.1 Start-up Watchdog Behavior

Following any reset event the watchdog is used to monitor the ECU start-up procedure. Once the reset is released the watchdog counter will start. In case the watchdog is not properly served (a trigger from microcontroller) within TWD(init), another reset is forced on RESET pin and the monitoring procedure is restarted. The watchdog will give three opportunities to microcontroller to initialize the system. In case the watchdog is not properly served for three times, then the system enters into sleep mode.

7.14.2 Window Watchdog Behavior

Whenever the device enters Normal mode, the Window mode of the watchdog is activated. This ensures that the microcontroller operates within the required speed; a too fast as well as a too slow operation will be detected. Watchdog triggering using the Window watchdog is illustrated in Figure 12.

Figure 12. Window Watchdog Triggering

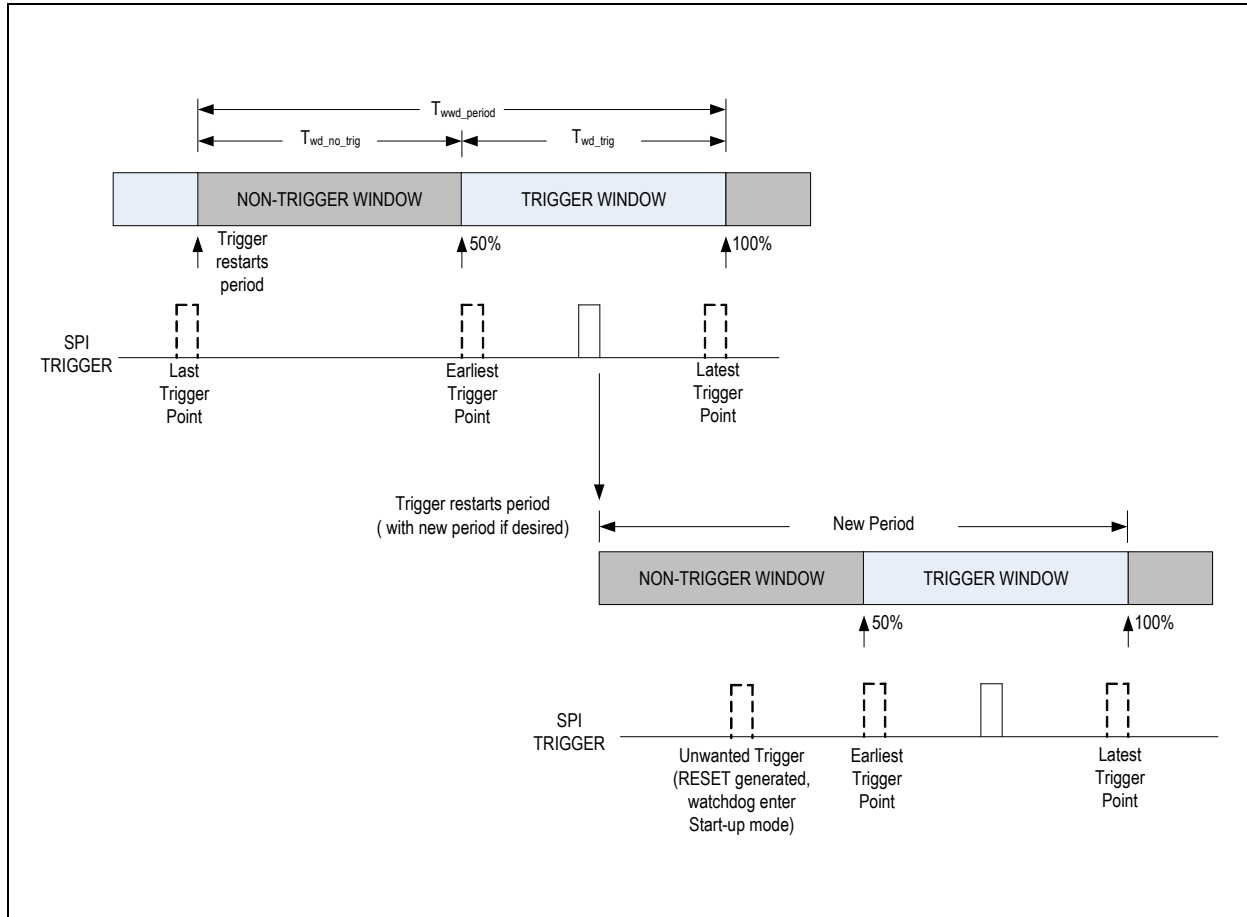


The AS8650A provides 8 different period timings. This timing can be changed through digital interface when desired. The period can be changed within any valid trigger window. Whenever the watchdog is triggered within the window time T_{wd_trig} , the timer will be reset to start a new period. The watchdog window is defined to be between 50% and 100% of the nominal programmed watchdog period. Any too early (trigger in non-trigger window) or too late watchdog trigger will result an immediate system reset on RESET pin and watchdog entering Start-up watchdog mode. During undervoltage condition on VLDO1 the watchdog timer is disabled.

7.14.3 Time-out Watchdog Behavior

Whenever the AS8650A operates in Standby mode, active watchdog operates in Time-out watchdog mode. The watchdog has to be triggered within the actual programmed period time $T_{wd_tout_period}$. The device provides 8 different possible periods for programming through digital interface. If the microcontroller fails to trigger the watchdog within trigger range then the system reset is generated on RESET pin and watchdog enters into Start-up watchdog mode. The time-out watchdog function is illustrated in Figure 13.

Figure 13. Time-out Watchdog Triggering

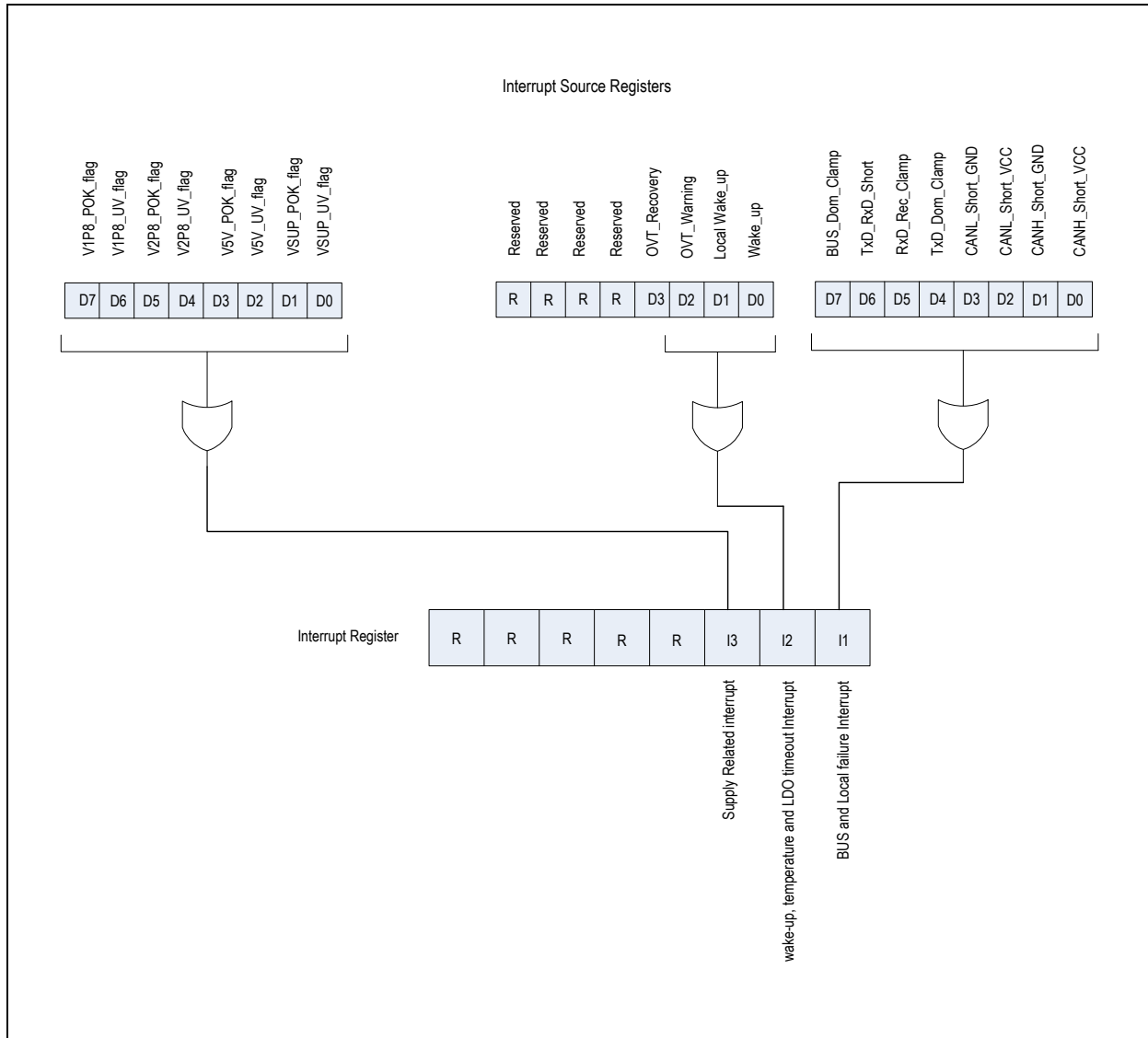


7.15 Interrupt Generation

The pin INTN is an interrupt output. The INTN is forced LOW if one bit in the Interrupt register is set. The Interrupt register bits are cleared when the microcontroller clears the corresponding interrupt source register. The Interrupt register will also be cleared during a system reset (RESET LOW). As there are microcontrollers with level sensitive or edge sensitive interrupt port, pin INTN will be HIGH for at least T_{INTN} after any of the interrupt source register is cleared. The Interrupt source register is cleared through write operation by overwriting 1 in to respective set bits position. Without further interrupts within T_{INTN} pin INTN stays HIGH, otherwise it will revert to LOW again.

The Interrupt register indicates the cause of an interrupt event. There are two levels of interrupt registers. First level register indicates the source region of interrupt and the second level register indicates the exact source of interrupt. With this structured interrupt, the microcontroller can trace source of interrupt by two read operations instead of polling for source of interrupt and also interrupts can be prioritized by microcontroller. The interrupt register structure is given in Figure 14. The register is cleared through digital interface write operation and upon any reset event. The hardware ensures no interrupt event is lost in case there is a new interrupt forced while reading the register.

Figure 14. Interrupt Register Structure



7.16 Status Registers

The AS8650A has three Flag status registers and one RESET reason register. The Flag status registers indicate the current status of flags which are related to respective interrupt source registers. The Flag status registers are Bus status register, Temperature status register and Supply status register. The microprocessor can read these registers any time to check the status of device. The function of each flag is listed in register space description in subsequent sections.

A RESET reason register indicates the reasons for RESET generation. Once the RESET pin goes low, the reason of this reset event is stored in RESET reason register. When RESET is released microprocessor can read this register to know the cause for last RESET signal. The RESET reason register is cleared once microprocessor reads this register through read operation. The bits functionality of this register is explained in register space description table.

8 Application Information

Device Interfaces. There are two ways to communicate with AS8650A, one is 4 wires SPI and other is I²C. The selection between these two interfaces is through I2C_EN pin, as shown in Table 19. The pins CS, SCLK, SDI, and SDO are used for SPI interface. For I²C interface, SCLK is used as I²C Clock and SDA is used as I²C data line. Pins SCLK_{I2C} / SCLK_{SPI} and SDA_{I2C} / SDI_{SPI} are multiplexed for both SPI and I²C interface. Since I2C_EN is a digital input pin, it has to be connected either to VLDO1 or GND.

Note: I2C_EN should not be changed during a I²C/SPI Read/Write operation. Maximum switching delay between I²C and SPI is 8μs.

Table 19. Device Interface Selection

| I2C_EN | Description |
|--------|-------------------------------|
| LOW | Interface is 4-wire SPI |
| HIGH | Interface is I ² C |

8.1 Serial Peripheral Interface

The Serial Peripheral Interface (SPI) provides the communication link with the microcontroller. The SPI is configured for half-duplex data transfer. The SPI provides access to configuration registers, control registers, and diagnostic registers. The modes of the AS8650A are changed by writing required code in to mode control register through SPI. The SPI is also used to enter into test and OTP modes. This interface is only slave interface and only master can initiate SPI operation.

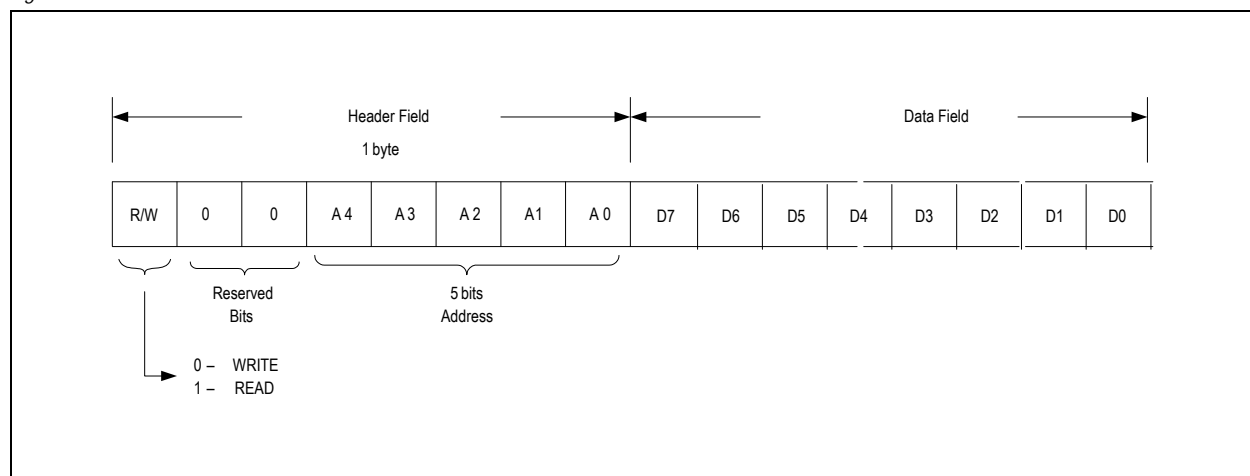
The SPI can work on both the clock polarities. The polarity of the clock depends on the value of SCLK at the falling edge of CS. At the falling edge of CS if SCLK is "1" then the SPI is positive edge triggered and if the SCLK is "0" then SPI is negative edge triggered logic (see Table 20).

Table 20. SPI Clock Polarity

| CS | SCLK | Description |
|-----|------|-------------------------------------------------------------------------------|
| LOW | HIGH | Serial data is transferred at falling edge and sampled at rising edge of SCLK |
| LOW | LOW | Serial data is transferred at rising edge and sampled at falling edge of SCLK |

The SPI protocol frame is divided in to two fields, the header field and the data field. The header field is 1 byte long containing a read/write command bit, 5 address bits and 2 reserved bits. The data field is of one data byte. The SPI frame format is shown in Figure 15. In the data phase MSB is sent first and LSB is sent last.

Figure 15. SPI Frame Format



8.1.1 SPI Write Operation

The SPI write operation begins with clock polarity selection at negative edge of CS, given in Table 20. Once the clock polarity is selected the SPI write command is given by providing '0' in R/W bit of the header field in first sampling edge at SDI pin. The 5 bits address of register to be written is provided at SDI pin in next five consecutive sampling edges of SCLK. The first 2 bits in header fields are reserved and set to 0. The data to be written is followed by last bit of header field. With each sampling edge a bit is sampled starting from MSB to LSB. During complete SPI write operation the CS has to be low. The SPI write operation ends with positive edge of CS. The wave form for SPI write operation with single data byte is shown in Figure 16 and Figure 17.

Figure 16. SPI Write Operation with Negative Clock Polarity and 1 Byte of Data Field

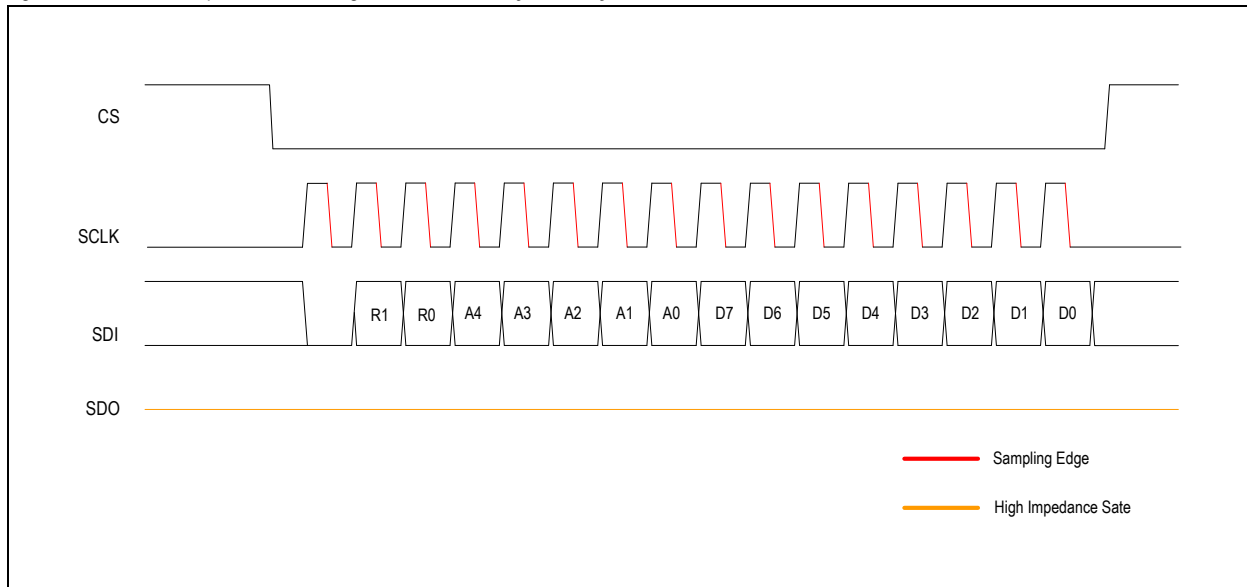
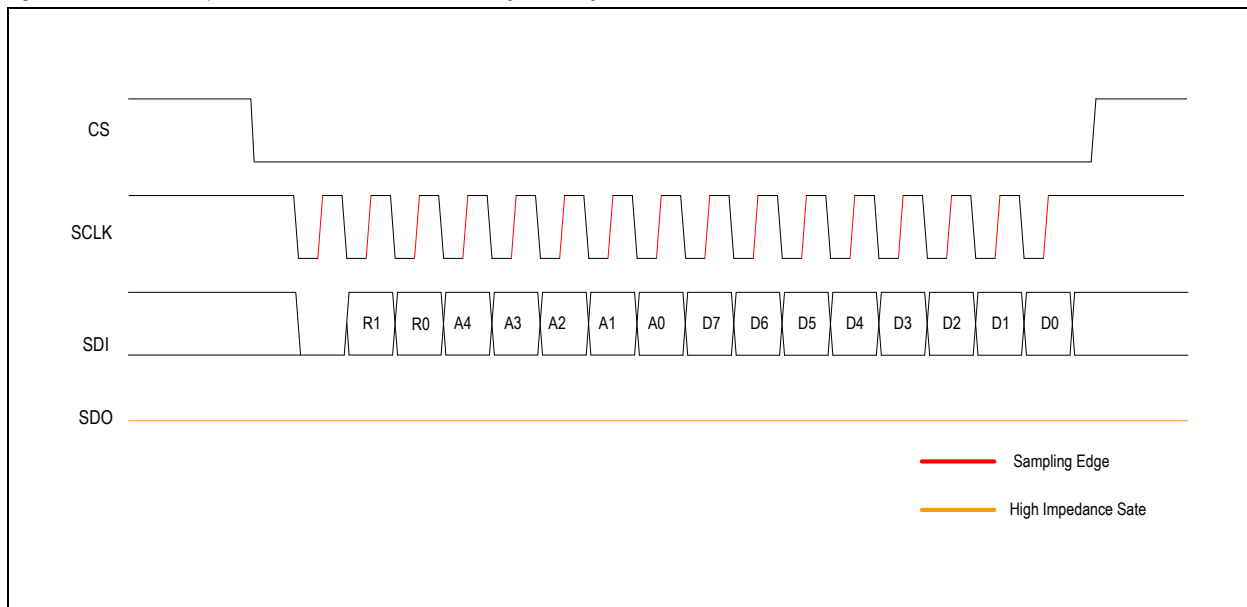


Figure 17. SPI Write Operation with Positive Clock Polarity and 1 Byte of Data Field



8.1.2 SPI Read Operation

The SPI read operation also begins with clock polarity selection at negative edge of CS, given in Table 20. Once the clock polarity is selected the SPI read command is given by providing '1' in R/W bit of the header field in first sampling edge at SDI pin. The 5 bits address of register to be read is provided at SDI pin in next five consecutive sampling edges of SCLK. The first 2 bits in header fields are reserved and set to 0. The read data is followed by last bit of header field on SDO pin. With each sampling edge a bit can be read on SDO pin starting from MSB to LSB. During complete SPI read operation the CS has to be low. The SPI read operation ends with positive edge of CS. The wave form for SPI read operation with single data byte is shown in Figure 18 and Figure 19.

Figure 18. SPI Read Operation with Negative Clock Polarity and 1 Byte of Data Field

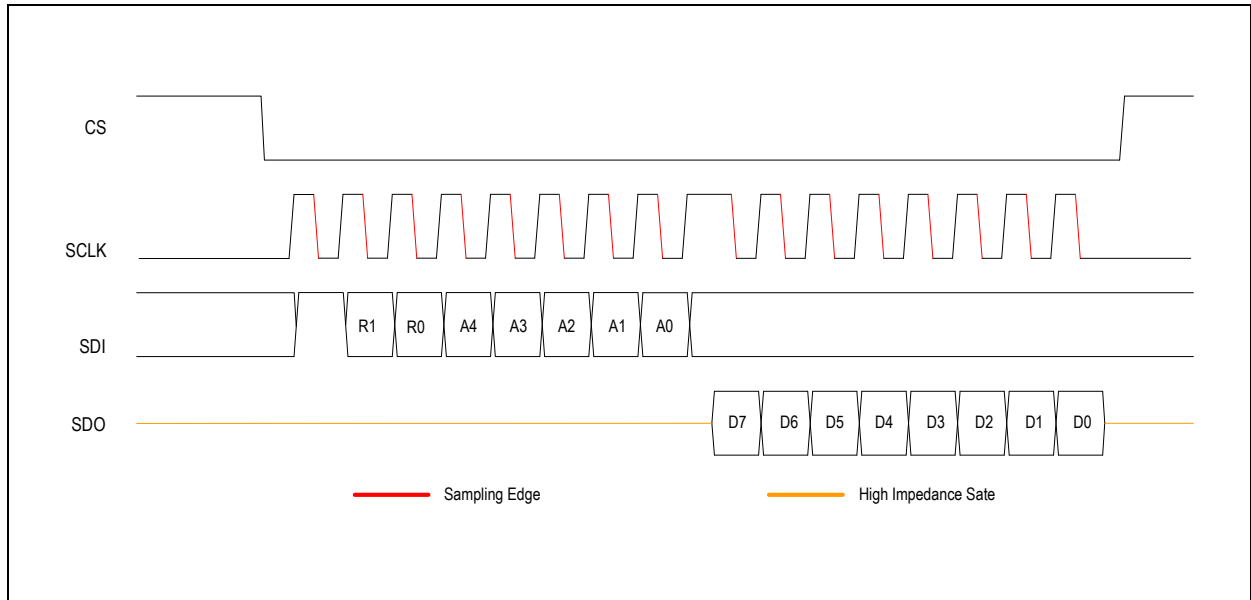
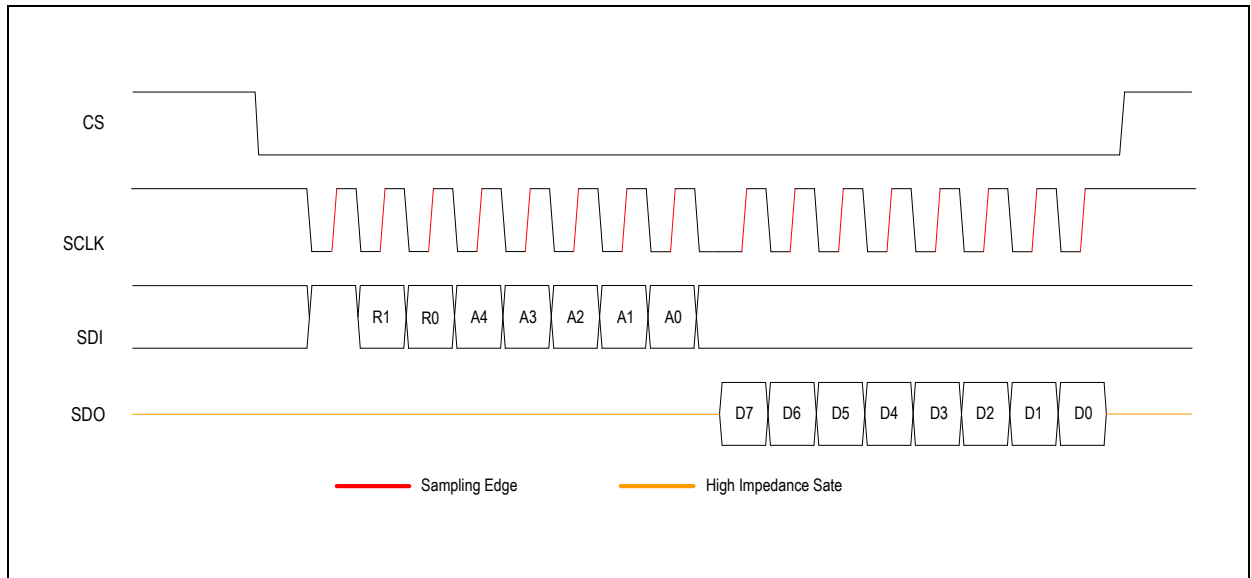


Figure 19. SPI Read Operation with Positive Clock Polarity and 1 Byte of Data Field



8.1.3 SPI Timing Diagram

Figure 20. Timing Diagram for SPI Write Operation

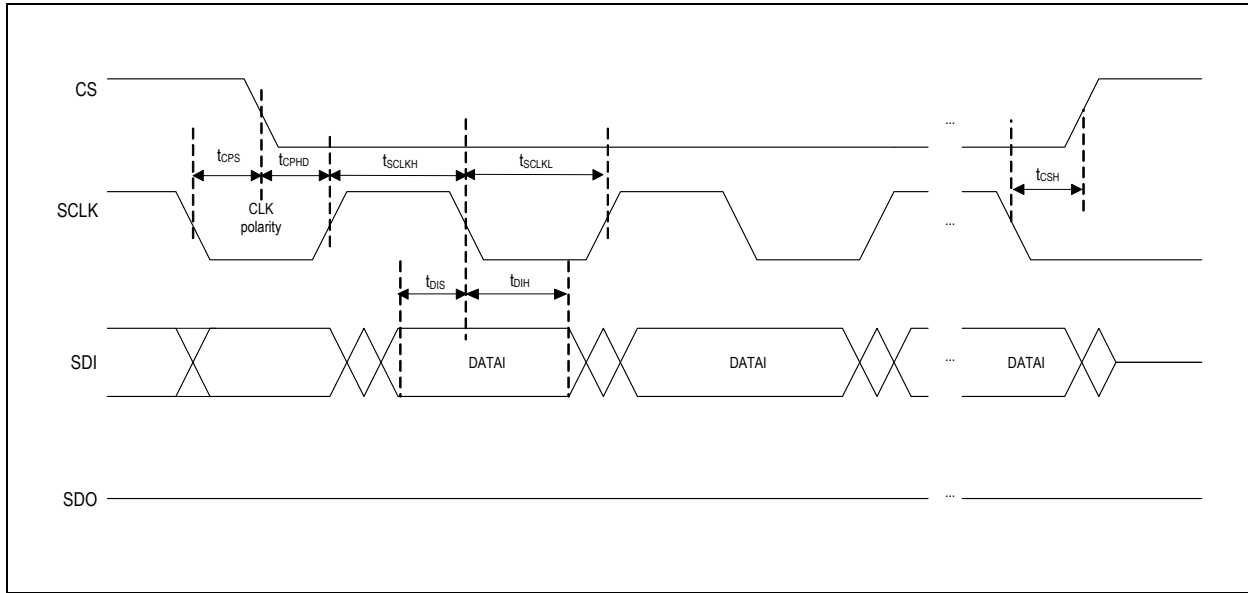
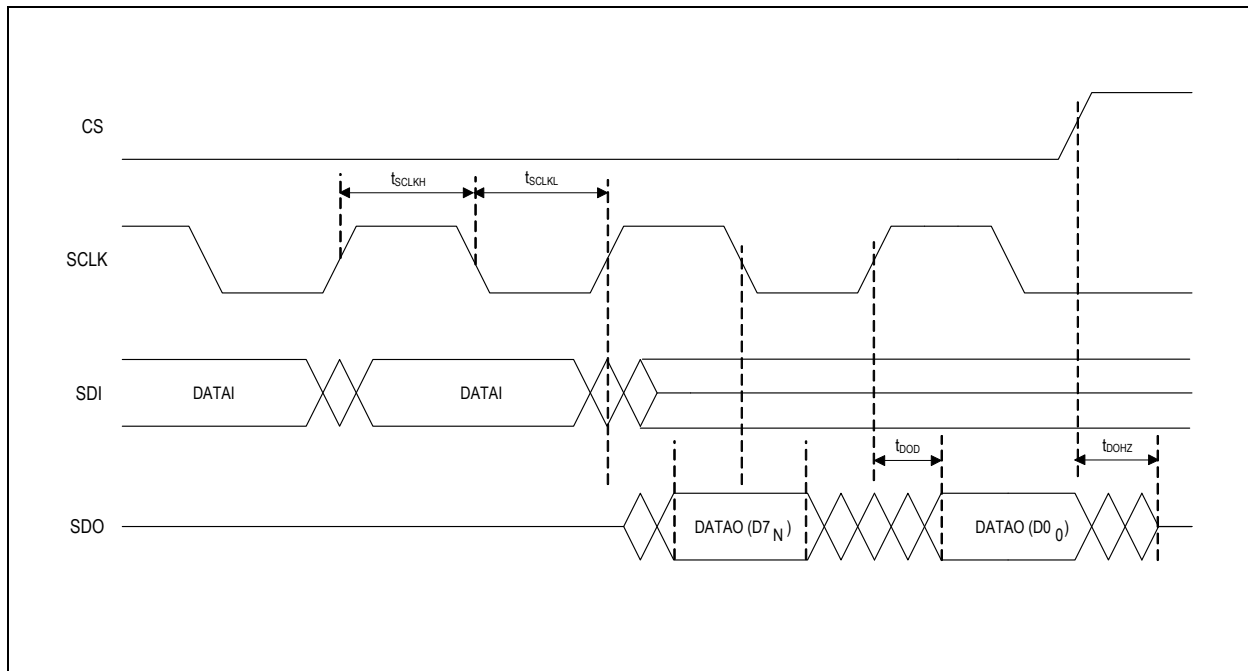


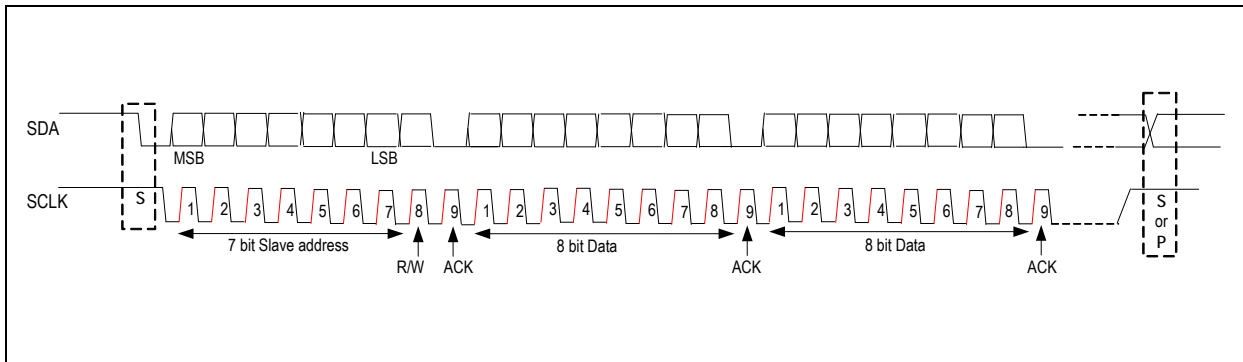
Figure 21. Timing Diagram for SPI Read Operation



8.2 Inter-Integrated Circuit (I²C) Interface

I²C is a bidirectional 2 line bus interface with a serial data line (SDA) and a serial clock line (SCLK) for inter IC control. This interface is only slave interface and only microcontroller can start and stop the I²C operation. The overview of I²C protocol is shown in Figure 22. A HIGH to LOW transition on SDA line while SCLK is HIGH is the START (S) condition and a LOW to HIGH transition on SDA line while SCLK is HIGH is the STOP (P) condition, as shown in Figure 22. The START and STOP conditions should always be generated by the microcontroller. After the START condition, microcontroller has to make sure that data on SDA line must be stable during the HIGH period of SCLK. The data should only change when SCLK line is LOW. The Bus is busy after the START condition and it is free after the STOP condition. Any number of data bytes can be transmitted between START and STOP. Each byte is followed by an acknowledgement (which is the ninth bit). The data transmitter always receives an acknowledgement from the data receiver at end of each byte. The data transmitter releases the SDA bus at start of LOW period of 8th clock pulse and data receiver acknowledges by pulling the SDA to LOW during the LOW period of the SCLK. The data receiver releases the bus at start of LOW period of 9th clock pulse of the SCLK and data transmitter gets the data bus. The AS8650A does not support general call address, START byte and high-speed mode.

Figure 22. I²C Bus Protocol



8.2.1 I²C Write Operation

After the START condition, microcontroller has to send, in the first byte, the 7-bit slave address and 0 into the R/W bit as shown in Figure 23. The microcontroller has to send the address of the register to be written in the second byte. The first 3 MSB bits are reserved and remaining 5 bits are used as address bits. The data is sent starting from MSB to LSB. The AS8650A sends acknowledgement on 9th clock pulse. In the next byte (3rd byte) microcontroller has to send the data to be written into addressed register. If it is a single write operation, after receiving the acknowledgment from AS8650A, microcontroller has to send START or STOP condition, as shown in Figure 23. In case of auto increment write operation, microcontroller should not generate START or STOP condition after the third byte. If microcontroller continuously writes then address pointer rolls back to the starting register address after reaching the last register address. Data bytes coming from the microcontroller are written at the consecutive address locations, starting from the address sent in first data byte. After each data byte, direction of the bus line changes and AS8650A acknowledges by pulling the SDA line LOW. To terminate the write operation microcontroller has to generate STOP or repeated START condition. For details, see Figure 24.

Figure 23. I²C Write Operation

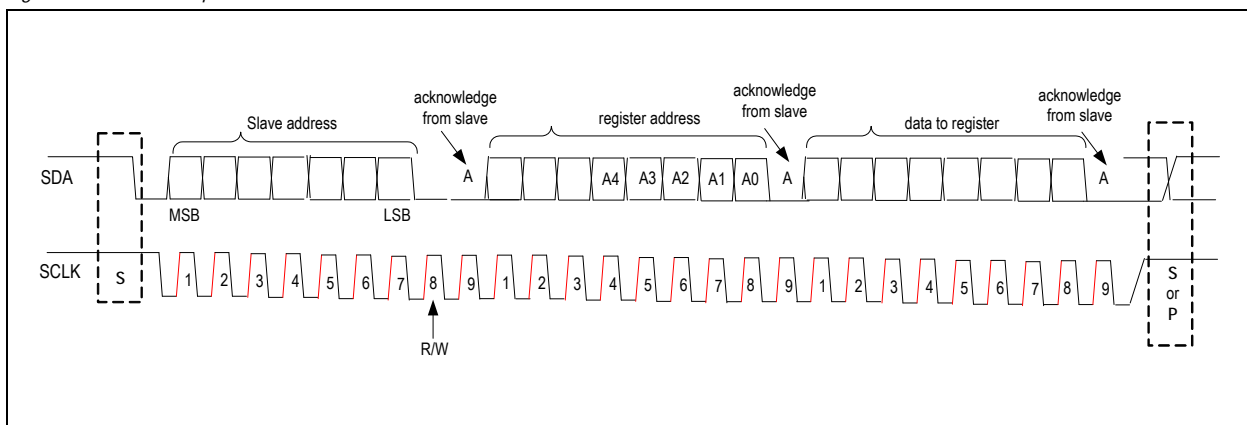
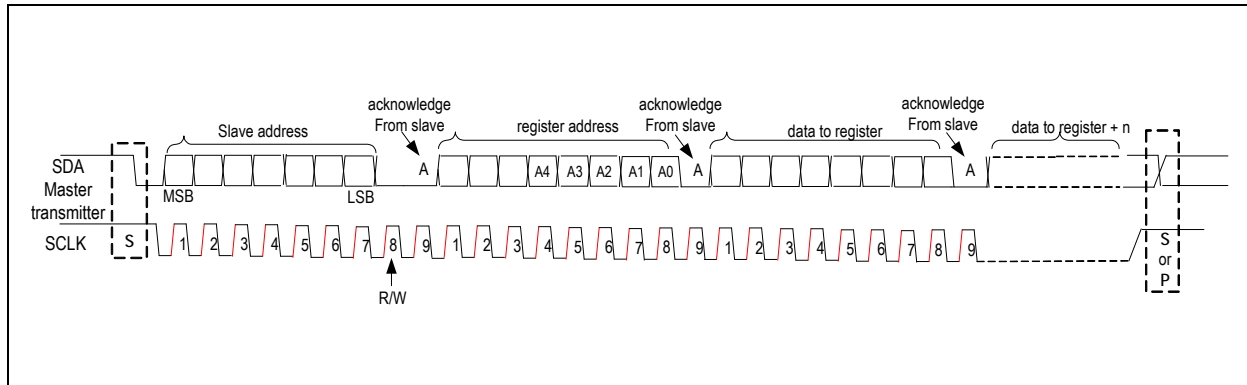


Figure 24. I²C Auto-increment Write Operation



8.2.2 I²C Read Operation

After the START condition, microcontroller has to send, in the first byte, the 7-bit slave address and 0 into the R/W bit as shown in Figure 25. The microcontroller has to send the address of the register to be written in the second byte. The first 3 MSB bits are reserved and remaining 5 bits are used as address bits. The data is sent starting from MSB to LSB. After receiving the acknowledgement on the 9th clock pulse, microcontroller has to send on the SDA line repeated START or STOP, as shown in Figure 25. If microcontroller sends STOP then microcontroller has to send START again. If microcontroller sends repeated START then there is no need to generate START again. The microcontroller again has to send the 7-bit slave address and writes 1 into the R/W bit (8th bit). Now AS8650A sends data of the corresponding addressed register in the next eight clock cycles. In case of single read, microcontroller does not acknowledge on the 9th clock pulse and generates START or STOP condition after the ninth clock pulse. If it is an auto increment read operation, microcontroller acknowledges on the 9th clock pulse and AS8650A sends data from the consecutive address locations, see Figure 25. If microcontroller continuously reads then address pointer rolls back to the starting register address after reaching the last register address. In the data phase MSB is sent first and LSB is sent last. After each data byte, microcontroller has to send the acknowledgement. The microcontroller can terminate the auto read operation by not generating acknowledgement for the last byte that was sent by the AS8650A and generates STOP or repeated START condition after the 9th clock pulse.

Figure 25. I²C Read Operation

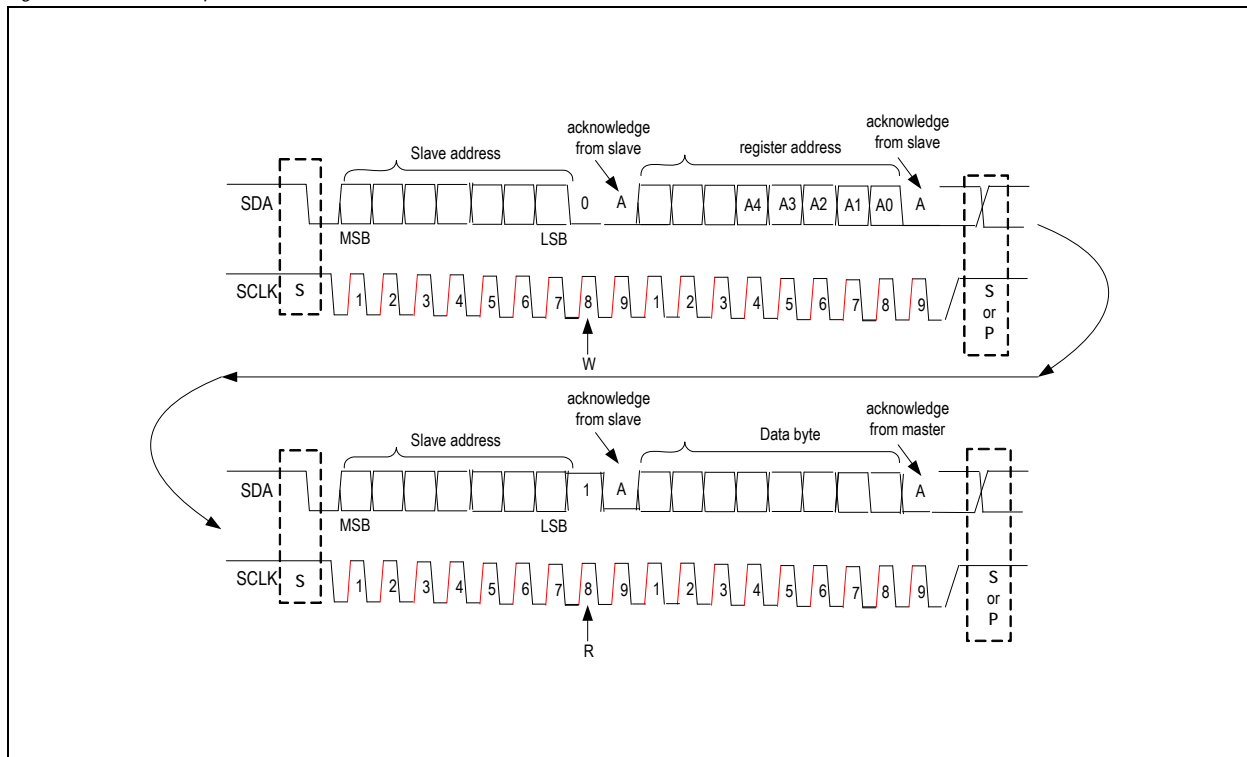


Figure 26. I²C Auto-increment Read Operation

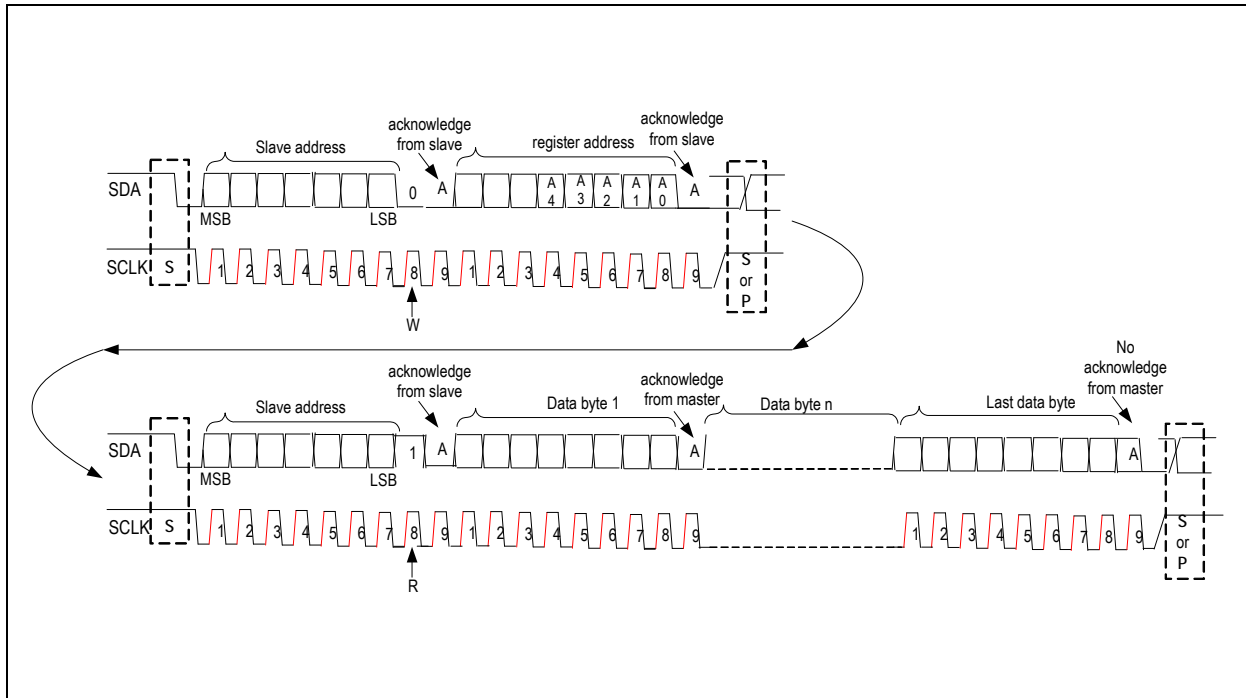
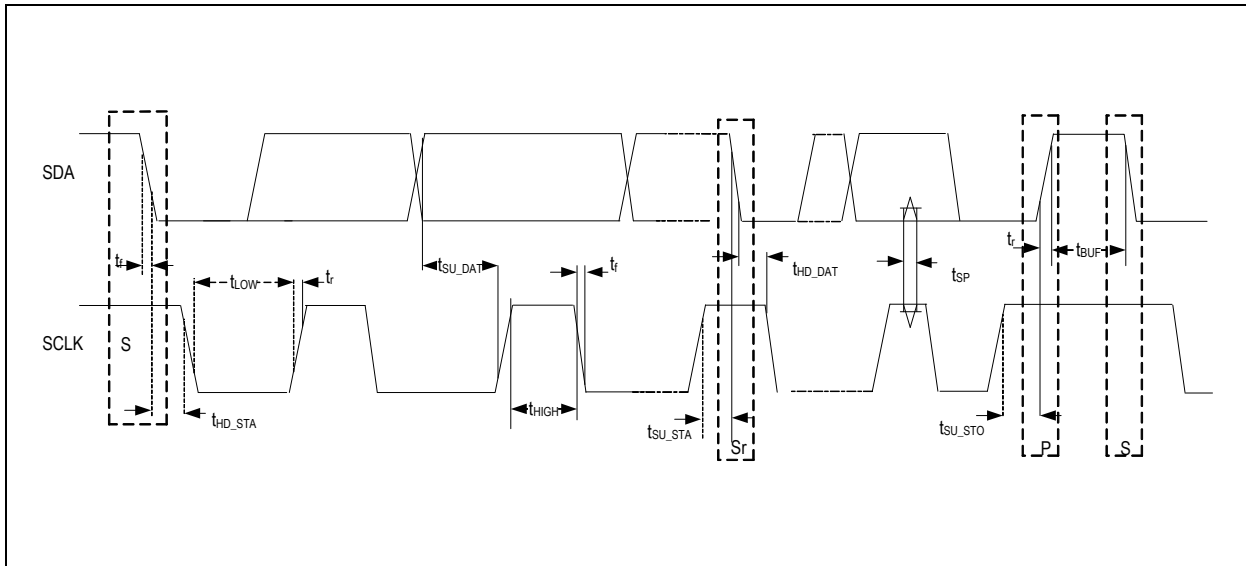


Figure 27. Definition of I²C Timing Parameters



8.3 Register Space

The AS8650A register space consists of configuration registers, control registers and diagnostic registers. All of these registers are accessible through SPI or I²C commands.

Table 21. Configuration Registers

| Addr | Register Name | POR Value | Bit | Type | Description | |
|------|----------------------------|------------------------|--------|------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------|
| 0x00 | Reserved | | | | Reserved | |
| 0x01 | Reserved | | | | Reserved | |
| 0x02 | WD Access Control Register | 0000_0000 POR_VLDO1 | D[7:0] | R/W | 0101_1010 | WD Configuration Register access Enabled Else WD Configuration Register access disabled |
| | | | | | 01 | WD disabled Else WD enabled |
| 0x03 | WD Configuration Register | 0000_1001 POR_VSUP | D[7:6] | R/W | Time-out Watchdog mode Window period Twd_tout_period. (Accuracy of the timings is ±25%) | |
| | | | D[5:3] | | 000 | 80 ms |
| | | | | | 001 | 160 ms |
| | | | | | 010 | 320 ms |
| | | | | | 011 | 480 ms |
| | | | | | 100 | 800 ms |
| | | | | | 101 | 1000 ms |
| | | | | | 110 | 2000 ms |
| | | | | | 111 | 4000 ms |
| | | | D[2:0] | | Window Watchdog mode Window period Twwd_period (50% of above value is trigger window) | |
| | | | | | 000 | 10 ms |
| | | | | | 001 | 40 ms |
| | | | | | 010 | 80 ms |
| | | | | | 011 | 120 ms |
| 100 | 160 ms | | | | | |
| 101 | 240 ms | | | | | |
| 110 | 320 ms | | | | | |
| 111 | 400 ms | | | | | |
| 0x04 | WD Trigger Register | 0000_0000 POR_VLDO1 | D[7:1] | W | Reserved | |
| | | | D[0] | | Watchdog trigger bit. The microcontroller set this bit within the required window of watchdog timer. After this internal counter is reset and this bit is cleared internally. | |

Table 21. Configuration Registers

| Addr | Register Name | POR Value | Bit | Type | Description | |
|------|----------------------------------------------------------------------------------------------------------------|-----------------------|--------|------|---------------------------------|------------------------------------------------------------------------------------------------------------------|
| 0x05 | Device Configuration Register | 0110_1101 POR_VSUP | D[7] | R/W | 0 | LDO3 disable in Standby mode |
| | | | D[6] | | 1 | LDO3 enable in Standby mode |
| | | | | | 0 | LDO3 disable in Receive only mode |
| | | | D[5] | | 1 | LDO3 enable in Receive only mode |
| | | | | | 0 | LDO3 disable in Normal mode |
| | | | D[4] | | 1 | LDO3 enable in Normal mode |
| | | | | | 0 | LDO2 disable in Standby mode |
| | | | D[3] | | 1 | LDO2 enable in Standby mode |
| | | | | | 0 | LDO2 disable in Receive only mode |
| | | | D[2] | | 1 | LDO2 enable in Receive only mode |
| | | | | | 0 | LDO2 disable in Normal mode |
| | | | D[1] | | 1 | LDO2 enable in Normal mode |
| | | | | | 0 | DCDC disable in sleep mode |
| | | | D[0] | | 1 | DCDC enable in sleep mode |
| 0 | BUS with low slew rate | | | | | |
| 0x06 | Mode Control Register | 0000_0000 POR_VSUP | D[7:6] | R/W | Reserved | |
| | | | D[5:4] | | Device state (Read-only values) | |
| | | | | | 0 | Device in STAND BY Mode |
| | | | | | 1 | Device in NORMAL Mode |
| | | | D[3:2] | | 10 | Device in RECEIVE ONLY Mode |
| | | | | | Reserved | |
| | | | D[1:0] | | 00 | STAND BY Mode |
| | | | | | 01 | NORMAL Mode |
| | | | | | 10 | RECEIVE ONLY Mode |
| | | | | | 11 | SLEEP Mode |
| 0x07 | Interrupt Register | 0000_0000 POR_VSUP | D[7:3] | R | Reserved | |
| | | | D[2] | | 0 | No Interrupt |
| | | | | | 1 | Supply Related Interrupt. The source of interrupt is known by reading interrupt source register 3 |
| | | | D[1] | | 0 | No Interrupt |
| | | | | | 1 | Wake-up & temperature Related Interrupt. The source of interrupt is known by reading interrupt source register 2 |
| | | | D[0] | | 0 | No Interrupt |
| 1 | BUS & Local Failure Related Interrupt. The source of interrupt is known by reading interrupt source register 1 | | | | | |

Table 21. Configuration Registers

| Addr | Register Name | POR Value | Bit | Type | Description | |
|------|-----------------------------|-------------------------------------------------------|--------|------|----------------------------------------------------------------------|-----------------------------------------------|
| 0x08 | Interrupt Source Register 1 | 0000_0000 POR_VSUP | D[7] | R/W | 0 | No Interrupt |
| | | | | | 1 | Interrupt due to BUS clamped to dominant |
| | | | D[6] | | 0 | No Interrupt |
| | | | | | 1 | Interrupt due to short TxD & RxD pins |
| | | | D[5] | | 0 | No Interrupt |
| | | | | | 1 | Interrupt due to RxD pin clamped to Recessive |
| | | | D[4] | | 0 | No Interrupt |
| | | | | | 1 | Interrupt due to TxD pin clamped to Dominant |
| | | | D[3] | | 0 | No Interrupt |
| | | | | | 1 | Interrupt due to CANL pin shorted to VCC |
| | | | D[2] | | 0 | No Interrupt |
| | | | | | 1 | Interrupt due to CANL pin shorted to GND |
| | | | D[1] | | 0 | No Interrupt |
| | | | | | 1 | Interrupt due to CANH pin shorted to GND |
| D[0] | 0 | No Interrupt | | | | |
| | 1 | Interrupt due to CANH pin shorted to VCC | | | | |
| 0x09 | Interrupt Source Register 2 | 0000_0000 POR_VSUP | D[7:4] | | Reserved | |
| | | | D[3] | 0 | No Interrupt | |
| | | | | 1 | Interrupt due to junction temperature falling back below T_{jrecv} | |
| | | | D[2] | 0 | No Interrupt | |
| | | | | 1 | Interrupt due to junction temperature exceeding T_{jwarn} | |
| | | | D[1] | 0 | No Interrupt | |
| | | | | 1 | Interrupt due to Local Wake up event on WAKE pin | |
| D[0] | 0 | No Interrupt | | | | |
| | 1 | Interrupt due to Wake up by BUS message (remote wake) | | | | |

Table 21. Configuration Registers

| Addr | Register Name | POR Value | Bit | Type | Description | |
|------|-----------------------------|-----------------------------------|--------|------|------------------------------|-------------------------------------|
| 0x0A | Interrupt Source Register 3 | 0000_0000 POR_VSUP | D[7] | R/W | 0 | No Interrupt |
| | | | | | 1 | Interrupt due to VLDO3_POK_flag set |
| | | | D[6] | | 0 | No Interrupt |
| | | | | | 1 | Interrupt due to VLDO3_UV_flag set |
| | | | D[5] | | 0 | No Interrupt |
| | | | | | 1 | Interrupt due to VLDO2_POK_flag set |
| | | | D[4] | | 0 | No Interrupt |
| | | | | | 1 | Interrupt due to VLDO2_UV_flag set |
| | | | D[3] | | 0 | No Interrupt |
| | | | | | 1 | Interrupt due to V5V_POK_flag set |
| | | | D[2] | | 0 | No Interrupt |
| | | | | | 1 | Interrupt due to V5V_UV_flag set |
| | | | D[1] | | 0 | No Interrupt |
| | | | | | 1 | Interrupt due to VSUP_POK_flag set |
| D[0] | 0 | No Interrupt | | | | |
| | 1 | Interrupt due to VSUP_UV_flag set | | | | |
| 0x0B | Reserved | 0000_0000 POR_VSUP | D[7:0] | | Reserved | |
| 0x0C | BUS Status Register | 0000_0000 POR_VSUP | D[7] | R | BUS clamped to dominant | |
| | | | D[6] | | TxD & RxD pins short | |
| | | | D[5] | | RxD pin clamped to Recessive | |
| | | | D[4] | | TxD pin clamped to Dominant | |
| | | | D[3] | | CANL pin shorted to VCC | |
| | | | D[2] | | CANL pin shorted to GND | |
| | | | D[1] | | CANH pin shorted to GND | |
| | | | D[0] | | CANH pin shorted to VCC | |
| 0x0D | Temperature Status Register | 0000_0000 POR_VSUP | D[7:2] | R | Reserved | |
| | | | D[1] | | OTM 140 Recovery flag | |
| | | | D[0] | | OTM 160 Warning flag | |
| 0x0E | Supply status Register | 1010_1010 POR_VSUP | D[7] | R | VLDO3_POK_flag | |
| | | | D[6] | | VLDO3_UV_flag | |
| | | | D[5] | | VLDO2_POK_flag | |
| | | | D[4] | | VLDO2_UV_flag | |
| | | | D[3] | | V5V_POK_flag | |
| | | | D[2] | | V5V_UV_flag | |
| | | | D[1] | | VSUP_POK_flag | |
| | | | D[0] | | VSUP_UV_flag | |

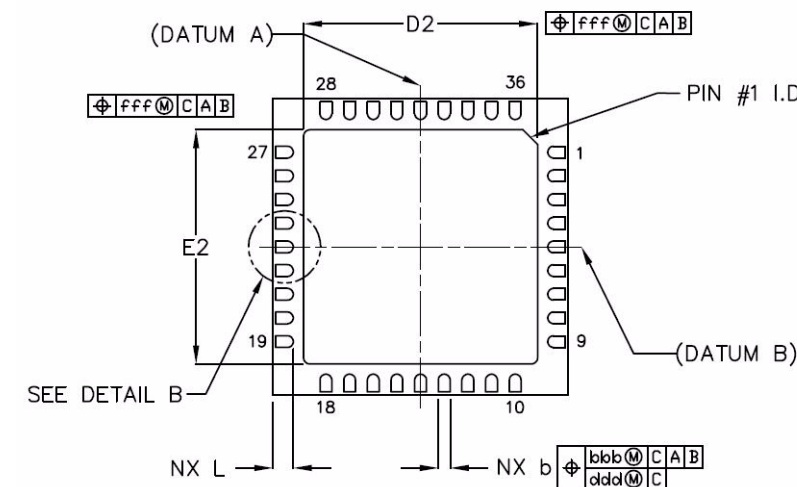
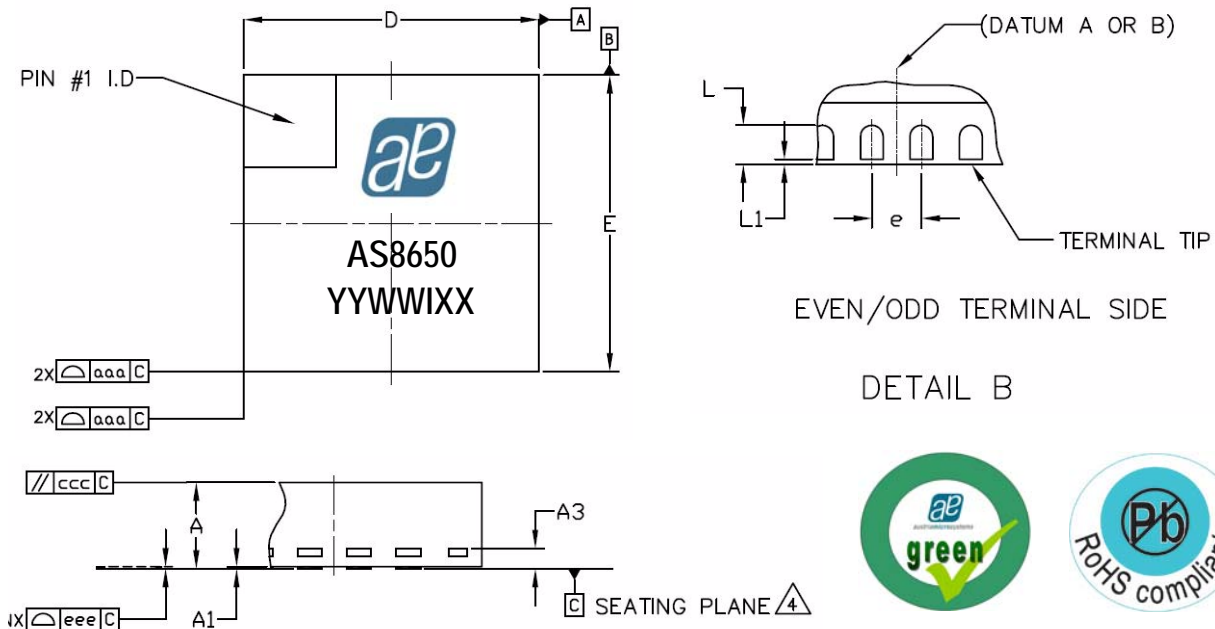
Table 21. Configuration Registers

| Addr | Register Name | POR Value | Bit | Type | Description |
|------|-----------------------|-----------------------|--------|------|------------------------------------------------|
| 0x0F | RESET Reason Register | 0000_0000 POR_VSUP | | R | These bits are cleared on microcontroller read |
| | | | D[7] | | Reserved |
| | | | D[6] | | SLEEP Mode exit by Local Wake up on WAKE pin |
| | | | D[5] | | SLEEP Mode exit by Remote wake |
| | | | D[4] | | Window Watchdog failure |
| | | | D[3] | | Timeout Watchdog failure |
| | | | D[2] | | Start-up Watchdog failure |
| | | | D[1] | | Undervoltage on VLDO1 |
| | | | D[0] | | OTM Shutdown flag |
| 0x10 | Backup Register | 0000_0000 POR_VSUP | D[7:0] | R/W | OTP_BITS[32:25] / MCU Backup Data |
| 0x11 | | | D[7:0] | | OTP_BITS[40:33] / MCU Backup Data |
| 0x12 | | | D[7:0] | | OTP_BITS[48:41] / MCU Backup Data |
| 0x13 | | | D[7:0] | | OTP_BITS[56:49] / MCU Backup Data |
| 0x14 | | | D[7:0] | | {1'b0, OTP_BITS[63:57]} / MCU Backup Data |
| 0x15 | | | D[7:0] | | {2'd0, Slave address[6:1]}/MCU Backup Data |
| 0x16 | | | D[7:0] | | 10bit_slave_address[3:0]/MCU Backup Data |
| 0x17 | | | D[7:0] | | MCU Backup Data |

9 Package Drawings and Markings

The device is available in a 36-pin QFN (6x6x0.9) package.

Figure 28. Drawings and Dimensions



| Symbol | Min | Nom | Max |
|--------|------|----------|------|
| A | 0.80 | 0.90 | 1.00 |
| A1 | 0 | 0.02 | 0.05 |
| A3 | - | 0.20 REF | - |
| L | 0.35 | 0.40 | 0.45 |
| L1 | 0 | - | 0.15 |
| b | 0.18 | 0.25 | 0.30 |
| D | | 6.00 BSC | |
| E | | 6.00 BSC | |
| e | | 0.50 BSC | |
| D2 | 4.60 | 4.70 | 4.80 |
| E2 | 4.60 | 4.70 | 4.80 |
| aaa | - | 0.15 | - |
| bbb | - | 0.10 | - |
| ccc | - | 0.10 | - |
| ddd | - | 0.05 | - |
| eee | - | 0.08 | - |
| fff | - | 0.10 | - |
| N | | 36 | |

Notes:

1. Dimensions and tolerancing conform to ASME Y14.5M-1994.
2. All dimensions are in millimeters, angle is in degrees.
3. Dimension b applies to metallized terminal and is measured between 0.25mm and 0.30mm from terminal tip. Dimension L1 represents terminal full back from package edge up to 0.15mm is acceptable.
4. Coplanarity applies to the exposed heat slug as well as the terminal.
5. Radius on terminal is optional.
6. N is the total number of terminals.

Marking: YYWWIXX.

| YY | WW | I | XX |
|-------------------------------------|--------------------|---------------------------|----------------------------|
| Last two digits of the current year | Manufacturing Week | Assembly plant identifier | Assembly traceability code |

Revision History

| Revision | Date | Owner | Description |
|----------|--------------|-------|---------------------|
| 1.0 | 29 Nov, 2010 | hgl | Initial release |
| 2.0 | 18 Oct, 2011 | | Updated for AS8650A |

Note: Typos may not be explicitly mentioned under revision history.

10 Ordering Information

The devices are available as the standard products shown in [Table 22](#).

Table 22. Ordering Information¹

| Ordering Code | Marking | Description | Delivery Form | Package |
|-----------------|---------|----------------------------------------------------------------------------------------|---------------|----------------------|
| AS8650A-ZQFP-01 | AS8650 | AS8650A Power Management device with high-speed CAN Interface (standard configuration) | Tape & Reel | 36-pin QFN (6x6x0.9) |

1. The AS8650A provides various configuration options during production. For more information, please contact our sales office.

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