



L4969

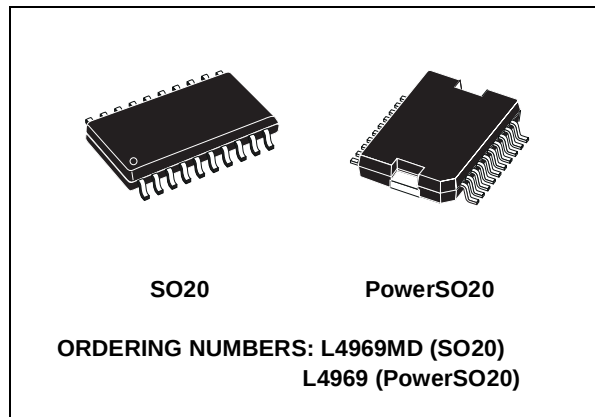
SYSTEM VOLTAGE REGULATOR WITH FAULT TOLERANT LOW SPEED CAN-TRANSCEIVER

PRODUCT PREVIEW

- OPERATING SUPPLY VOLTAGE 6V TO 28V, TRANSIENT UP TO 40V
- LOW QUIESCENT CURRENT CONSUMPTION, LESS THAN 100 μ A IN SLEEP MODE
- TWO VERY LOW DROP VOLTAGE REGULATORS 5V/100mA AND 5V/200mA
- SEPARATE VOLTAGE REGULATOR FOR CAN-TRANSCEIVER SUPPLY WITH LOW POWER SLEEP MODE
- RESET LOGIC
- SERIAL INTERFACE
- CAN TRANSCEIVER (LOW SPEED, DOUBLE WIRE) WITH FAULT TOLERANCE
- VOLTAGE SENSE COMPARATOR

DESCRIPTION

The L4969 is an integrated circuit containing 3 inde-



pendent Voltage Regulators and a standard fault tolerant low speed CAN line interface in multipower BCD3S process.

It integrates all main local functions for automotive body electronic applications connected to a CAN bus.

Figure 1. Block Diagram

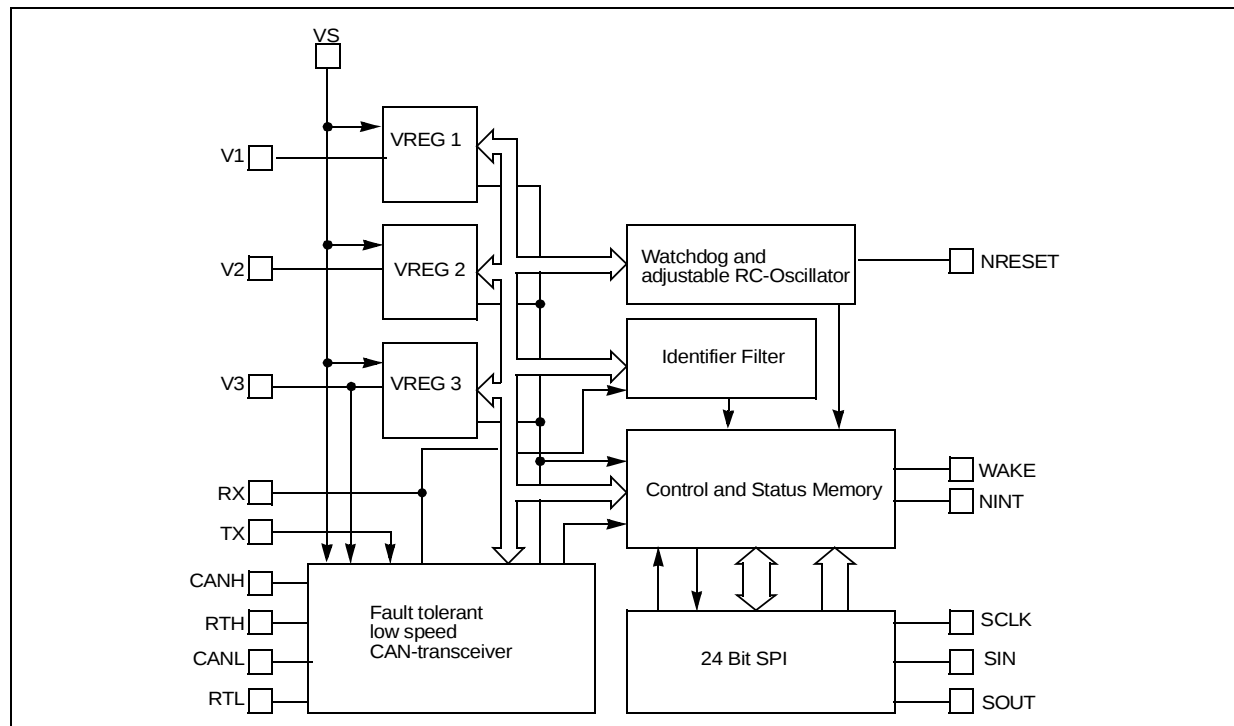


Figure 2. Pin Connection

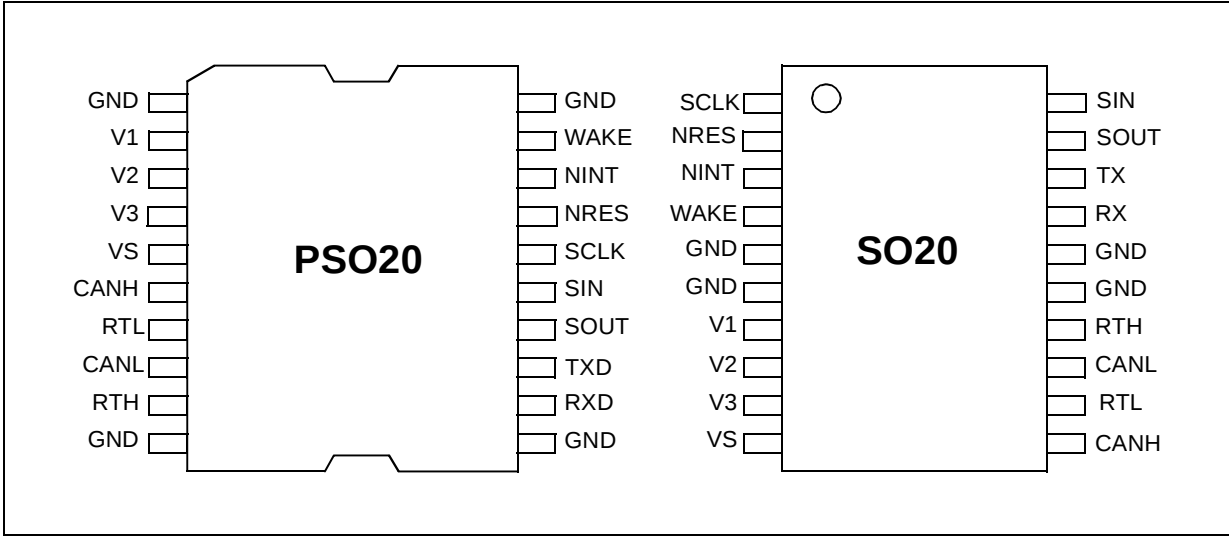


Table 1. Pin Functions

Pin No. (PSO20)	Pin No. (SO20)	Pin Name	Function
1, 10, 11, 20	5,6, 15, 16	GND	Power Ground
2	7	V1	Microcontroller Supply Voltage
3	8	V2	Peripheral Supply Voltage
4	9	V3	Internal CAN Supply
5	10	VS	Power Supply
6	11	CANH	CANH Line Driver Output
7	12	RTL	CANL Termination Source
8	13	CANL	CANL Line Driver Output
9	14	RTH	CANH Termination Source
12	17	RXD	Act. Low CAN Receive Dominant Data Output
13	18	TXD	Act. Low CAN Transmit Dominant Data Input
14	19	SOUT	Serial Data Output
15	20	SIN	Serial Data Input
16	1	SCLK	Serial Clock
17	2	NRES	Act. Low Reset Output
18	3	NINT	Act. Low Interrupt Request
19	4	WAKE	Dual Edge Triggerable Wakeup Input

Table 2. Thermal Data

Symbol	Parameter	Value	Unit
R _{thj-a}	Thermal resistance junction-ambient	40 ¹⁾	K/W
R _{thj-c}	Thermal resistance junction-case	3	K/W

Note: 1. Typical value soldered on a PC board with 8 cm² copper ground plane (35μm thick).

Table 3. Absolute Maximum Ratings

Symbol	Parameter	Value	Unit
V _{VSDC}	DC operating supply voltage	-0.3 ... +28	V
V _{VSTR}	Transient operating supply voltage (T < 400ms)	-0.3 ... +40	V
I _{OUT1...} I _{OUT3}	Output currents	Internally limited	
T _{STG}	Storage temperature	-65 ... +150	°C
T _J	Operating junction temperature	-40 ... +150	°C
V _{OUT1}	Externally forced output voltage OUT1	-0.3 ... +6.3	V
V _{OUT2}	Externally forced output voltage OUT2	-0.3 ... V _S +0.3	V
V _{OUT3}	Externally forced output voltage OUT3	-0.3 ... +6.3	V
V _{inli}	Input voltage Logic inputs: SIN, SOUT, RxD, SCLK	-0.3 ... +7	V
V _{inliW}	Input voltage WAKE	-0.3 ... V _S +0.3	V
V _{canh}	Voltage CANH line	-10 ... +27	V
V _{canht}	Voltage CANH line t < 0.1ms	-40 ... +40	V
V _{canl}	Voltage CANL line	-10 ... +27	V
V _{canlt}	Voltage CANL line t < 0.1ms	-40 ... +40	V

Notes: 1. The circuit is ESD protected according to MIL-STD-883C.

2. Current forced means voltage unlimited but current limited to the specified value.

Voltage forced means voltage limited to the specified values while the current is not limited.

Table 4. Electrical Characteristics

V_S = 14V, T_J = -40°C to 150°C unless otherwise specified.

Item	Symbol	Parameter	Test Conditions	Values			Unit
				Min.	Typ.	Max.	
1	Supply Current						
1.1	I _{SSL}	All Regulators off, (CAN Standby)				100	μA
1.1.1	I _{SSLWK}	V1 off, V2 off, V3 on (CAN RX only)				4	mA
1.2	I _{SSB}	V1 only (CAN Standby)				200	μA
1.3	I _S	All Regulators on, (CAN active, TX high)	I _{OUT1} = -100mA I _{OUT2} = -10mA No CAN load.			150	mA

Table 4. Electrical Characteristics (continued)

Item	Symbol	Parameter	Test Conditions	Values			Unit
				Min.	Typ.	Max.	
2	Voltage Regulator 1						
2.1	V _{O1}	V1 output voltage	6V < V _S < 28V -400μA< -I _O <-100mA	4.9	5	5.1	V
2.2	V _{O1}		T _J < 125°C -50μA <-I _O <-400μA	4.7	5	5.3	V
2.3	V _{DP1}	Dropout voltage 1	V _S = 4.8V				
2.4			I _{OUT1} = -10mA		0.1	0.2	V
			I _{OUT1} = -100mA		0.2	0.4	V
2.5	V _{OL01}	Load regulation 1	-1mA <-I _O <-100mA			40	mV
2.6	I _{LIM1}	Current limit 1	0.8V < V _{O1} < 4.5V	105	200	400	mA
2.7	V _{OLI1}	Line regulation 1	6V < V _S < 28V I _{O1} = -1mA			30	mV
2.8	T _{OVT1}	Overtemp flag 1	6V < V _S < 28V		140		°C
2.9	T _{OTKL1}	Thermal shutdown 1	6V < V _S < 28V		200		°C
2.10	V _{res}	Min V1 reset threshold voltage	RTCR = 0		4.5		V
			RTCR = 1		4.0		V
3	Voltage Regulator 2 and 3						
3.1	V _O	Output voltage	6V < V _S < 28V -1mA <-I _O <-200mA	4.8	5	5.2	V
3.2	V _{DP}	Dropout voltage	I _{O UT} = 200mA V _S = 4.8V			0.7	V
3.3	V _{OLO}	Load regulation	-1mA < -I _O < -200mA			50	mV
3.4	I _{LIM}	Current limit	0.8V < V _O < 4.5V	210	400	800	mV
3.5	V _{OLI}	Line regulation	6V < V _S < 28V I _{OUT} = -5mA			75	mV
3.6	T _{OVT}	Overtemp flag	6V < V _S < 28V		140		°C
3.7	T _{OTKL}	Thermal shutdown	6V < V _S < 28V		170		°C
4	Reset and Watchdog						
4.1	t _{RDnom}	Reset pulse duration		0.5	1	1.5	ms
4.2	t _{WDstart}	Reset pulse pause (startup watchdog)		38	47.5	57	ms

Table 4. Electrical Characteristics (continued)

Item	Symbol	Parameter	Test Conditions	Values			Unit
				Min.	Typ.	Max.	
4.2.1	t_{WDswS}	Watchdog window start (Software window Watchdog)	SWDC = 8	2	2.5	3	ms
			SWDC = 9	4	5	6	ms
			SWDC = 10	8	10	12	ms
			SWDC = 11	20	25	30	ms
4.2.2	t_{WDswE}	Watchdog window end (Software window watchdog)	SWDC = 8	4	5	6	ms
			SWDC = 9	8	10	12	ms
			SWDC = 10	16	20	24	ms
			SWDC = 11	40	50	60	ms
4.3	t_{WD1C}	System Watchdog 1	WD1C = 8	60	80	100	ms
			WD1C = 9	120	160	200	ms
			WD1C = 10	250	320	400	ms
			WD1C = 11	500	640	780	ms
			WD1C = 12	640	800	980	ms
4.4	t_{WD2C}	System Watchdog 2	WD2C = 8	0.75	1	1.25	s
			WD2C = 9	1.5	2	2.5	s
			WD2C = 10	3	4	5	s
			WD2C = 11	6	8	10	s
			WD2C = 12	30	45	60	min
4.5	V_{RESL}	Reset output LOW voltage	$R_{resV1} = 10K$ $V1 > 1.5V$			0.4	V
5	CAN Line Interface						
5.1	V_{DropH}	CANH voltage drop (dominant state)	$I_{CANH} = 40mA$			1.4	V
5.2	V_{DropL}	CANL voltage drop (dominant state)	$I_{CANL} = -40mA$			1.4	V
5.3	t_d	Propagation delay (rec to dom state)	$C_{load} = 3.3n$		1		μs
5.4	S_{RD}	Bus output slew rate (r -> d)	10% ... 90% $C_{Load} = 3.3n$		5		V/ μs
5.5	R_{RTH}, R_{RTL}	Termination resistance		0.5		16	K Ω
5.6	V_{CCFS}	Force Standby mode (fail safe)	V_S	2.75		4.5	V
5.7	$V_{H_{RXD}}$	High level output voltage on RXD		$V3 - 0.9$		$V3$	V

Table 4. Electrical Characteristics (continued)

Item	Symbol	Parameter	Test Conditions	Values			Unit
				Min.	Typ.	Max.	
5.8	VL _{RxD}	Low level output voltage on RXD		0		0.9	V
5.9	V _{d_r}	Differential receiver dom to rec threshold $V_{CANH} - V_{CANL}$	No bus failures (common mode range $\pm 5V$)	-3.25		-2.65	V
5.10	V _{r_d}	Differential receiver rez to dom threshold $V_{CANH} - V_{CANL}$	No bus failures (common mode range $\pm 5V$)	-3.25		-2.65	V
5.11	V _{d_rF}	Differential receiver dom to rec threshold $V_{CANH} - V_{CANL}$	Bus failures (common mode range $\pm 5V$)	0.4	0.7	1	V
5.12	V _{CANHr}	CANH recessive output voltage	TXD = V _I R _{TH} < 4K			0.2	V
5.13	V _{CANHd}	CANH dominant output voltage	TXD = 0 I _{CANH} = 40mA	V _I - 1.4V			V
5.14	V _{CANLr}	CANL recessive output voltage	TXD = V _I R _{RTL} < 4K	V _I - 0.2V			V
5.15	V _{CANLd}	CANL dominant output voltage	TXD = 0 I _{CANL} = -40mA			1.4	V
5.16	I _{CANH}	CANH dominant output current	TXD = 0 V _{CANH} = 0V	-70	100	-130	mA
5.17	I _{CANL}	CANL dominant output current	TXD = 0 V _{CANL} = 14V	70	100	130	mA
5.18	I _{LCANH}	CANH Sleep mode leakage current	Sleep mode. V _{CANH} = 0V		0		μA
5.19	I _{LCANL}	CANL Sleep mode leakage current	Sleep mode. V _{CANL} = 0V V _S = 12V		0		μA
5.20	V _{WakeH}	CANH wakeup voltage	Sleep/ standby mode	1.2	1.9	2.7	V
5.21	V _{WakeL}	CANL wakeup voltage	Sleep/ standby mode	2.4	3.1	3.8	V
5.22	V _{canhs}	CANH single ended receiver threshold	Normal mode. -5V < CANL < V _S	1.5	1.82	2.15	V
5.23	V _{canls}	CANL single ended receiver threshold	Normal mode. -5V < CANH < V _S	2.7	3.1	3.4	V
5.24	V _{OVH}	CANH overvoltage detection threshold	Normal mode. -5V < CANL < V _S	6.5	7.2	8.0	V
5.25	V _{OVL}	CANL overvoltage detection threshold	Normal mode. -5V < CANH < V _S	6.5	7.2	8.0	V

Table 4. Electrical Characteristics (continued)

Item	Symbol	Parameter	Test Conditions	Values			Unit
				Min.	Typ.	Max.	
5.26	V _{SOVH}	CANH overvoltage detection threshold	Sleep/ standby mode		7.2		V
5.27	R _{T_{RTH}}	internal RTH to GND termination resistance	Normal mode. No failures. 1V < V _{RTH} < 4V		45		Ω
5.28	I _{T_{RTH}}	internal RTH to GND termination current	Normal mode. (failure EIII) 1V < V _{RTH} < 4V		75		μA
5.29	R _{T_{RTL}}	internal RTL to V _{CC} termination resistance	Normal mode. No failures. 1V < V _{RTL} < 4V		45		Ω
5.30	R _{T_{RTL}} F	internal RTL to V _{CC} termination current	Normal mode. (failure EIV, EVI, EVII) 1V < V _{RTH} < 4V		75		μA
5.31	R _{T_{RTL}} S	internal RTL to V _S termination resistance	Standby/ sleep mode. No failures. 1V < V _{RTL} < V _S		13		KΩ
6	Digital I/O						
6.1	V _{SINL}	Low level input voltage		0		0.9	V
6.2	V _{SINH}	High level input voltage		V1 - 0.9		V1	V
6.3	V _{SCLKL}	Low level input voltage		0		0.9	V
6.4	V _{SCLKH}	High level input voltage		V1 - 0.9		V1	V
6.5	V _{TXL}	Low level input voltage		0		0.9	V
6.6	V _{TXH}	High level input voltage		V1 - 0.9		V1	V
6.7	V _{WakeL}	Low level input voltage		0		0.9	V
6.8	V _{WakeH}	High level input voltage		V1 - 0.9		V1	V
6.9	V _{SoutH}	High level output voltage		V1 - 0.9		V1	V
6.10	V _{SoutL}	Low level output voltage		0		0.9	V
6.11	V _{R_{XDH}}	High level output voltage		V1 - 0.9		V1	V
6.12	V _{R_{XDL}}	Low level output voltage		0		0.9	V
6.13	I _{oh_{R_{XD}}}	High level output current	R _{XD} = 0		1.0		mA
6.14	I _{ol_{R_{XD}}}	Low level output current	R _{XD} = 5V		1.0		mA
6.15	I _{oh_{S_{OUT}}}	High level output current	S _{OUT} = 0		1.0		mA
6.16	I _{ol_{S_{OUT}}}	Low level output current	S _{OUT} = 5V		1.0		mA

Table 4. Electrical Characteristics (continued)

Item	Symbol	Parameter	Test Conditions	Values			Unit
				Min.	Typ.	Max.	
6.17	I _{OH} INT	High level output current	INT = 0		1.0		mA
6.18	I _{OL} INT	Low level output current	INT = 5V		1.0		mA
6.19	I _{OH} Reset	High level output current	RESET = 0		100		μA
6.20	I _{OL} Reset	Low level output current	RESET = 5V		1.0		mA
7	Serial Data Interface						
7.1	t _{Start}	SIN low to SCLK low setup time (frame start)		100			ns
7.2	t _{Setup}	SIN to SCLK setup time (write)		100			ns
7.3	t _{Hold}	SIN to SCLK hold time (write)		100			ns
7.4	t _D	SCLK to SOUT delay time (read)				500	ns
7.5	t _{CKmax}	SCLK maximum cycle time (timeout)				1.5	ms
7.6	t _{GAP}	Interframe Gap		5			us
8	Diagnostic Functions						
8.1	V _{Smin}	Sense comparator detection threshold			7.2		V
8.2	G _{SCANH}	CANH groundshift detection threshold			-1		V
9	CAN Error Detection						
9.1	N _{EdgeH}	Nr of dom to rec edges on CANL to detect permanent rez CANH	Operating mode (EI_V)	3			Edges
9.2	N _{EdgeHR}	Nr of dom to rec edges to detect recovery of CANH	Operating mode (EI_V)	3			Edges
9.3	N _{EdgeL}	Nr of dom to rec edges on CANH to detect permanent rez CANL	Operating mode (EII_IX)	3			Edges
9.4	N _{EdgeLR}	Nr of dom to rec edges to detect recovery of CANL	Operating mode (EII_IX)	3			Edges
9.5	t _{EIII}	CANH to V _S short circuit detection time	Operating mode (EIII)	0.9	1.8	3.6	ms
			Sleep/standby mode (EIII)	0.9	1.8	3.6	ms
9.6	t _{EIIIR}	CANH to V _S short circuit recovery time	Operating mode (EIII)	0.4	0.9	1.8	ms
			Sleep/standby mode (EIII)	0.4	0.9	1.8	ms

Table 4. Electrical Characteristics (continued)

Item	Symbol	Parameter	Test Conditions	Values			Unit
				Min.	Typ.	Max.	
9.7	t_{EIV}	CANL to GND short circuit detection time	Operating mode (EIV)	0.4	0.9	1.8	ms
			Sleep/standby mode (EIV)	0.4	0.9	1.8	ms
9.8	t_{EIVR}	CANL to GND short circuit recovery time	Operating mode (EIV)	10	30	50	μ s
			Sleep/standby mode (EIV)	0.4	0.9	1.8	ms
9.9	t_{EVI}	CANL to VS short circuit detection time	Operating mode (EVI)	0.4	0.9	1.8	ms
9.10	t_{EVIR}	CANL to VS short circuit recovery time	Operating mode (EVI)	200	500	750	μ s
9.11	t_{EVII}	CANL to CANH short circuit detection time	Operating mode (EVII)	0.4	0.9	1.8	ms
9.12	t_{EVIIR}	CANL to CANH short circuit recovery time	Operating mode (EVII)	10	30	50	μ s
9.13	t_{EVIII}	CANH to VDD short circuit detection time	Operating mode (EVIII)	0.9	1.8	3.6	ms
			Sleep/standby mode (EVIII)	0.9	1.8	3.6	ms
9.14	t_{EVIIR}	CANH to VDD short circuit recovery time	Operating mode (EVIII)	0.4	0.9	1.8	ms
			Sleep/standby mode (EVIII)	0.4	0.9	1.8	ms
9.15	t_{FailTX}	TX permanent dominant detection time (Fail safe)	Operating mode (EX)	0.4	0.9	1.8	ms
9.16	$t_{FailTXR}$	TX permanent dominant recovery time (Fail safe)	Operating mode (EX)	1	4	8	μ s

1.0 FUNCTIONAL DESCRIPTION

1.1 General Features

The U435 is a monolithic integrated circuit which provides all main functions for an automotive body CAN network.

It features two independent regulated voltage supplies V1 and V2, an interrupt and reset logic with internal clock generator, Serial Interface and a low speed CAN-bus transceiver which is supplied by a separate third voltage regulator (V3).

The device guarantees a clearly defined behavior in case of failure, to avoid permanent CAN bus errors.

The device operates in three different modes:

- a) Sleep mode:
 - V1 is off
 - V2 is off
 - V3 is off
 - CAN-Transceiver: active with reduced performance
 - Watchdog active

The total current consumption is $< 100\mu\text{A}$.

b) Standby mode: V1 is on (μC in stop mode)
 V2 is off
 V3 is off
 CAN-Transceiver: active with reduced performance

The total current consumption is $< 200\mu\text{A}$.

c) Operating mode: V1 is on
 V2 is on
 V3 is on

V1 Output Voltage

The V1 regulator uses a DMOS transistor as an output stage. With this structure very low dropout voltage at currents up to 100mA is obtained. The dropout operation of the standby regulator is maintained down to 4V input supply voltage. The output voltage is regulated up to the transient input supply voltage of 40V. With this feature no functional interruption due to overvoltage pulses is generated. The output 1 regulator is switched off in sleep mode. Through metal option the output 1 voltage can be set to 3.3V.

V2 Output Voltage

The V2 regulator uses the same output structure as the output 1 regulator except to being short circuit proof to V_S , and to be rated for the output current of 200mA. The V2 output can be switched on and off through a dedicated enable bit in the control register. In addition a tracking option can be enabled to allow V2 follow V1 with constant offset. This feature allows consistent A/D conversion inside the μC (supplied by V1) when the converted signals are referenced to V2.

V3 Output Voltage

The third voltage regulator of the device generates the supply voltage for the internal logic and the CAN-transceiver. In operating mode it is capable of supplying up to 200mA in order to guarantee the required short circuit current for the CAN_H driver. The sleep and operating modes are switched through a dedicated enable bit.

Internal Supply Voltage

A low power sleep mode regulator supplies the internal logic in sleep mode.

1.2 CAN Transceiver

- Supports double wire unshielded busses
- Baud rate up to 125KBaud
- Short circuit protection (battery, ground, wires shorted)
- Single wire operation possible (automatic switching to single wire upon bus failures)
- Bus not loaded in case of unpowered transceiver

The CAN transceiver stage is able to transfer serial data on two independent communication wires either differentially (normal operation) or in case of a single wire fault on the remaining line. The physical bitcoding is done using dominant (transmitter active) and overwritable recessive states. Too long dominant phases are detected internally and further transmission is automatically disabled (malfunction of protocol unit does not affect communication on the bus, "fail-safe" - mechanism). For low current consumption during bus inactivity a sleep mode is available. The operating mode can be entered from the sleep mode either by local wake up (μC) or upon detection of a dominant bit on the CAN-bus (external wake up).

Ten different errors on the physical buslines can be distinguished:

1.3 Detectable Physical Busline Failures

N	Type of Errors	Conditions
Errors caused by damage of the datalines or isolation		
I	CANH wire interrupted (tied to Ground or termination)	Edgecount difference > 3
II	CANL wire interrupted (floating or tied termination)	Edgecount difference > 3
III	CANH short circuit to V _{BAT} (overvoltage condition)	V(CANH) > 7.2V after 32us
IV	CANL short circuit to GND (permanently dominant)	V(CANL) < 3.1V & V(CANH)-V(CANL) < -3.25V after 1.3ms
V	CANH short circuit to GND (permanently recessive)	Edgecount difference > 3
VI	CANL short circuit to V _{BAT} (overvoltage condition)	V(CANL) > 7.2V after 32us
VII	CANL shorted to CANH	V(CANH) - V(CANL) < -3.25V after 1.3ms
Errors caused by misbehavior of transceiver stage		
VIII	CANH short circuit to VDD (permanently dominant)	V(CANH) > 1.8V & V(CANH) - V(CANL) < -3.25V after 1.3ms
IX	CANL short circuit to VDD (permanently recessive)	Edgecount difference > 3
Errors caused by defective protocol unit		
X	CANH, CANL driven dominant for more than 1.3ms	

Not all of the 10 different errors lead to a breakdown of the whole communication.
So the errors can be categorized into 'negligible', 'problematic' and 'severe':

Negligible Errors

Transmitter

Error I and II (CANH or CANL interrupted but still tied to termination)
Error IV and VIII (CANH or CANL permanently dominant by short circuit)
In all cases above data can still be transmitted in differential mode.

Receiver

Error I and II (CANH or CANL interrupted but still tied to termination)
Error V and IX (CANH or CANL permanently recessive by short circuit)
In all cases above data can still be received in differential mode.

Problematic Errors

Transmitter

Error III and VI (CANH or CANL show overvoltage condition by short circuit)
Data is transmitted using the remaining dataline (single wire)

Receiver

Error III and VI (CANH or CANL show overvoltage condition by short circuit)
Data is received using the remaining dataline (single wire)

Severe Errors

Transmitter

Error V and IX (CANH or CANL permanently recessive by short circuit)

Data is transmitted on the remaining dataline after short circuit detection

Error VII (CANH is shorted to CANL)

Data is transmitted on CANH or CANL after overcurrent was detected

Error X (attempt to transmit more than 10 successive dominant bits (at lowest bitrate specified)

Transmission is terminated (fail safe)

Receiver

Error VII (CANH is shorted to CANL)

Data is received on CANH or CANL after detection of permanent dominant state

Error IV and VIII (CANH or CANL permanently dominant by short circuit)

Data is received on CANH or CANL after short circuit was detected

Error X (reception of a sequence of dominant bits, violating the protocol rules)

Data is received normally, error is detected by protocol-unit

The error conditions is signaled issuing an error flag inside a dedicated register which is readable by the μ C through the serial interface. The information of the error type (I through X) is also stored into this register.

1.4 Oscillator

A low power oscillator provides an internal clock. In sleep mode (Watchdog active) the output frequency is 250kHz, if the Watchdog function is not requested, the internal Oscillator is switched off.

In standby and operating mode the oscillator is running at 1MHz, and can be calibrated in a range from -16% to +16% using the μ C-XTAL as a reference.

1.5 Watchdog

A triple function programmable watchdog is integrated to perform the following tasks:

- Wakeup Watchdog:
When in sleep or standby mode the watchdog can generate a wakeup condition after a programmable period of time ranging from 80ms up to 45 minutes
- Startup Watchdog:
Upon V1 power-up or μ C failure during SPI supervision (see SW-Watchdog) a reset pulse is generated periodically every 50ms for 2.5ms until activity of the μ C is detected (SPI sequence) or no acknowledge is received within 7 cycles (350ms). In this condition the device is forced into Sleep mode until a Wakeup is detected and a startup cycle is reinitialized.
- Window Watchdog:
After passing the startup sequence, this watchdog request an acknowledge by the μ C via the SPI within a programmable timing frame, ranging from 2.5 ... 5ms up to 20 ... 40ms. Upon a missing or misplaced acknowledge the Startup Watchdog is initialized.

1.6 Identifier Filter

A 12-Bit CAN-ID-filter is implemented allowing wakeup via specific CAN-messages thus aiding the implementation of low power partial communication networks like standby diagnostics without the need to power-up the whole network.

To guarantee the detection of the programmed Identifiers, the local RC-oscillator can be calibrated to allow the programmable Bittime logic to extract the incoming stream with a maximum of tolerance over temperature deviation.

1.7 Power-on Reset

Upon Power-on ($V_S > 3.5V$), the internal reset forces the device into a predefined power-on state:

- V1 on
- V2 off
- V3 off
- CAN-Standby mode
- ID-Filter disabled
- Startup Watchdog active

With V_S below 5V the regulator V1 will follow V_S with minimum drop. The μC retrieves a reset if V1 is dropping below a programmable voltage level of either 4.5V (default) or 4.0V. The programmed state of the U435 remains unchanged.

1.8 Ground Shift Detection

In case of single wire communication via CANH the signal to noise ratio is low. Detecting the local ground shift can be used as an additional indicator on the current signal quality. The information of the integrated ground shift detector will be refreshed upon every falling edge on TX and can be read from the CAN Transceiver Status Register (CTSR).

It will be set, if $V(\text{CANH}) < -1V$, reset if $V(\text{CANH}) > -1V$ at the falling edge of TX.

1.9 Thermal Protection

The device features three independent thermal warning circuits which monitor the temperature of the V1 output, the V2 output and the CAN_H and CAN_L drivers together with voltage regulator V3. Each circuit sets a separate overtemperature flag in a register which is read and writable by the serial interface. The overtemperature flags cause an interrupt to the μC . The μC is able to switch V1, V2 and CAN drivers on and off through dedicated enable registers. To enhance system security following strategy is chosen for thermal warning and shutdown:

- 3 independent warning flags are set at 140°C for V1, V2 and V3/CAN-Transceiver
- at 170°C V2 and V3 switched off
- at 200°C V1 is switched off
- V2 and V3 can be switched on again through the μC
- V1 can be switched on again at wake-up (Watchdog wake-up, CAN wake-up, external wake-up)

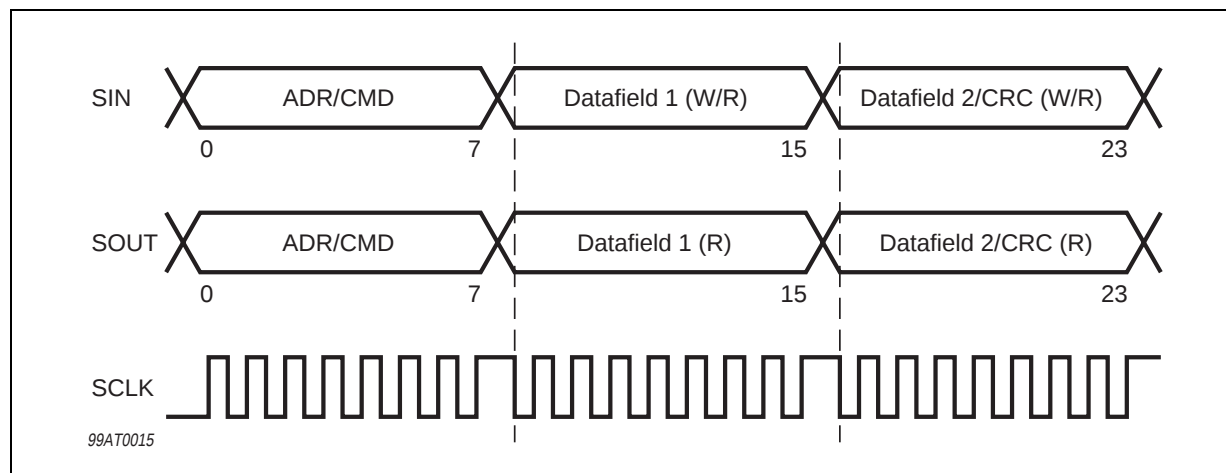
Note, that if no wakeup source is set for V1 a 1sec watchdog timeout will be established to enable a proper retry cycle.

1.10 Serial Interface (SPI)

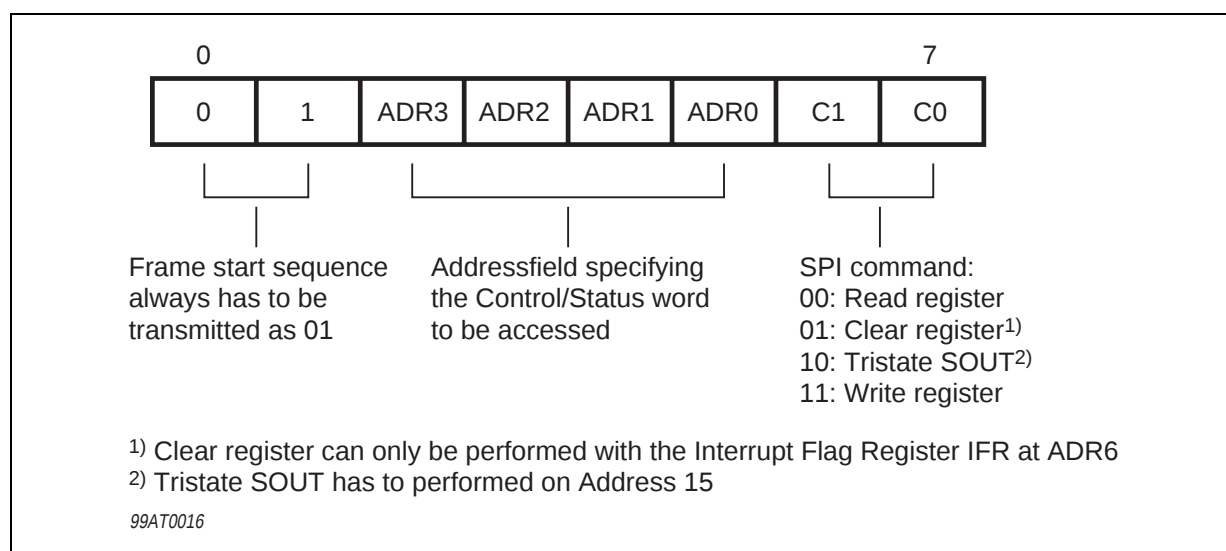
A standard serial peripheral interface (SPI) is implemented to allow access to the internal registers of the U435. A total of 12 Registers with different datalengths can be directly read from or written to, providing the requested address at the beginning of a dataframe. Upon every access to this interface, the content of the register currently accessed is shifted out via SOUT. All operations are performed on the rising edge of SCLK. If a frame is not completed, the interface is automatically reset after 1.5ms of SCLK idle time (auto timeout detection).

Due to limited pin count on this device the chip select has to be programmed explicitly (see Tristate SOUT) and will return to the normal output mode after a fixed period of 1.5ms after the last foreign SPI interaction.

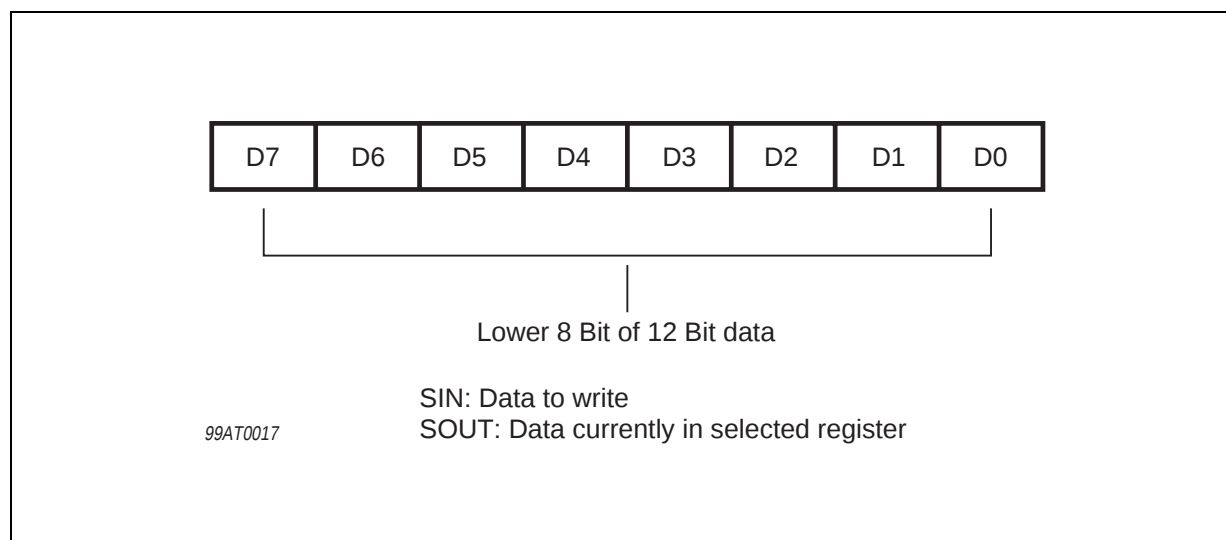
The dataframe format used described below:

General Dataframe Format:

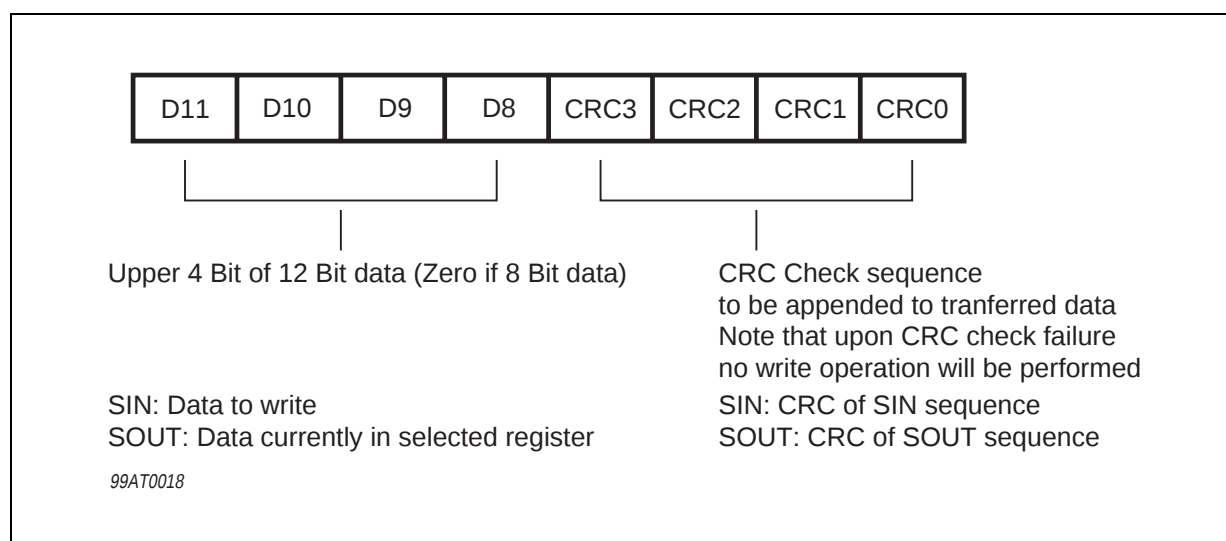
Data is sampled on the rising edge of the clock and SOUT will change upon SCLK falling. SOUT will show a copy of SIN for the Address/Command field for initial data path checks. Independent of the command state, SOUT will show the content of the register addressed. SIN contains either data to be written or arbitrary data for all other operations. The transaction will be terminated with four bit of data followed by a 4-Bit wide CRC (Cyclic Redundancy Check) as a result of either SIN related data or calculated automatically on data returned via SOUT. Here the μ C has to provide the correct sequence in order to get the write command activated inside. A CRC-failure is signalled via NINT. For returned data the CRC can also be used to verify a successful transfer.

Address/Command Field

The Address/Command field starts with a 2-Bit start sequence consisting of '01'. Any other sequence will lead to a protocol error signalled via the NINT. The addressfield is specifying the register to be accessed. The SPI command flags allow in addition to the normal read/write operation to either clear a register after read (operating only on IFR) or to disable SOUT to allow communication between μ C and other peripherals using the same SPI. The SOUT function is automatically reestablished after 1.5ms following the last transaction and will be signalled via NINT.

Datafield #1

Datafield #1 contains either the lower 8 bits of a 12-Bit frame or the complete byte of an 8-Bit transfer. Note, that SOUT is always showing the content of the register currently accessed and not a copy of SIN as during the Address/Command field.

Datafield #2/CRC

Datafield #2 contains either the upper four bits of a 12-Bit frame or zeros in case of an 8-Bit transfer. This field is followed by a four bit CRC sequence that is calculated based upon the polynom 0x11h (17 decimal). This sequence is simply the remainder of a polynomial division performed on the data previously transferred. If the CRC appended to the SIN sequence fails, any writing will be disabled and an error is signalled via NINT. Another remainder is calculated on the SOUT stream and appended accordingly to allow the application software to validate the correctness of incoming data. To aid evaluation, the CRC checking can be turned off by writing arbitrary data with a valid CRC to address 15. CRC-checking will be reenabled upon another operation of this kind (Toggled information).

1.11 Memory Map

Table 5. U435 Memory Map

ADR	Group	MSB	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
0	VRCR	Undefined Register Memory				EUV3	EUV2	RTC0	TRC	RES	ENV3	ENV2	DISAR
1	CTCR					ACT	TXEN	RES	RES	RES	RES	RES	RES
2	GPTR					RES	RES	RES	RES	TM1	TM0	TMUX	TEN
3	RCADJ					CG1	CG0	PGEN	SIGN	ADJ3	ADJ2	ADJ1	ADJ0
4	WDC					WDEN	SWEN	SWT1	SWT0	WDT3	WDT2	WDT1	WDT0
5	GIEN					ISET	IRES	EUV	EOVT	EEW	ECW	EWV	EIFW
6	IFR	ESPI	ISPI	IRES	UV23	UVVS	OVT3	OVT2	OVT1	WKE	WKC	WKW	WKIF
7	CTSR	RES	RES	RES	GSH	EX	EVIII	EVII	EVI	EIV	EIII	EII	EI
8	ID01	C11	C10	C01	C00	B11	B10	B01	B00	A11	A10	A01	A00
9	ID23	F11	F10	F01	F00	E11	E10	E01	E00	D11	D10	D01	D00
10	BTL	PS23	PS22	PS21	PS20	PS13	PS12	PS11	PS10	TD3	TD2	TD1	TD0
11	NAV	Undefined Register Memory											
12	NAV												
13	NAV												
14	TEST	T11	T10	T09	T08	T07	T06	T05	T04	T03	T02	T01	T00
15	SYS	Undefined Register Memory				CRC	TRI	WNDF	STF	OTF	UCF	WAKE	NPOR

The memory space is divided up into 16 different registers each being directly accessible using the SPI.

Each register contains specific information of a functional group.

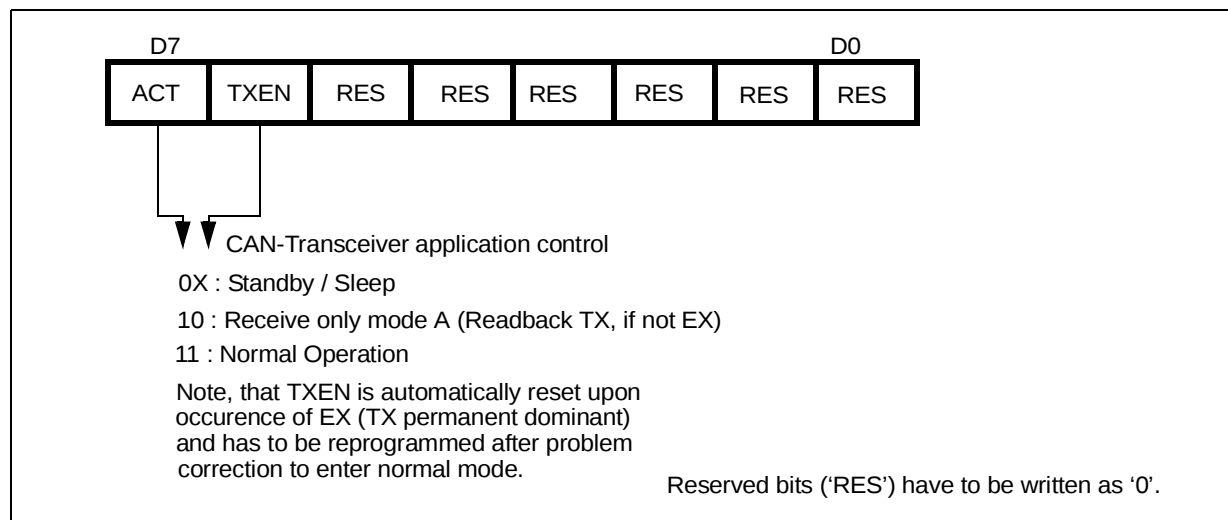
In general all reserved bitpositions ('RES') have to be written with '0'.

Undefined bits are read as '0' and cannot be overwritten.

In addition there is one register (CTSR) being read only, thus any write attempt will leave the register content unchanged.

Certain interlock mechanism exist to prevent unwanted overwriting of important functions i.e. voltage regulators or oscillator adjustments. These mechanisms are described with the functions of these registers.

ADR 1: CTCR CAN-Transceiver Control Register



Three basic operating modes are available using different logic combinations on ACT and TXEN. Each of these modes in conjunction with other inputs has its unique combination of parameters inside the specification:

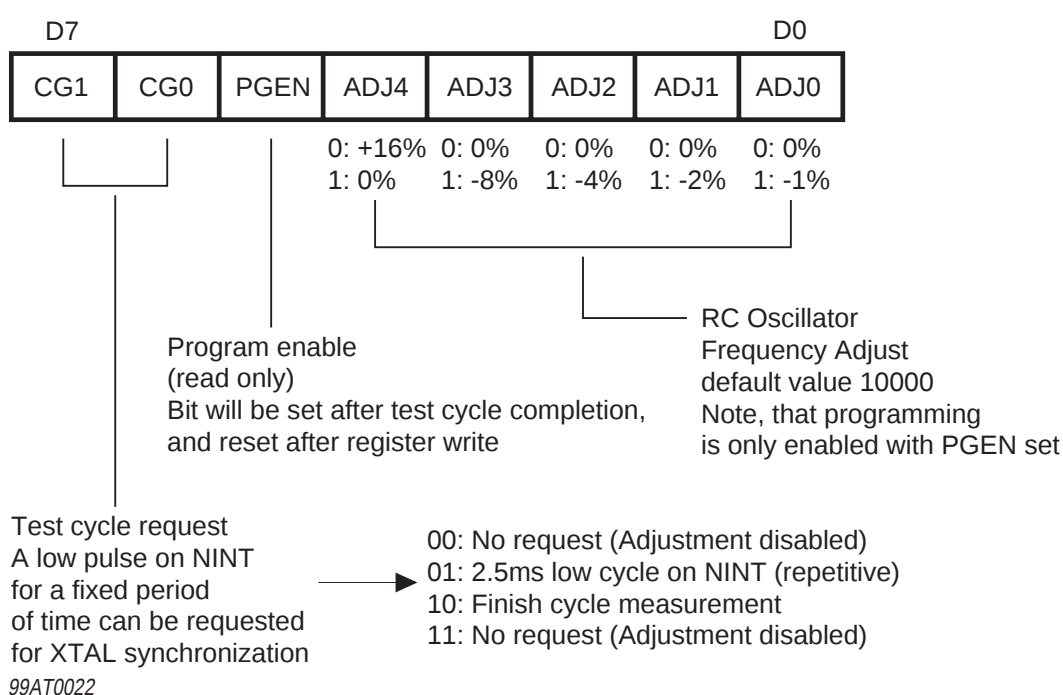
Table 6. Operating Modes of the CAN Lineinterface

Input Signals						Mode	Output Signals				
ACT	TXEN	TX	CANH	CANL	V3		RTL	RTH	CANH	CANL	RX
0	X	X	RTH	RTL	ON	Standby	V _{BAT}	GND	OFF	OFF	1
1	0	1/0	RTH	RTL	ON	RXonly	V _{DD}	GND	OFF	OFF	TX
1	0	1	$\bigwedge$	RTL	ON	RXonly	V _{DD}	GND	OFF	OFF	$\bigvee$
1	0	1	RTH	$\bigvee$	ON	RXonly	V _{DD}	GND	OFF	OFF	$\bigvee$
1	1	1	RTH	RTL	ON	Normal	V _{DD}	GND	ON	ON	1
1	1	0	RTH	RTL	ON	Normal	V _{DD}	GND	V _{DD}	GND	0
1	1	1	$\bigwedge$	RTL	ON	Normal	V _{DD}	GND	ON	ON	$\bigvee$
1	1	1	RTH	$\bigvee$	ON	Normal	V _{DD}	GND	ON	ON	$\bigvee$
1	1	0 ^{*1}	RTH	RTL	ON	Error X	V _{DD}	GND	OFF	OFF	1
1	X	1	V _{DD} ^{*1}	RTL	ON	Error VII, VIII	V _{DD}	ISRC	OFF	ON	CANL
1	X	1	V _S ^{*1}	RTL	ON	Error EIII, VII, VIII	V _{DD}	ISRC	OFF	ON	CANL
1	X	1	GND	$\bigvee \times 3$	ON	Error EI_V	V _{DD}	GND	ON	ON	$\bigvee$
1	X	1	$\bigwedge \times 3$	V _{DD}	ON	Error EII_IX	V _{DD}	GND	ON	ON	$\bigvee$
1	X	1	RTH	V _S ^{*1}	ON	Error EVI	ISRC	GND	ON	OFF	CANH
1	X	1	RTH	GND ^{*1}	ON	Error EVII, EIV	ISRC	GND	ON	OFF	CANH
1	X	1	CANL ^{*1}	CANH ^{*1}	ON	Error EVII	ISRC	GND	ON	OFF	CANH

*1) "shorted to ..."

ADR 2: GPTR Global Parameter and Test Register

This register is to be used for testpurpose only, all bits have to remain 'zero'

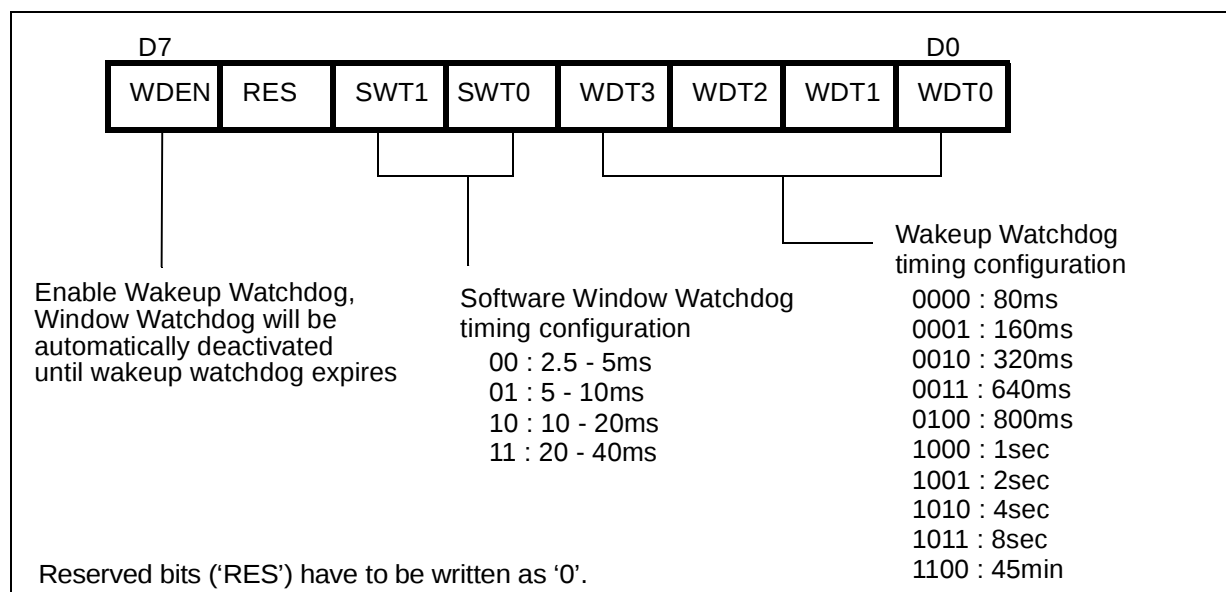
ADR 3: RCADJ RC-Oscillator Adjust register

During normal operation the μ C can set CG1 and CG0 to '01' to force a 200Hz rectangular waveform on NINT with 50% duty cycle. Note, that all other pending interrupts have to be cleared before.

After the XTAL driven timer of the μ C calculated the relative cycle time and the corresponding deviation, CG1 and CG0 have to be set to '10' to disable the adjustment cycle on NINT. From the deviation calculated by the μ C, the correction factor of the RC-oscillator -16% to + 16% can be reprogrammed with CG1 and CG0 set to '00' or '11'. ('11' can be used to indicate that calibration has already been performed).

Note, that overwriting this register is only valid, if the cycle measurement was started and terminated properly. This can be tested by evaluating PGEN either prior to or during correction (Read back via SOUT).

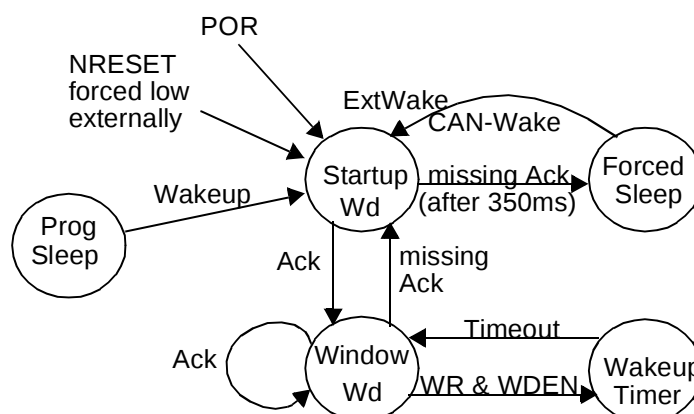
ADR4: WDC Watchdog Control Register



The Startup Watchdog is not programmable and will always generate a 2.5ms low cycle on NRESET followed by a 47.5ms high cycle until an Acknowledgment will occur. If no Acknowledge is received after the 7th cycle, the device will automatically be forced into Sleep mode.

Acknowledgment and Reset of Startup and Window Watchdog is automatically performed by overwriting (or rewriting) this register.

Watchdog configuration:



After power-on-reset of VS and V1 or wakeup from Sleep or NRESET being forced low externally, the Startup Watchdog is active, supervising the proper startup of the V1 supplied uC. Upon missing SPI write operation to the WDC register after 7 reset cycles (2.5ms active, 47.5ms high) the Sleep mode is entered.

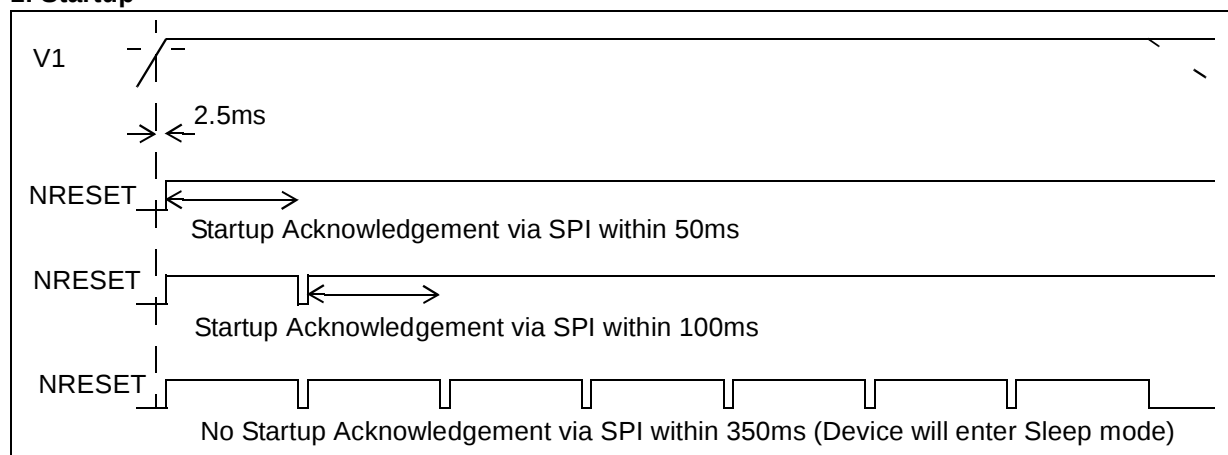
Leaving the forced Sleep mode will be automatically performed upon wakeup via CAN, an edge on WAKE or upon device powerup.

After successful startup, the Window Watchdog supervision is activated, meaning, that the uC has to send an acknowledge within a predefined, programmable window.

Upon failure, a reset is generated and the Startup Watchdog is reactivated.

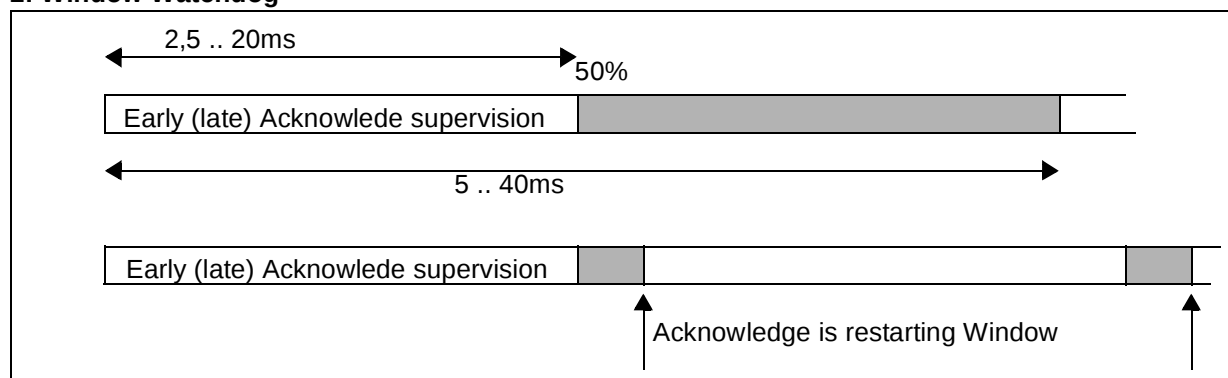
If the Timer function is requested, the window watchdog is deactivated until expiry of the wakeup time.

1: Startup



After powerup, the U435 is expecting the uC to send an acknowledgement within a predefined segmented timing frame of 7 x 50ms. A missing acknowledgement until after the 350ms will force the device into sleep mode until either external or CAN wakeup or POR cause a restart of the sequence above.

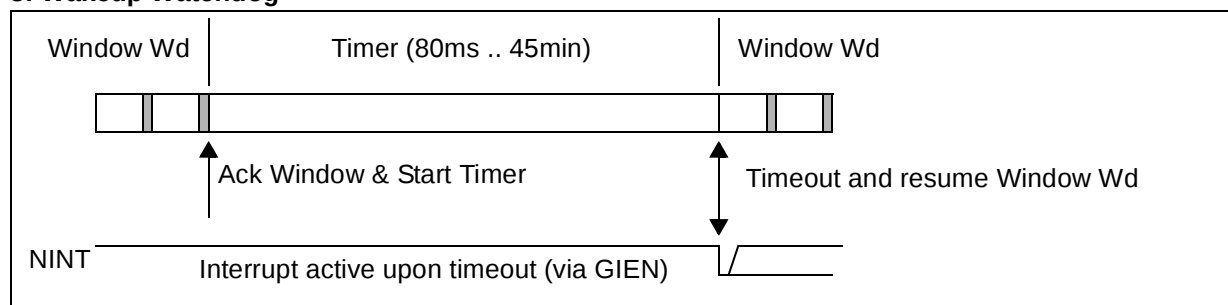
2: Window Watchdog



After successful acknowledgement of the Startup sequence, the Window watchdog is automatically activated and controlling proper uC activity by supervising an incoming acknowledge to ly within a predefined programmable window.

Upon every acknowledge the watchdog is restarting the window.

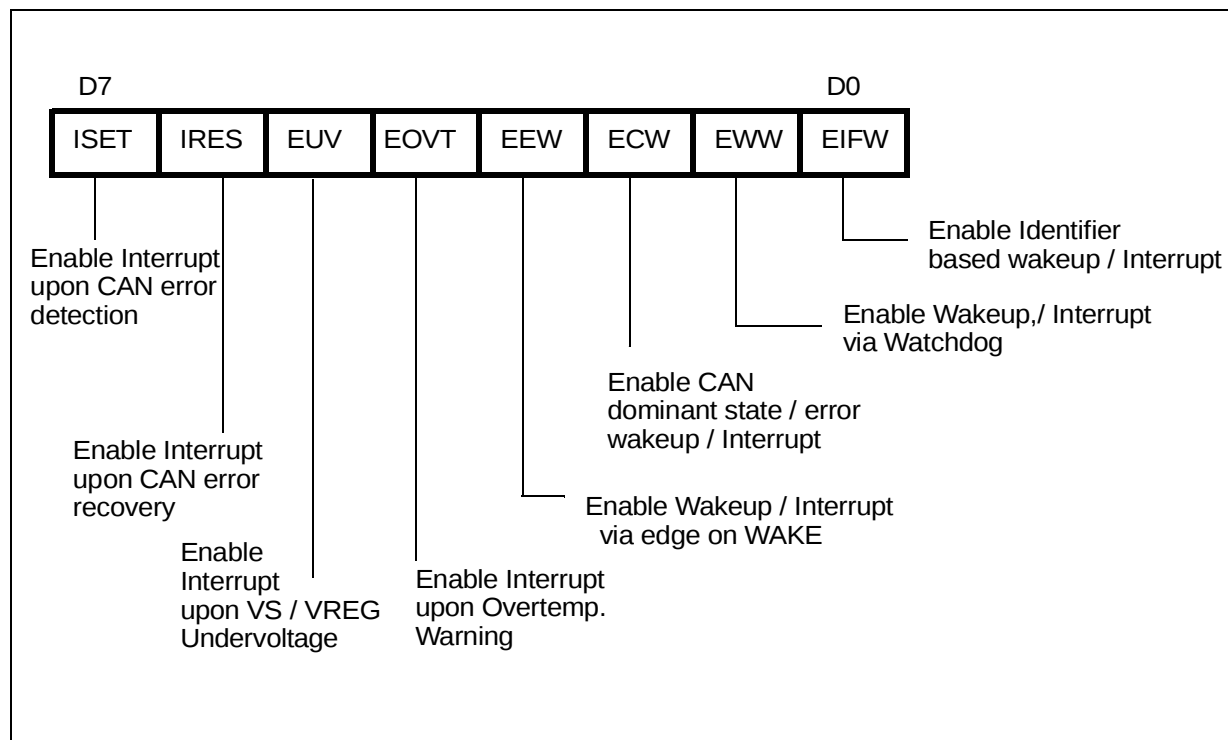
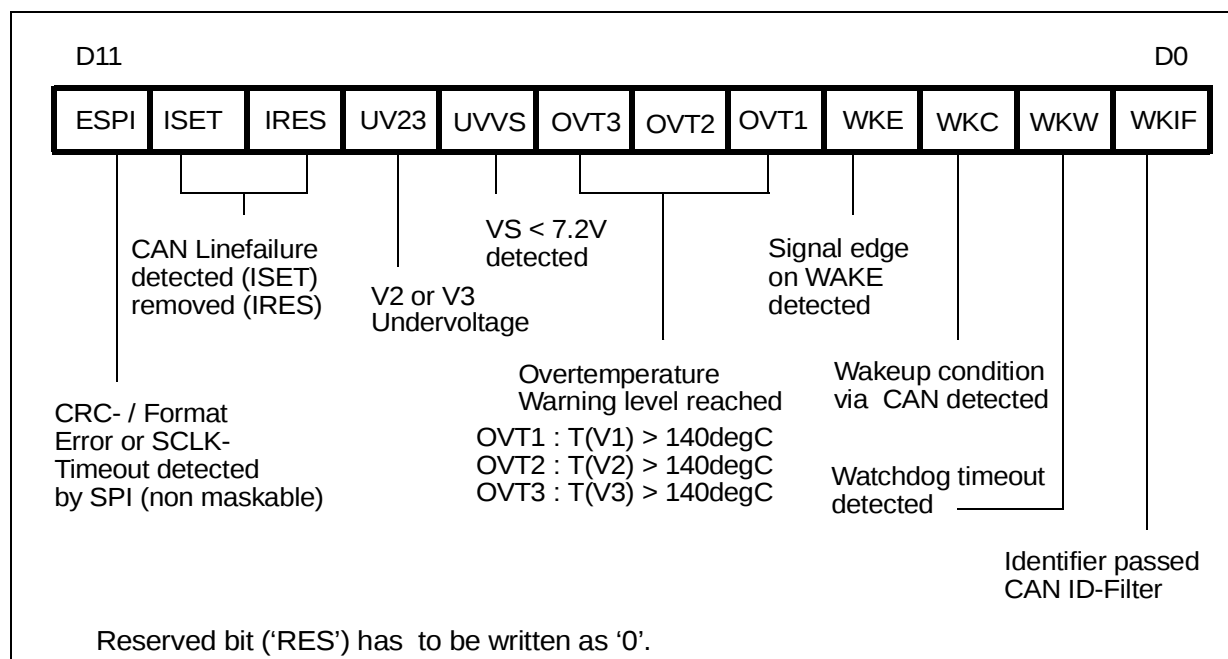
3: Wakeup Watchdog



If the Timer is activated during Normal mode by setting WDC, an "acknowledge-free" sequence is started for a predefined programmable time. Window Watchdog activity is resumed after expiry of the timer.

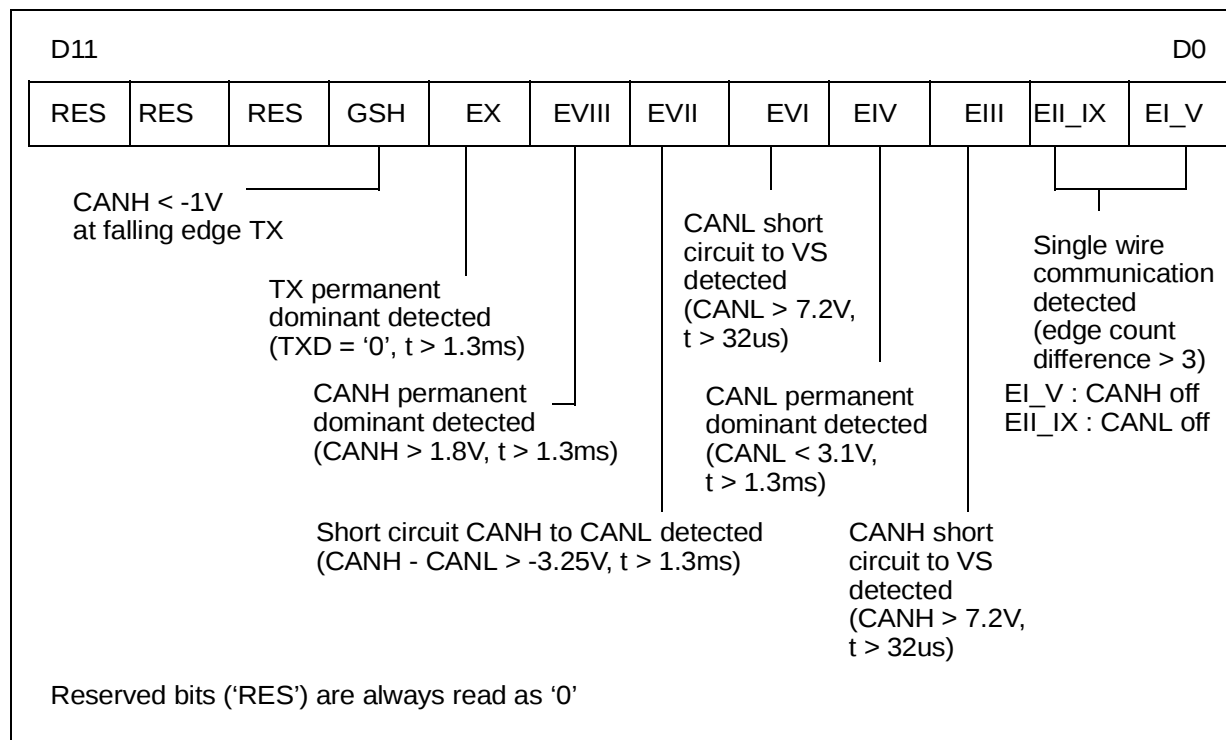
To be able to detect the timeout, the corresponding interrupt enable must be set in GIEN.

This mode can also be used to allow a bootstrap loader mode with longer execution times than the maximum specified window. Correct startup of this loader is safely detected upon missing response following the timeout.

ADR5: GIEN Global Interrupt Enable Register**ADR6: IFR Interrupt Flag Register**

Except ESPI all bits in this register are maskable in GIEN. Any masked bit will force NINT low until the register content is reset (either explicitly or by SPI 'clear register').

ADR7: CTSR CAN Transceiver Status Register



Note, that this register is read only and only provides the unlatched information on current buserrors.

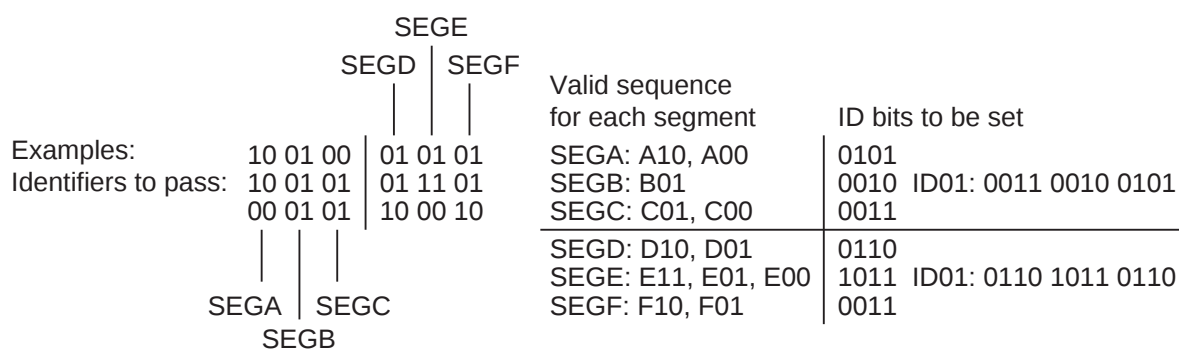
Identifier of CAN Frame can be divided up into 6 segments numbered from 'A' to 'F'.

For each segment a filter register is implemented, enabling different pass functions on every two bit wide block.

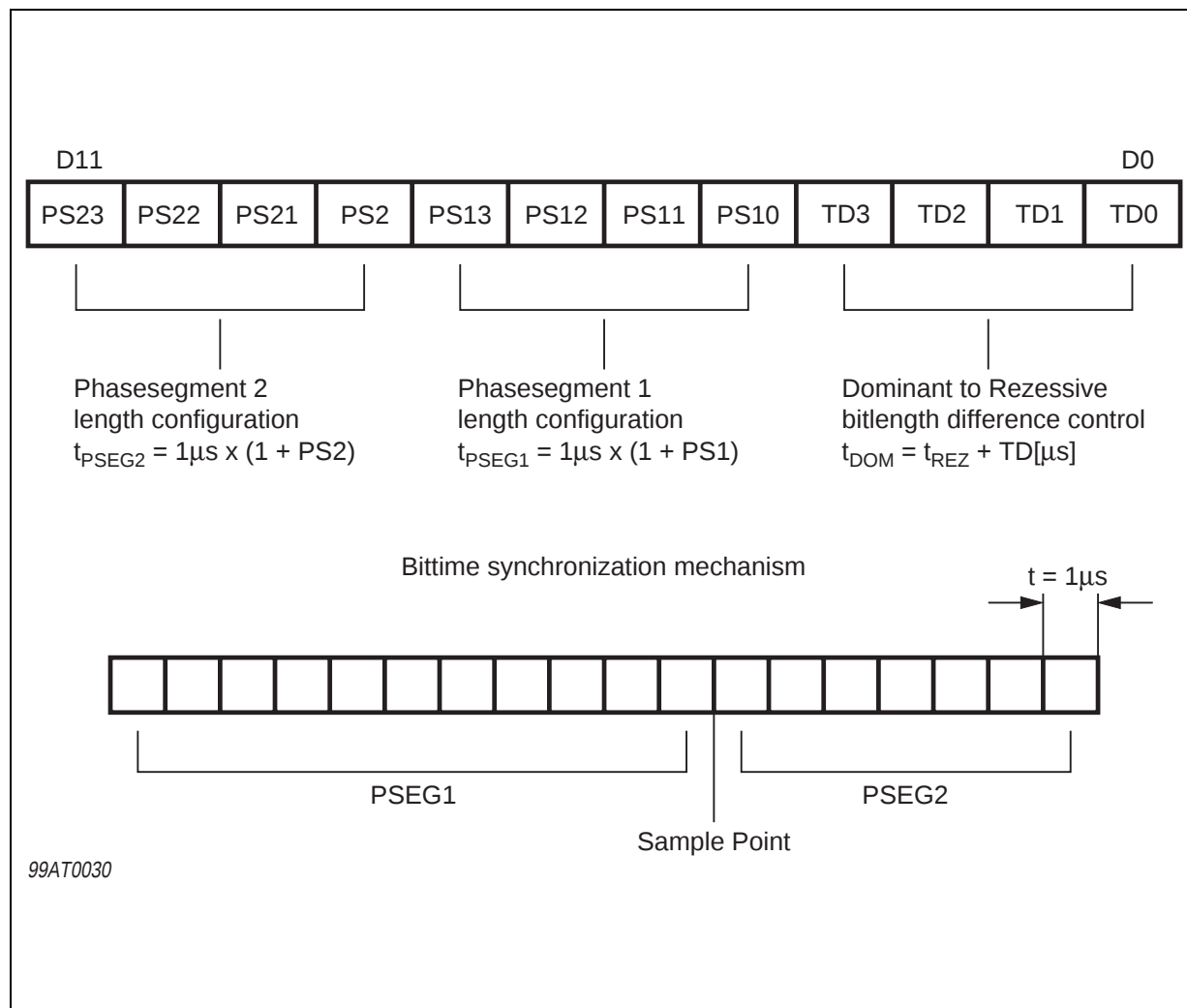
Segments A through C (ID01) are located at ADR 8 with MSB 'C11'

Segments D through F (ID23) are located at ADR 9 with MSB 'F11'

Note, that clearing a complete segment disables the whole filter.



ADR 10: BTL Identifier Filter Bittime Logic Control Register



The total bitlength equals the sum of PSEG1 + PSEG2 in units of μs .

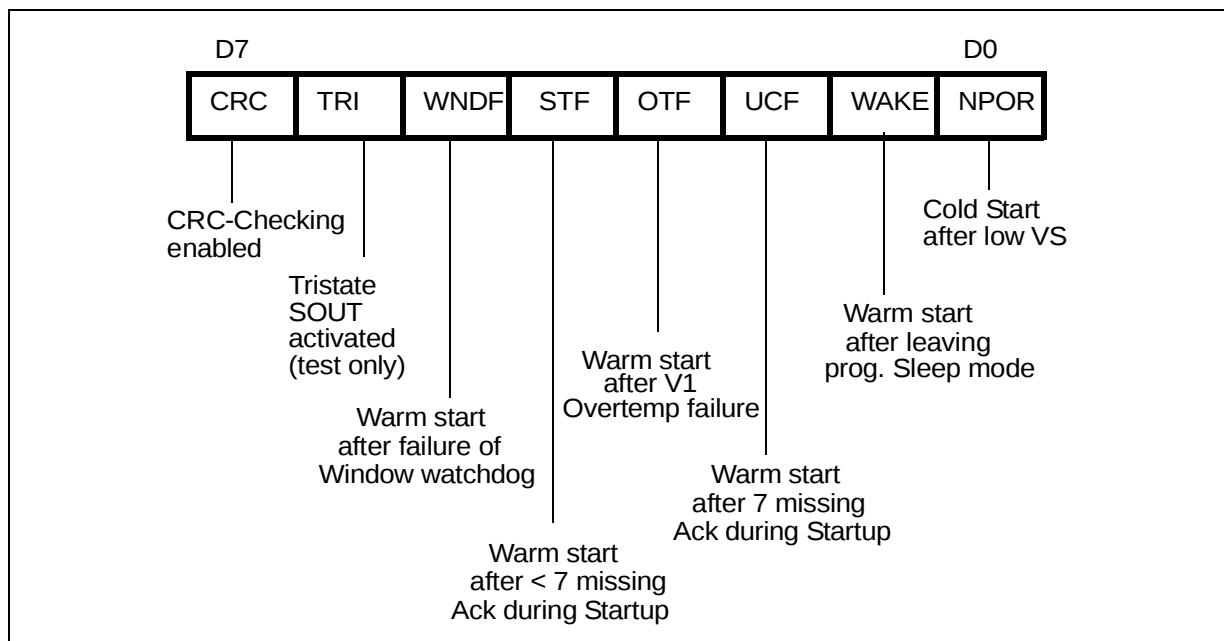
The location of the sampling point is determined by the length of PSEG1.

At the start of frame (initial recessive to dominant edge) the bitlength counter is reset.

Upon every signal edge the counter will be lengthened or shortened according to location of the transition within the programmed boundaries of PSEG1 or PSEG2. If the edge lies within PSEG1 additional cycles are inserted in order to shift the sampling point to a safe location after the settling of the input signal. If the signal transition is located within PSEG2, this segment will be shortened accordingly with the goal of the next edge to lie at the beginning of PSEG1.

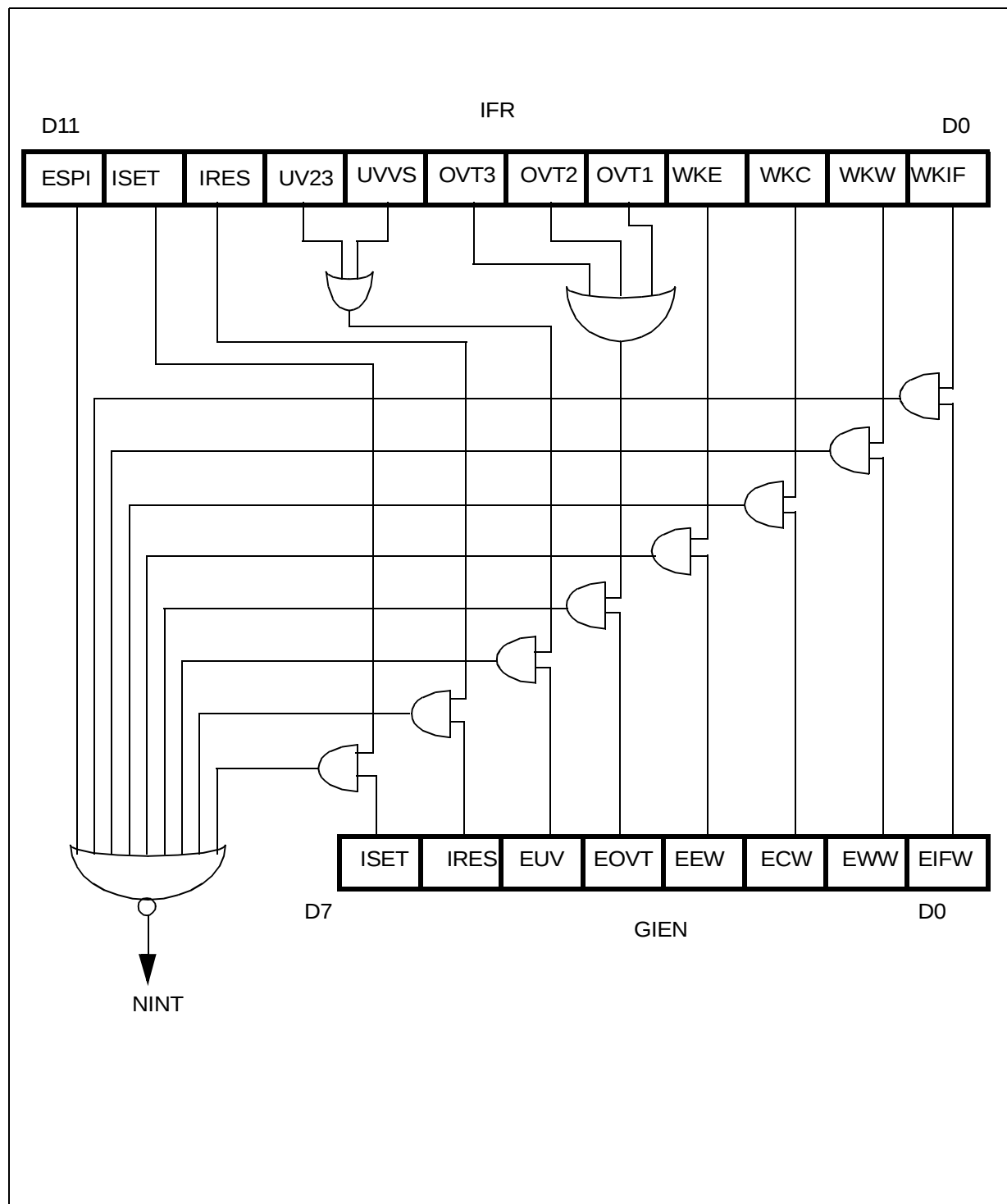
The amount of cycles one segment is lengthened or shortened is determined by the type of edge (rec -> dom or dom -> rec) and the programming of TD: The resynchronization jump width will be either set to '1' (dom -> rec edge) or to $1 + TD$ (rec -> dom edge).

Note, that the length of one timequanta depends on the offset of the on chip RC-oscillator and therefore on the accuracy of calibration (see register RCADJ (ADR 3) for details on frequency correction)

ADR 15: SYS System Status Register

The lower 6 bit of this register can be used to analyze the reason of startup (after NRESET low). This information is valid until the first Watchdog-Acknowledge, and will then be reinitialized to 000001.

3.0 INTERRUPT MANAGEMENT

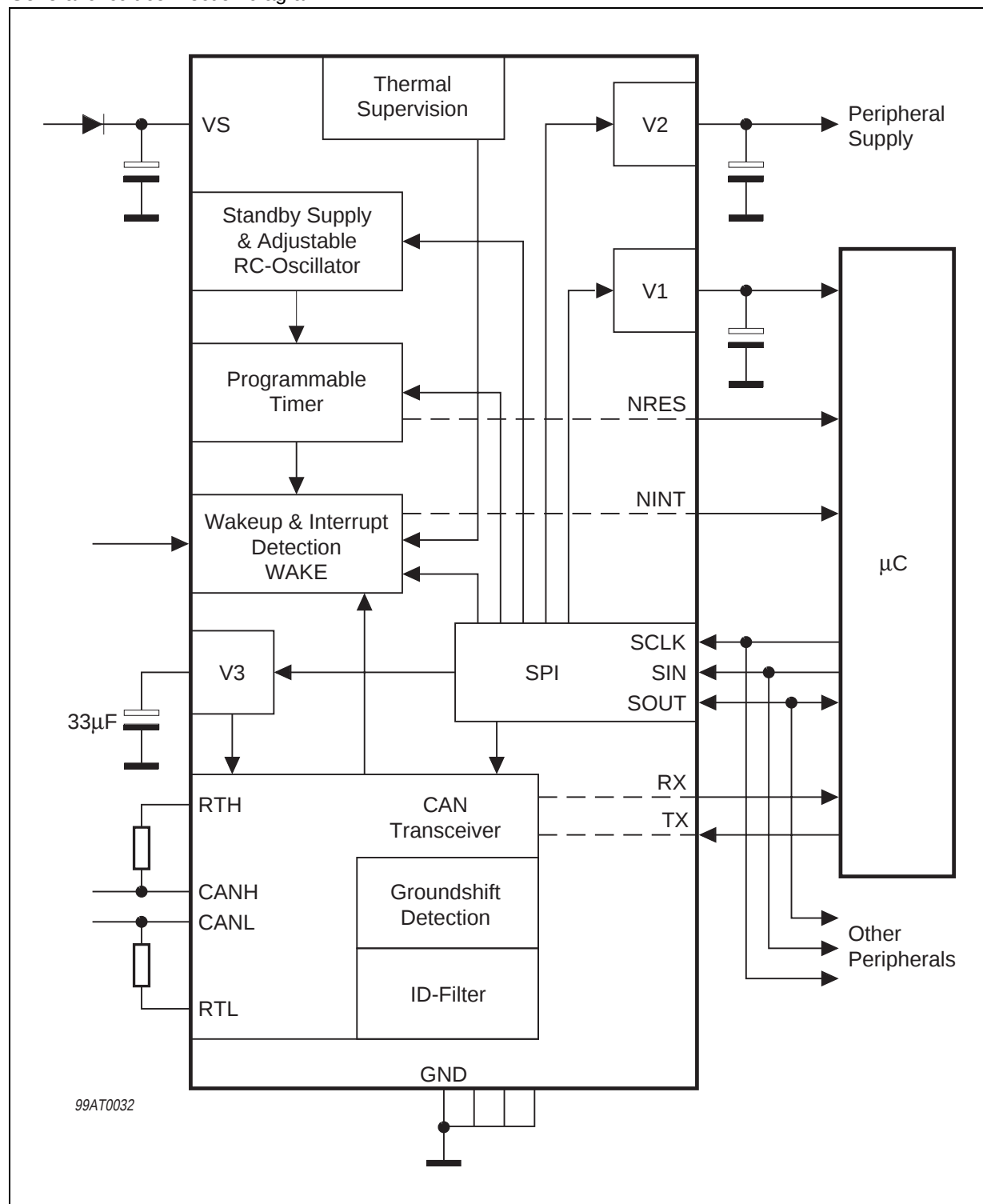


All Interrupt flags (in IFR) except ESPI can be masked in the global interrupt enable register (GIEN).

An Interrupt will be signalled by NINT going low until either the corresponding mask or the flag itself will be reset by the application software. An autoreset function is available for IFR, allowing to remove all interrupt flags after reading their state (see SPI).

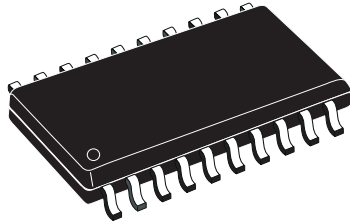
4.0 REMARKS FOR APPLICATION

General circuit connection diagram

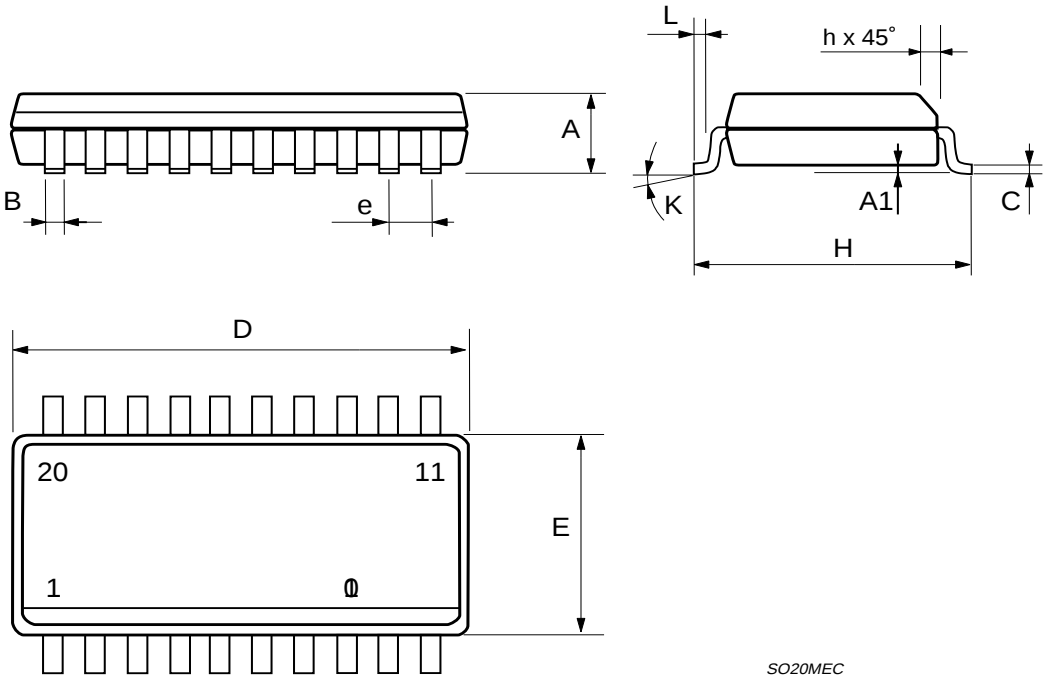


DIM.	mm			inch		
	MIN.	TYP.	MAX.	MIN.	TYP.	MAX.
A	2.35		2.65	0.093		0.104
A1	0.1		0.3	0.004		0.012
B	0.33		0.51	0.013		0.020
C	0.23		0.32	0.009		0.013
D	12.6		13	0.496		0.512
E	7.4		7.6	0.291		0.299
e		1.27			0.050	
H	10		10.65	0.394		0.419
h	0.25		0.75	0.010		0.030
L	0.4		1.27	0.016		0.050
K	0° (min.)8° (max.)					

**OUTLINE AND
MECHANICAL DATA**



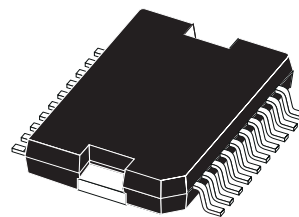
SO20



DIM.	mm			inch		
	MIN.	TYP.	MAX.	MIN.	TYP.	MAX.
A			3.6			0.142
a1	0.1		0.3	0.004		0.012
a2			3.3			0.130
a3	0		0.1	0.000		0.004
b	0.4		0.53	0.016		0.021
c	0.23		0.32	0.009		0.013
D (1)	15.8		16	0.622		0.630
D1	9.4		9.8	0.370		0.386
E	13.9		14.5	0.547		0.570
e		1.27			0.050	
e3		11.43			0.450	
E1 (1)	10.9		11.1	0.429		0.437
E2			2.9			0.114
E3	5.8		6.2	0.228		0.244
G	0		0.1	0.000		0.004
H	15.5		15.9	0.610		0.626
h			1.1			0.043
L	0.8		1.1	0.031		0.043
N	10° (max.)					
S	8° (max.)					
T		10			0.394	

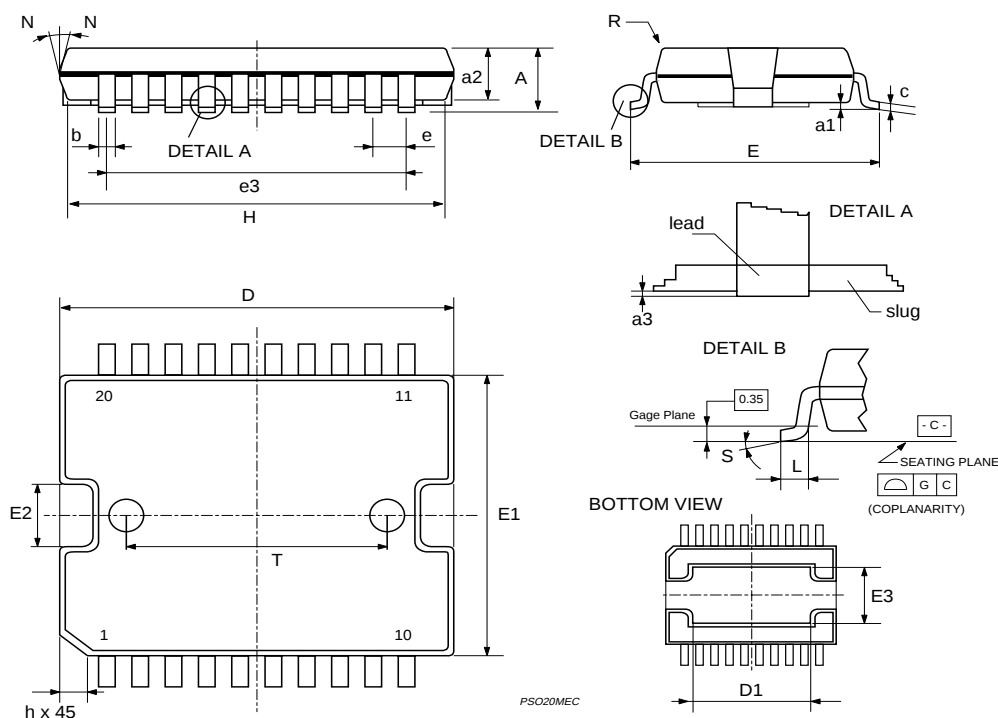
(1) "D and F" do not include mold flash or protrusions.
- Mold flash or protrusions shall not exceed 0.15 mm (0.006").
- Critical dimensions: "E", "G" and "a3"

OUTLINE AND MECHANICAL DATA



JEDEC MO-166

PowerSO20



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