AMS
Austria Mikro Systeme International AG

AS8410

PWM DC Motor Regulator

Data Sheet (Preliminary)
Rev. 1.0, December 2000

1 Key Features

The AS8410 builds up a complete PWM DC Motor current regulation loop with an external n-channel power FET. A full diagnosis of motor failures with stand-alone failure handling procedures is integrated.

One of the most important features of this ASSP namely in automotive applications is the slew rate regulated switching of the external power FET. This technology enables two features of the DC motor regulator, which was up to now impossible to realise at the same time:

- **An excellent EMC behaviour (very low RF emission in the whole frequency range)**
- **A high power efficiency > 95 %   (fall / rise time < 150 ns)**

A short overview of the main features of the AS8410 is given here below:

Main properties:
- Complete PWM DC motor regulator with an external power FET
- Single voltage supply in the range VB = 6 V … 35 V (Vpump$_{max}$ = 45 V)
- Analogue motor current regulation loop (two modes: set value as digital duty ratio of a low frequency (e.g. 10 Hz) or as an analogue voltage in the range V_{in} = 0 … 5 V)
- High power efficiency of the whole regulator module (> 95 %)
- Low RF emission in the whole frequency range
- Fully protected, analogue / digital failure handling procedures (see below: Security functions)

- Simple programming possibilities for different classes of DC motors and different operating modes (set value input, over temperature-handling procedure)
- Applicable directly on the automotive board supply battery (burst and surge)

- Automatic sleep mode controlled by the set value

Security functions:
1. Extensive diagnosis of the DC motor and the power FET, failures handling procedures and report of the failures:
    1.1 Over current detection and protection
    1.2 No load detection of the motor
    1.3 Open wire detection (motor or power switch)
    1.4 Short circuit of the power switch detection
    1.5 Blocked motor detection and protection
    1.6 Short-circuited motor segments detection and protection
    1.7 Protection of the power FET and the ASIC, if the motor works in generator mode
2. Over- / Under Voltage detection and protection
3. Over Temperature detection and protection in two modes

2 General Description

Package and Marking

Package: **SOIC16 wide outline**

SOIC16	
Marking	
AS8410	ASSP number
YY	Production year
WW	Production week
XXX	Assembly-ID

SOIC16 wide outline			
(measure in mm)			
	min.	nom.	max.
A	2,46	2,56	2,64
A1	0,13	0,22	0,29
A2	2,29	2,34	2,39
B	0,35	0,41	0,48
C	0,23	0,25	0,32
D	10.21	10.34	10.46
E	7,42	7,52	7,59
e	1.27 BSC		
H	10.16	10.31	10.41
h	0.25	0.33	0.41
L	0,61	0,81	1,02
α	0°	5°	8°

Table 2.1: Dimensions and marking
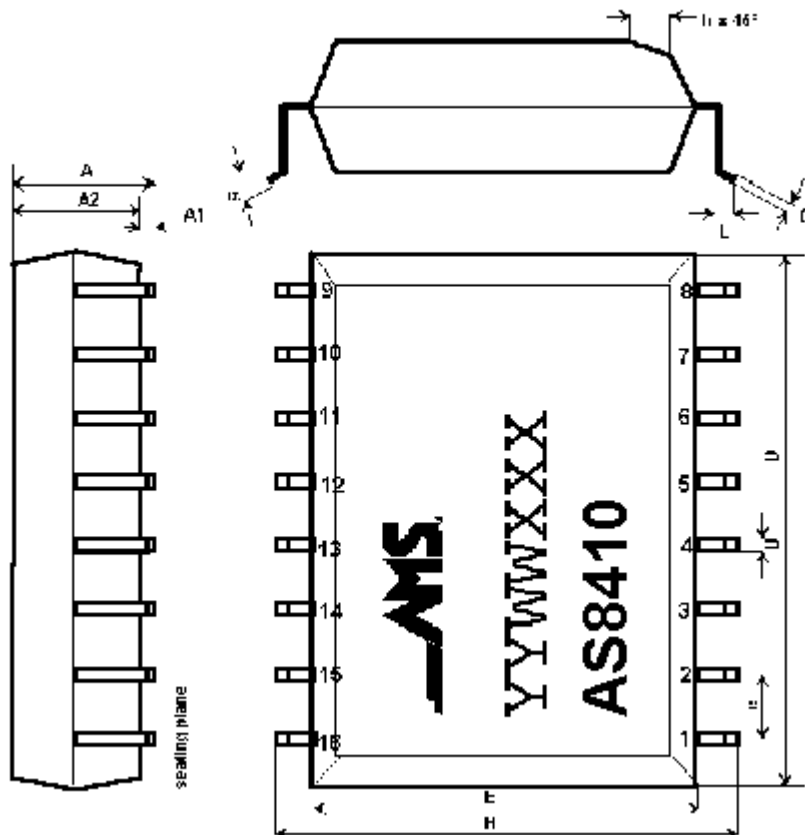
Fig. 2.1 Dimensions and marking

Maximal Ratings (ASSP out of operation)

Symbol	Parameter	min	max	Unit	Note
Vbat	Supply voltage	-0,5	50	V	
Vpump	Pumped supply	-0,5	50	V	[1]
VDD	Regulated 5V-supply	-0,5	7	V	
I_{IMmax}	Maximal input currents	-30	30	mA	$V_{IN} < V_{IN\,min}$ or $V_{IN} > Vbat$
V_{INA}	Analogue input voltage	- 0.3	35	V	[2]
I_{src1} or I_{src2}	Input currents at pins SRC1 or SRC2		2	mA	
Θ_{STG}	Storage Temperature	-55	150	°C	
Θ_{LEAD}	Solder Temperature		260	°C	[3]
P_{TOT}	Maximal power dissipation		0.4	W	
ESD	Electrostatic discharge voltage		1000	V	[4]
[1] GND = Ground [2] except for Pins SRC1 and SRC2 [3] 260 °C for 10 s (reflow soldering), 360 °C for 3 s (manual soldering) [4] HBM: R = 1.5 kΩ, C = 100 pF					

Operating Conditions

The following conditions are valid in the temperature range Θ_{RT} = -40 °C to +120 °C and the supply voltage range Vbat = 6.5 V to 35 V.

Symbol	Parameter	min	typ	max	Unit	Note
Vbat	Supply voltage	6.5	12	35	V	
I_{DDA}	Current consumption in sleep mode (power down mode)			400	µA	1
I_{DDB}	Current consumption (at Vbat in normal mode 1 or 2)			10	mA	2
Vpump	Pumped supply voltage	11	Vbat+10	45	V	
VDD	Regulated 5V-supply	4,7	5,0	5,3	V	
I_{SRC1}, I_{SRC2}	max. current into the current inputs SRC1 or SRC2			400	µA	3
V_{IN}	Voltage at set value input pin IN	GND - 0,3		Vbat + 0,5	V	
V_{MODE}	Voltage at the MODE pin	GND - 0,3		Vbat + 0,5	V	
V_{CMP}, V_{CMN}	Voltage at the current meas-urement input pins CMp, CMN	GND - 3,5		Vbat + 0,5	V	
V_{out}	Voltage at the output pin OUT	GND - 0,3		Vpump	V	
I_{out}	Max. output current at pin OUT (t < 1µs)	-300		300	mA	4
V_{analog}	Analogue input voltage	GND - 0,3		VDD + 0,5	V	5

1 valid in mode 2 only (MODE = low) and Vbat = 12 V
2 without output current at pin OUT
3 the inputs SRC1 and SRC2 must be current limited by the external circuitry (max. 400 µA)
4 max. duration of the current pulse = 1µs
5 valid for the pins OSC, TP, Cint1, Cint2

Pinout and Package Description

| Pin	Name	Typ	Description
1	Vpump	Output	Pumped supply voltage: Vpump = Vbat + 10 V
2	Pump_ctrl	Output	Connection of the capacitor Cp1 of the charge pump
3	Vbat	Power	positive supply voltage
4	VDD	Output	5V regulator output
5	MODE	Input	Selection of the operating mode
6	IN	Input	Set value input
7	OSC	Input	Connection of the reference current resistor (1 V output)
8	Cint2	Input	RC filter of the set value
9	Cint1	Input	Connection of the capacitor of the regulation loop
10	TP	Input	Temperature measurement input
11	CMp	Input	Motor current measurement input (positive side)
12	CMn	Input	Motor current measurement input (negative side)
13	SRC1	Input	Slew rate regulation input (rising edge)
14	SRC2	Input	Slew rate regulation input (falling edge)
15	GND	Power	Ground
16	OUT	Output	Power FET control output (Gate drive)
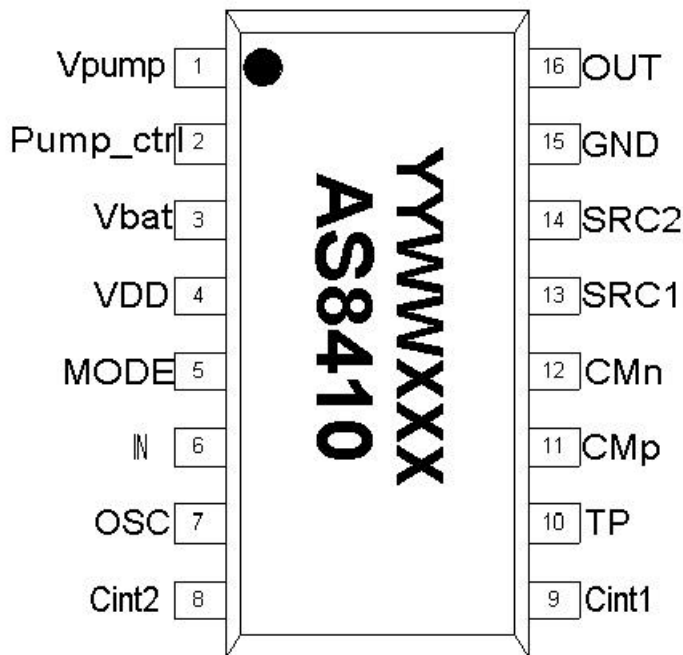
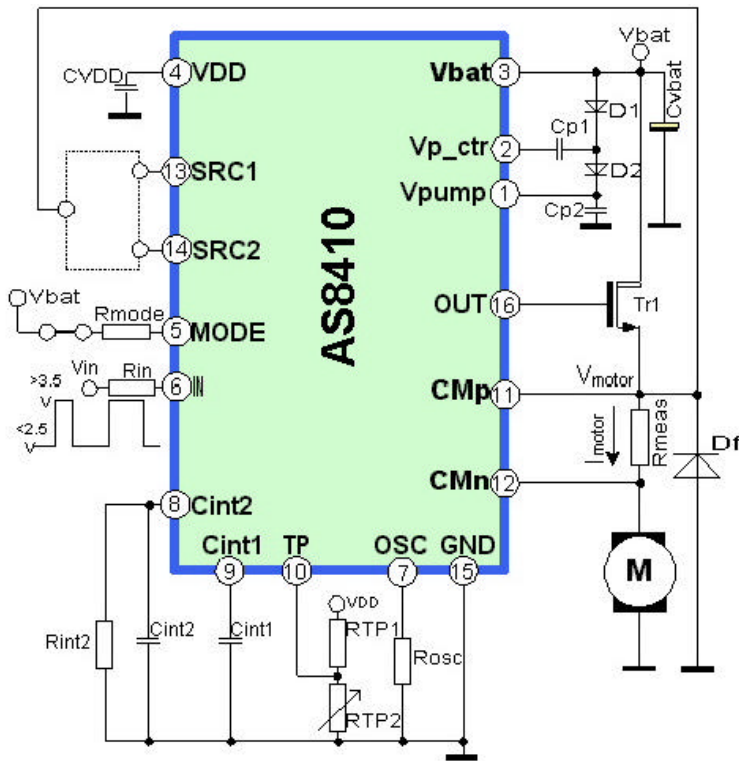Fig 2.2 Pinning of the SOIC16 package

3 Applications

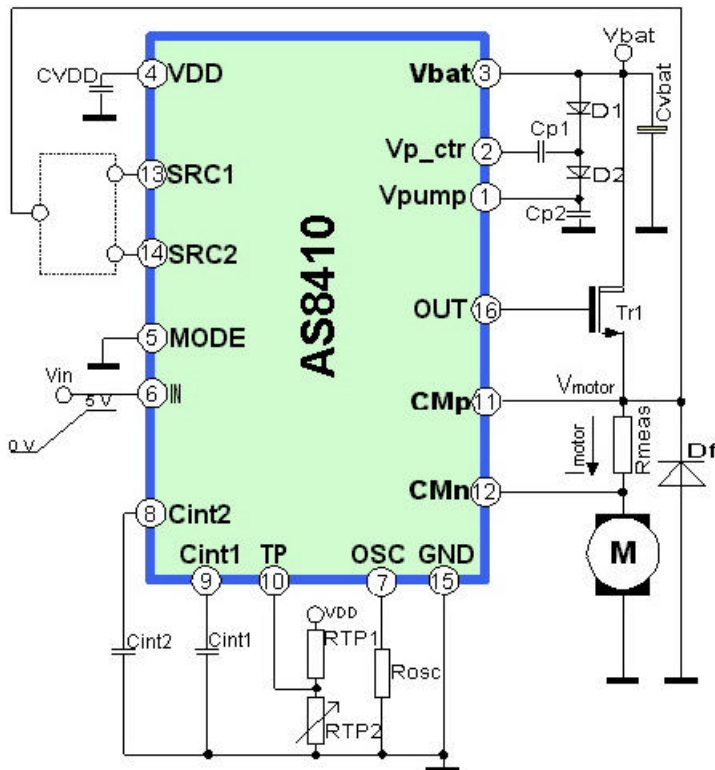Fig. 3.1 Operating mode 1 (OM1) of the motor regulator (e.g. automotive application)

Fig. 3.2 Operating mode 2 (OM2) of the motor regulator

Meaning and Settings of the external devices

Symbol	Description	Typical value	Application Note
Regulation loop settings / slew rate regulation			
R_{OSC}	Resistor of the reference current generation I_{ref}	100 kΩ	The voltage at the pin OSC is regulated to V_{OSC} = 1 V. The reference current is therefore 10 μA. This current is used for three functions: 1. The oscillator frequency (I_{ref} = 10μA generates f_{OSC} = 18 kHz, f_{OSC} is a linear function of I_{ref}) 2. Generation of the internal set value voltage in OM1 together with the resistor R_{int2}. 100% set value is build by a voltage of 2 V at pin Cint2: $V_{Cint2}(100\%) = I_{ref} * R_{int2} = 2$ V 3. Reference current for the power FET driver / Slew rate regulation (linear function between I_{ref} and driver output current I_{OUT})
R_{meas}	Motor current measurement resistor	Dependent on the nominal motor current I_{motor_nom}	The voltage drop over the R_{meas} must be 50 mV for the nominal motor current: R_{meas} = 50 mV / I_{motor_nom}
R_{int2}	Resistor to convert the incoming duty ratio of the set value in OM1 to the set value voltage V_{Cint2}	200 kΩ	$V_{Cint2}(100\%) = I_{ref} * R_{int2} = 2$ V
C_{int2}	Filter capacitor of the set value conversion in OM1	> 2.2 μF	Dependent on the incoming PWM frequency f_{IN_PWM} f_{IN_PWM} = 10 Hz → C_{int2} > 2.2 μF
C_{int1}	Capacitor to set the regulation loop time constant and failure handling time constant	100 nF	The time constant of the failure handling T_{fail} is determined by the max. current at pin Cint2 (I_{Cint1_max} = 10 μA … 15 μA) and the min. voltage to start the PWM generator (1.66 V): $T_{fail} = (C_{int1} * 1.66$ V $) / I_{Cint1\_max}$
SRC1 SRC2	Feedback circuitry of the slew rate regulation	Dependent on the application (motor and environment)	Application Support of Austria Mikro Systeme AG will be guaranteed
Protection Resistors			
R_{IN}	Protection resistor of the pin **IN**	330 Ω	Needed in automotive applications
R_{MODE}	Protection resistor of the pin **MODE**	1 kΩ	Needed in automotive applications
Temperature Sensor			
R_{TP1} R_{TP2}	Resistor divider of the temperature sensor	$R_{TP1} + R_{TP2}$ < 10 kΩ	The threshold voltage at the pin TP must be 0.5 *VDD or ($R_{TP1} = R_{TP2}$)

			$V_{TP} < 0.5 *VDD \rightarrow$ over temp. $V_{TP} > 0.5 *VDD \rightarrow$ no over temp.
Charge pump and 5V Regulator			
C_{p1} C_{p2}	Charge pump capacitors	100 nF … 200 nF	The capacitor value is dependent on the external power FET to drive (C_{gate_source})
D1 D2	Diodes of the charge pump	$V_{break} > $ Vbat + 10 V $I_{max} > $ 50 mA	
C_{VDD}	Filter capacitor of the 5V regulator	100 nF	
C_{Vbat}	Filter Capacitor of the Vbat	1000 µF	The capacitor value is dependent on the motor power. Typical value: 1000 µF pro 100 W motor power in automotive application.
Power Switch and Free wheel diode			
Df	Free wheel diode	Dependent on the max. motor current and voltage	
Tr1	Power FET		
Austria Mikro Systeme International AG gives all necessary application support to the user of this PWM DC Motor Regulator device AS8410.			

4 Functional Description and Electrical Parameters

The main functions of this PWM-Switch-Regulator are summarised in section 1.3.
The normal regulation loop is build by an analogue difference-integrator, both the input set value at pin **IN** and the measured motor current (at pins **CMp** and **CMn**) are transformed to the chip internal control signals. The difference signal is integrated on the capacitor connected to the pin **Cint1** and the voltage at this pin is controlling the PWM generator and closes so the regulation loop. So the regulation time constant can be determined in width range by the external capacitor at the pin **Cint1**.
The AS8410 can be used in two different modes controlled by the pin **MODE** :

Operating Mode 1 (OM1: V_{MODE} = high):
- The set value must be given at pin **IN** as the duty ration of a low frequency digital signal ($f_{IN} > 10$ Hz).
- The Over Temperature reaction: 100 % duty ratio of the FET-driver output (permanent switch on the motor) as long as the temperature is higher than the predefined threshold value (typical automotive application, the heating source is not the electrical system but the combustion engine).

Operating Mode 2 (OM2: V_{MODE} = low):
- The set value must be given at pin **IN** as analogue voltage in the range $V_{IN} = 0 \ldots 5$ V
- The Over Temperature reaction: The motor is regulated down to not cross the predefined temperature threshold (like a thermostat if the heating source is the electrical system itself).

The adaptation of the AS8410 to the DC motor (nominal motor current and power FET) will be realised by the value of the motor current measurement resistor R_{meas} and by the slew rate controlling currents into the pins **SRC1** and **SRC2** as described in section 3.4.1.

The detection of the different kinds of motor failures is realised by comparing the actual measured motor working point and the normal motor characteristic. Each motor failure is then treated by the AS8410 with an adapted failure handling procedure described in section 3.4.2.
A failure report signal is generated and sent to the pin **IN** by pull down this pin.
Also the over temperature and the over / under voltage failure are treated by the AS8410 itself.
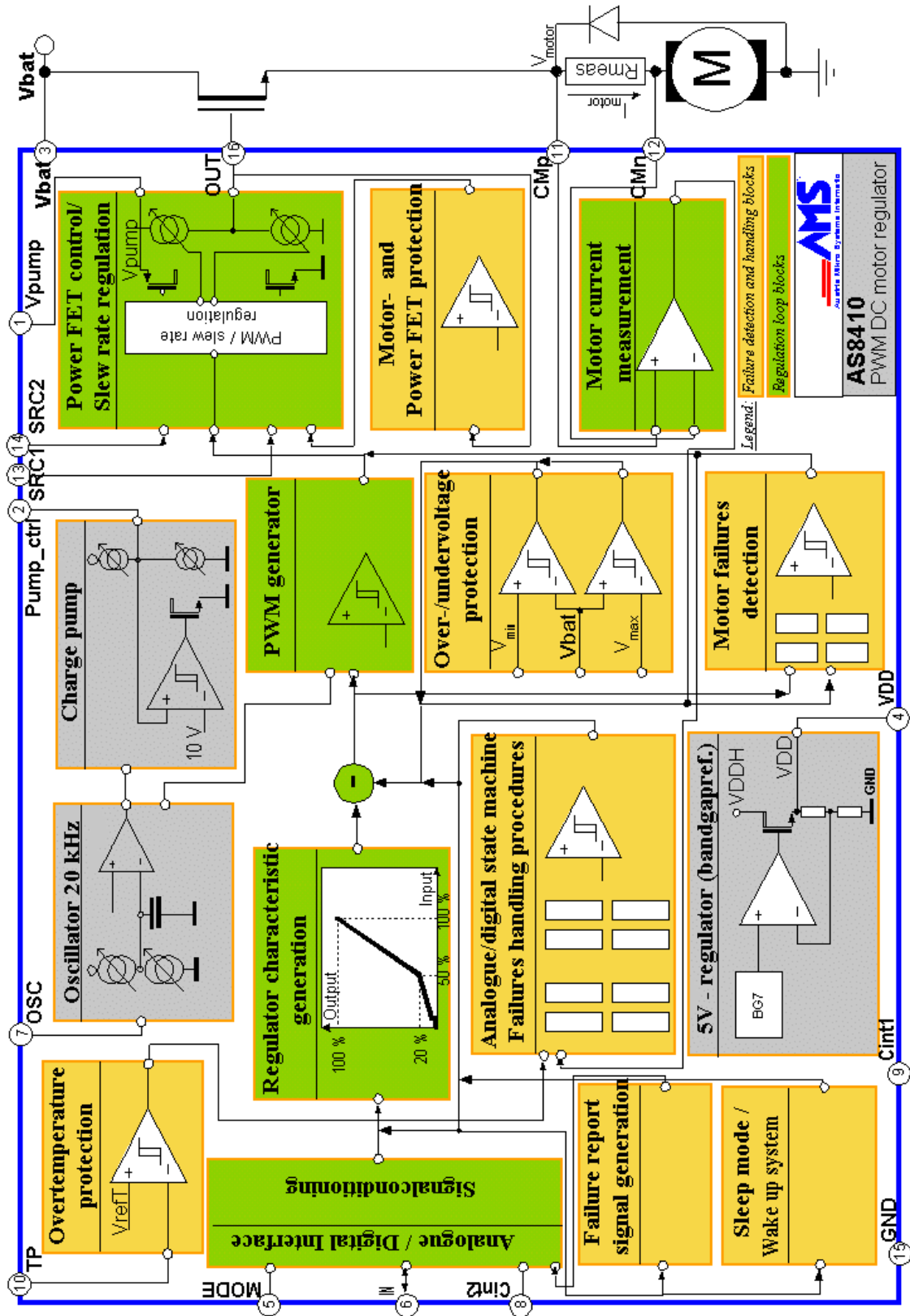
Figure 4.1: Simplified Block diagram of the AS8410

4.1 Normal Operating Mode (regulation loop)

The regulation loop of the AS8410 consist of the following functional blocks:

1. Analogue / Digital Interface with signal conditioning (set value input / failure signal output **IN**, modus input **MODE** and low pass filter input **Cint2)**
2. Regulator characteristic generator (high resolution of the set value for set values < 50 % and lower resolution for set values 50 % … 100 %)
3. Difference generator at the pin **Cint1** (V_{Cint1} = (set value) – (motor current value))
4. PWM generator (controlled by the voltage V_{Cint1} and the 20 kHz oscillator)
5. Power FET driver with slew rate regulation controlling the external power FET gate connected at pin **OUT**
6. Motor current measurement unit (measuring and converting the voltage over the external resistor R_{meas} connected at the pins **CMp** and **CMn**)
7. Oscillator (20 kHz) and reference current generator (regulated V_{OSC} = 1 V at pin **OSC** with external resistor R_{osc} = 100 kΩ)
8. Charge pump with external capacitors at the pins **Pump_ctrl** and **Vpump**
9. 5V-regulator with bandgap reference

4.1.1   Analogue / Digital Interface, Signal Conditioning

This interface consists of the three pins **MODE**, **IN** and **Cint2**. The interface sets the operating mode by the signal MODE, monitors and converts the input set value at the pin **IN** and drives the pin **IN** to the low level in case of a detected failure in operating mode 1.

In operating mode 1 (OM1) the incoming low frequency PWM signal is converted in a dc voltage by switching a current I_{cint2} = 10 μA with the incoming duty ratio to the pin **Cint2** with R_{int2} / C_{int2} (typical: 200 kΩ / 2.2 μF). V_{cint2} must be in the range V_{cint2} = 0 … 2 V.

The monitor of the set value V_{Cint2} generates two internal logical signal P00 and P10 to treat the sleep / wake function and the input failure detection in operating mode 1, the hysteresis of these detections is given in Fig. 4.2.

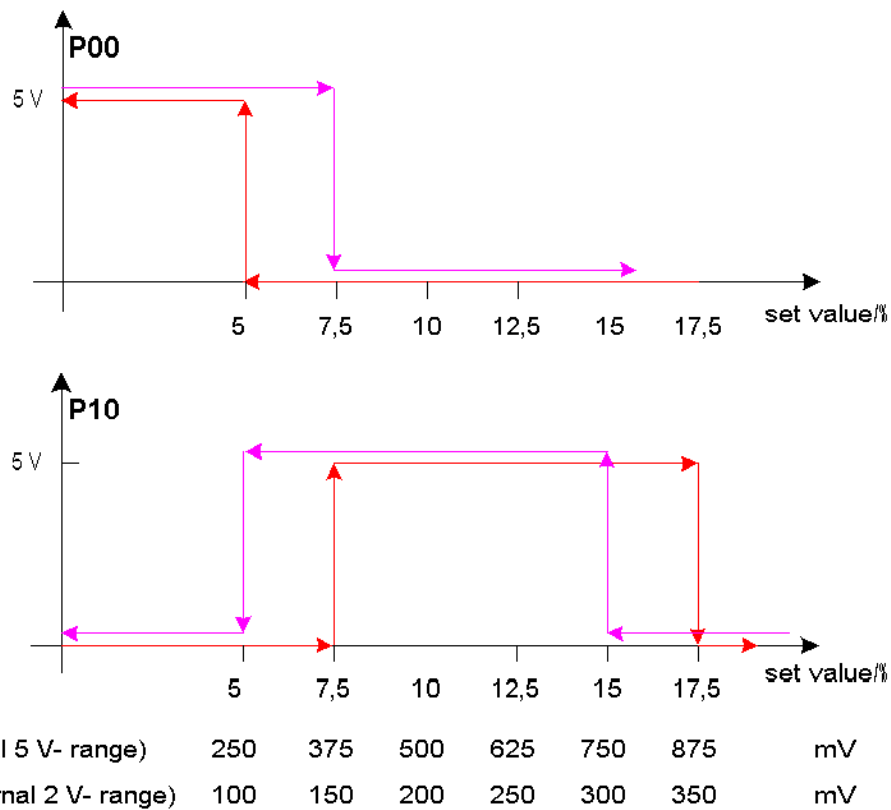| Symbol	Meaning	Meaning of the level	
MODE	Operating mode of the AS8410	MODE = high ➲	Operating mode 1 (OM1)
		MODE = low ➲	Operating mode 2 (OM2)
P00	Detection of the 5 % threshold value of the set value	P00 = high ➲ P00 = low ➲	Set value < 5 % Set value > 5 %
P10	Detection of the 10 % threshold value of the set value	P10 = high ➲ P10 = low ➲	Set value = 5 % ... 17.5 %) Set value outside of this range

	250	375	500	625	750	875	
Vin (external 5 V- range)	250	375	500	625	750	875	mV
Vcint2 (internal 2 V- range)	100	150	200	250	300	350	mV

Fig. 4.2 Monitoring of the set value (generation of the signals P00 and P10)

Symbol	Parameter	min	typ	max	Unit	Note
Operating Mode selection MODE						
V_{MODE_low}	Low-level of MODE			4,3	V	
V_{MODE_high}	High-level of MODE	5,7		Vbat	V	
Set value input signal IN (OM1)						
f_{IN}	Frequency of the PWM set value input	10			Hz	
Duty	Duty ratio of the PWM input	0		100	%	
V_{IN_low}	Low-level of the PWM input	0		3,35	V	
V_{IN_high}	High-level of the PWM input	3,65		Vbat	V	
I_{Cint2}	Switched current high level at pin Cint2	9,8	10,0	10,4	μA	
Set value input signal IN (OM2)						
V_{IN_OM2}	Input voltage range of V_{IN} (0 % … 100 %)	0		5	V	
Signal conditioning of the signal at the pin IN						
I_{IN_high}	High level current at pin IN (internal pull up)	2.7		3.6	mA	
$I_{IN\_failure}$	Failure signal current at pin IN (internal pull down)	3.0		10.0	mA	

4.1.2 Regulator Characteristic, PWM Generator

The external set value, incoming at pin **IN,** is transformed in both modes (OM1 and OM2) to the internal dc voltage in the range 0 … 2 V corresponding to 0 % … 100 % set value.
A function generator transforms then this set value voltage to a function with two different gradients: a) The input range 0 % … 50 % is transformed to the output range 0 % … 20 %
              b) The input range 50 % … 100 % is transformed to the output range

In this way the resolution of the set value input is higher in the first half of the input range (low motor currents: 0% … 20%) than in the second half one (higher motor currents 20% … 100%). A special behaviour is implemented for very low input set values in the following way for the operating mode 1 (OM1) and operating mode 2 (OM2):
        a) OM2: For low input set values (< 10%) the system is put in sleep mode
              Condition: (P00 or P10) and (/MODE)
        b) OM1: For very low input set values (0 < set value < 5%, duty ratio nearly or
              equal 0 is taken as input failure: short circuit of the input line to ground),
              the internal set value is put to 100 % →security mode: The motor is
              permanently switched on and so cooling the heating engine.
              For input set values in the range 5% < set value < 10% the system is put in a
              special sleep mode.

The difference of the set value output of this block and the internal control value coming from the motor measurement unit is controlling the PWM generator (voltage at the pin **Cint1**) and so generating the duty ratio of the 20 kHz PWM signal what controls the power FET driver.

The time constant of this regulation loop can be chosen in very width ranges by the external capacitor connected at the pin **Cint1**.

4.1.3 Power FET driver, Slew rate regulation

The Power FET driver is controlled in two different ways:
First by the digital output of the PWM generator to realise the duty ratio of the motor drive and so to regulate the motor current in the closed loop.
Second by the analogue motor voltage to regulate the slew rate during the rising and falling edge of the motor voltage. This control is executed by an external feedback of the motor voltage to the pins **SRC1** (rising edge) and **SRC2** (falling edge). The two currents incoming to these pins are amplified by a factor of about 1000 and drive then the gate of the external power FET. The supply voltage of this driver is about 10 V higher than the Vbat (n-channel power FET) and is delivered by the on chip charge pump at pin **Vpump**.

Symbol	Parameter	min	typ	max	Unit	Note
Vpump	Pumped supply voltage	11	Vbat+10	43,00	V	
$V_{SRC1/SRC2}$	Voltage at the pins SRC1 or SRC2		0.70	0.90	V	[1]
I_{SRC1} or I_{SRC2}	Input current into the pins SRC1 or SRC2			400	µA	
I_{OUT}	Output current pin OUT	-300		300	mA	[2]
I_{OUT}/I_{SRC1} I_{OUT}/I_{SRC2}	Current amplification factor (high currents)	900	1100	1600		[3]
I_{OUT}/I_{SRC1} I_{OUT}/I_{SRC2}	Current amplification factor (low currents)	900	1400	1700		[4]
t_S	Delay			100	ns	

[1] This input must be current limited by the external circuitry (max. 400 µA).
[2] max. pulse duration = 1µs
[3] valid for I_{OUT} = 5 mA ... 300 mA and Vbat = 12 V , Vpump = 22 V
[4] valid for I_{OUT} = 1 mA ... 5 mA and VDDA = 12 V , Vpump = 22 V
(For a fixed output current the tolerance of the current amplification factor is less than 10%.)

4.1.4   Charge pump

The charge pump generates a supply voltage about 10 V higher than the system supply voltage
Vbat (Vpump = Vbat + 10 V) to drive the gate of the external high side power FET switch.
In the case of the min. supply voltage Vbat = 6 V, the pumped voltage Vpump is about 11 V.
The load current of the external capacitors Cp1 and Cp2 is limited to max. 40 mA to prevent RF
emissions by high current peaks.

Symbol	Parameter	min	typ	max	Unit	Note
VPP	Pumped voltage difference VPP = (Vpump – Vbat)	9,0	10,0	12,0	V	[1]
I_{Cp1}, I_{Cp2}	Currents to the external capacitors			40	mA	
DV	Ripple of the pumped voltage Vpump		0,50	0,70	V	[2]
f_{PWM}	Frequency (internal oscillator)		18		kHz	

[1] valid for Vbat = (12.. 33) V (for Vbat = 6 V is VPP = 5 V), Vpump = Vbat + VPP
[2] valid for I_{Vpump} = 300 mA (pulse duration < 1µs and f_{OSC} = 18 kHz), C_{p1} = C_{p2} = 400 nF

4.1.5   Motor current measurement unit

The motor measurement unit works with an external current measurement resistor in the high
side motor line. The nominal measurement differential voltage $(V_{CMp} – V_{CMn})_{nom}$ is fixed to
50 mV (corresponding to 100% of the motor current). So the value of this measurement resistor
is given by R_{meas} = 50 mV / I_{motor_nom} .
The over current detection is fixed by a motor current 60 % over the nominal motor current
(I_{motor_over} = 1.6 * I_{motor_nom}). The switch off of the motor in case of an over current (or short circuit
of the motor) is realised in less than 2 µs.

Symbol	Parameter	min	typ	max	Unit	Note
$V_{CMp/CMn}$	Common mode voltage at the pins CMn or CMp	-1.15		Vbat	V	
$V_{CM\_diff\_nom}$	Nominal differential voltage of the motor current measurement input $(V_{CMp} – V_{CMn})_{nom}$		50		mV	[1]
$V_{CM\_diff\_over}$	Threshold voltage of the over current detection		1,6 * $V_{CM\_diff\_nom}$			[2]
FI	Relative motor current measurement error		2		%	[3]

[1] I_{motor_nom} = $V_{CM\_diff\_nom}$ / R_{meas}
  R_{meas} is the motor current measurement resistor.
[2] Over current detection at I_{motor_over} = 1,6 * I_{motor_nom}
[3] FI < 2 % of I_{motor_nom} , FI = (I_{motor} – I_{motor_meas}) / I_{motor_nom}
  valid for static $V_{CMp/CMn}$ or for: Vbat = 12 V , Vpump = 22 V , switching edges of $V_{CMp/CMn}$
  (V_{CMp/CMn_min} = -0.7 V and V_{CMp/CMn_max} = Vbat) with $t_{rise/fall}$ > 200 ns

4.1.6　Oscillator, Reference Voltage / Current Generator

The oscillator is used to control the PWM generator and the charge pump with a frequency of typical 18 kHz.

The reference current I_{ref} of this oscillator is generated by a temperature compensated voltage regulator which delivers a stable voltage of 1 V at pin **OSC**, the R_{OSC} = 100 kΩ at this pin generates the reference current. This reference current is used for other functions of this chip too (see section 3).

Symbol	Parameter	min	typ	max	Unit	Note
V_{OSC}	Reference voltage at pin **OSC**	0.96	1.00	1.04	V	
f_{OSC}	Oscillator frequency	17,0	18,0	19,0	kHz	
$T_{rise/fall}$	Rise or fall time of the clock			100	ns	
I_{ref}	Reference current	9,6	10,0	10,4	µA	[1]
[1] I_{ref} must be generated by the external resistor R_{OSC} = 100 kΩ at the pin **OSC**						

4.1.7　5V Regulator (bandgap reference)

The 5V-regulator generates the supply voltage for all internal low voltage blocks and the rough reference voltage for the 1 V-regulator to generate the reference current I_{ref}. This regulated 5 V supply can also be used externally (e.g. for the temperature sensor at pin **TP**).

This externally usable 5 V will be switched off in the sleep mode.

Symbol	Parameter	min	typ	max	Unit	Note
Vbat	Supply voltage of the regulator	6,5	12	35	V	
VDD	Regulated voltage	4,7	5,0	5,3	V	[1]
I_{VDD_OUT}	External load current at pin VDD			3	mA	
[1] external capacitor to ground C_{VDD} = 100 nF						

4.1.8　Failures Detection, Failure Handling Procedures

Three different kinds of failure detections and protections are implemented:

1. Failure detection of the load circuit (DC motor and power FET)

1.1 Over current detection and protection

1.2 No load detection of the motor and protection

1.3 Open wire detection (motor or power switch)

1.4 Short circuit of the power switch detection

1.5 Blocked motor detection and protection

1.6 Short-circuited motor segments detection and protection

1.7 Protection of the power FET and the ASIC, if the motor works in generator mode

2. Failure detection of the supply voltage Vbat (Over- / Under Voltage)

3. Over Temperature detection and protection in two modes

For all detected failures an adequate failure handling procedure is integrated to fully protect the motor regulator module. This failure procedures works without interaction of the controlling µP and so the AS8410 can also be used to develop regulator modules without µP. Nevertheless the most important failures are reported in operating mode 1 (OM1) by pull down the set value input pin **IN** with a current source (3 mA … 10 mA).

4.1.8.1 Motor Failures

The principle of the load circuit (motor and power FET) failure detection and handling procedures is the following:

   a) <u>Motor failure detection principle:</u> The motor current at the high side of the motor and the average value of the motor voltage is permanently measured. In this way the actual motor working point is monitored and permanently compared with the normal motor characteristic. This comparison delivers then the different motor or power FET failures.

   b) <u>Failure handling procedures:</u> After the detection of any motor or power FET failure, the control of the motor is taken by internal settings (no longer by the input set value **IN**) to protect the whole system.
   After a predefined time the AS8410 restarts the control by the input set value again and monitors the motor and power FET.
   This procedure is repeated up the failure disappears (or the controlling µP is executing a protection reaction by itself).

The main internal setting values and reactions of the different load circuit failures in OM1 are listed here below:

1. Over current or short circuit of the motor
   Handling: a) switch off the motor immediately (delay < 1 µs)
   b) report of the failure at the pin **IN**
   c) check the failure condition again after a waiting time
   d) reuse the input set value, if the over current condition is over

2. No load of the motor
   Handling: a) report of the failure at the pin **IN**
   b) internal setting of the set value to 75 %
   c) reuse the input set value, if the no load condition is over

3. Open wire (motor or power FET line)
   Handling: a) report of the failure at the pin **IN**
   b) internal setting of the set value to 75 %
   c) reuse the input set value, if the open wire condition is over

4. Short-circuited power switch (power FET)
   Handling: a) report of the failure at the pin **IN**
   b) internal setting of the set value to 75 %
   c) reuse the input set value, if the short-circuit condition is over

5. Mechanically blocked motor
   Handling: a) report of the failure at the pin **IN**
   b) pull down the motor
   c) check the failure condition again after a waiting time
   d) reuse the input set value, if the blocked motor condition is over

6. Short-circuited commutator segments (dirt of the lamellas)
    Handling: a) internal setting of the set value to 100 % (cleaning of the lamellas)
                     b) regulation of the motor with adapted characteristic or switch off the
                        motor if the motor current cross over the over current threshold
                     c) reuse the input set value, if the short-circuit condition is over

7. Protection function for the power FET and the AS8410 itself, if the motor works as
    generator due to its mechanical inertia
    Handling: a) The gate potential of the power FET is permanently monitored, if this
                        potential is to high in the switch off case of the driver, the power FET
                        gate will be protected
                     b) If the power FET gate is returned in the normal region (the motor speed
                        of the off switched motor is low enough), the normal driver function is
                        reused.

The figure 4.3 is showing an example of the sequence of AS8410 internal events during failures
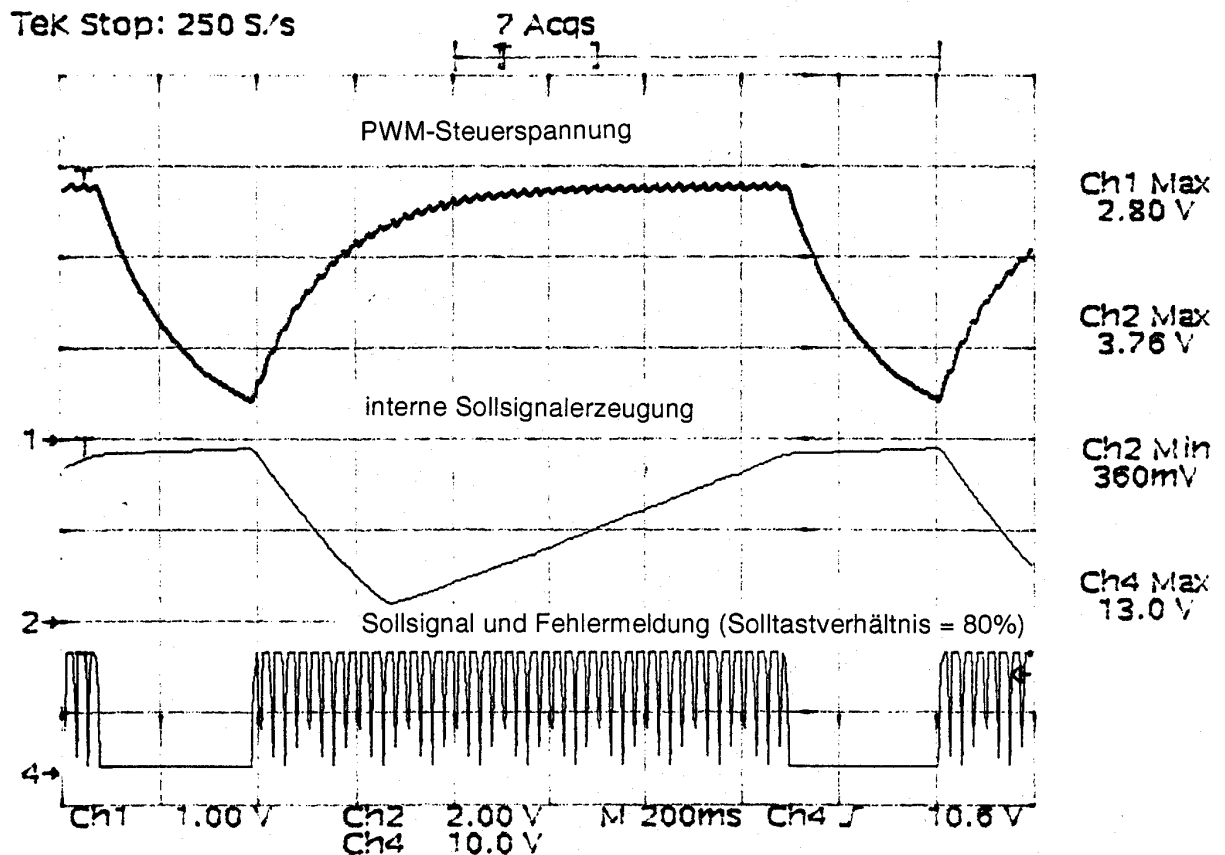handling procedure in a reduced time scale.

Fig. 4.3   Example of a failure handling procedure

4.1.8.2   Over / Under Voltage Detection and Protection

The over / under voltage detection is used to prevent undefined system status.
Over or under voltage detected:
      Handling: a) switch off the motor
                b) reuse the input set value, if the supply voltage returns in the
                  permissible range

Symbol	Parameter	min	typ	max	Unit	Note
Vbat	Monitored supply voltage	5	12	50	V	
V_{bat_min}	Threshold voltage of the under voltage detection	6,2	6,50	6,7	V	falling
V_{bat_max}	Threshold voltage of the over voltage detection	32	33	34	V	rising

4.1.8.3   Over Temperature Detection and Protection

The over temperature detection is realised with an external temperature sensor (e.g. NTC resistor) connected to the pin **TP** and the supply **VDD**. The threshold value of the temperature detection is fixed at the voltage level $V_{refT} = 0.5 * VDD$ at the pin **TP**.

Symbol	Parameter	min	typ	max	Unit	Note
VDD	5V supply at pin VDD	4,7	5,00	5,3	V	
V_{refT}	Threshold voltage of the temperature detection		0.5*VDD		V	[1]
V_{refT_hys}	Hysteresis of the threshold voltage		50		mV	
[1] Over temperature if $V_{TP} < 0.5*VDD$ No over temperature if $V_{TP} > 0.5*VDD$ Cross current of the external resistor divider must be > 1 mA						

Handling of the over temperature failure:
Operating Mode 1 (V_{MODE} = high):
- The Over Temperature reaction: 100 % duty ratio of the FET-driver output (permanent switch on the motor) as long as the temperature is higher than the predefined threshold value (typical automotive application, the heating source is not the electrical system but the combustion engine to be cooled).

Operating Mode 2 (V_{MODE} = low):
- The Over Temperature reaction: The motor is regulated down to not cross the predefined temperature threshold (like a thermostat if the heating source is the electrical system itself).