

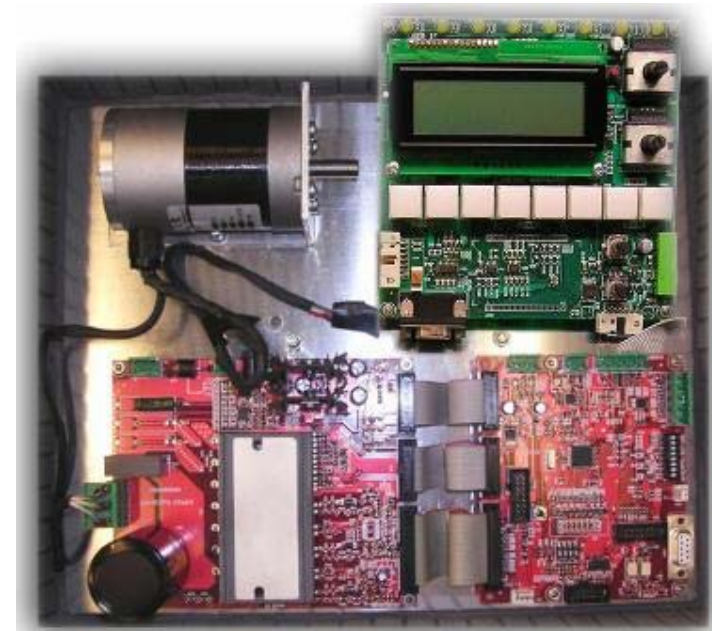
New Sensorless Motor Control Reference Platform for Permanent Magnet AC motors



MCRP05 – Platform 3-phase Brushless AC & ACIM

Renesas Technology Europe

Vincent Mignard
Segment Marketing
RTE – CID
June 08



1. MCPR01 to MCRP05

BLDC motor



- Brushless
- Trapezoidal
- Sensorless

BLDC motor



- Brushless
- Trapezoidal
- Sensored

BLAC/ACIM motor



- Brushless
- Sinusoidal FOC
- Sensorless, OSCD



DC motor



- Brushed
- Triac controlled
- Appliance simu.

Asynch. motor



- Brushless
- Vector controlled
- Sensorless

2. MCRP05 - Key selling points

BLAC motor



High Switching frequency

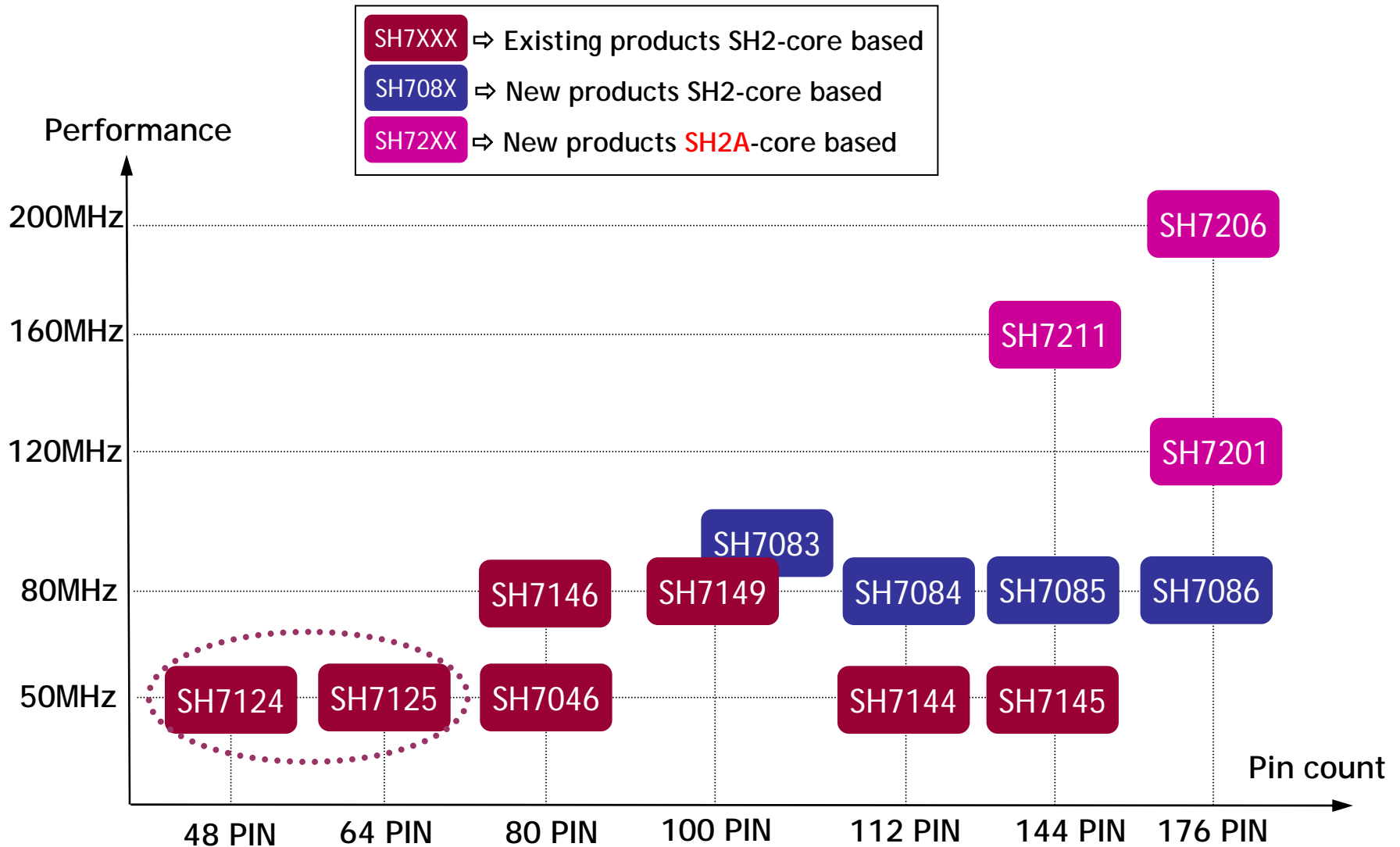
Sensorless – One Shunt Current Detection

Fully vector controlled (FOC)

Sinusoidal control

Drive Motor & control the system

2. Motor Control 32-bit RISC MCU (with MTU2 and/or MTU2S)



3. Why SH Tiny?



- Low pin count
48 PIN, 16KB flash

- Fast MAC unit
Fast multiplication
& addition

- Fast RISC MCU
65MIPS, 50MHz
- Low consumption
Only 0.5 MIPS/mW



- Safety functions
Watch Dog timer, flash
protection

- Dedicated MTU2
Generate any PWM &
trigger ADC

- Fast 10-bit ADC
2 μ s, 2 independent S/H

3. SH Tiny: 32-bit MAC module

Ensure quick regulation

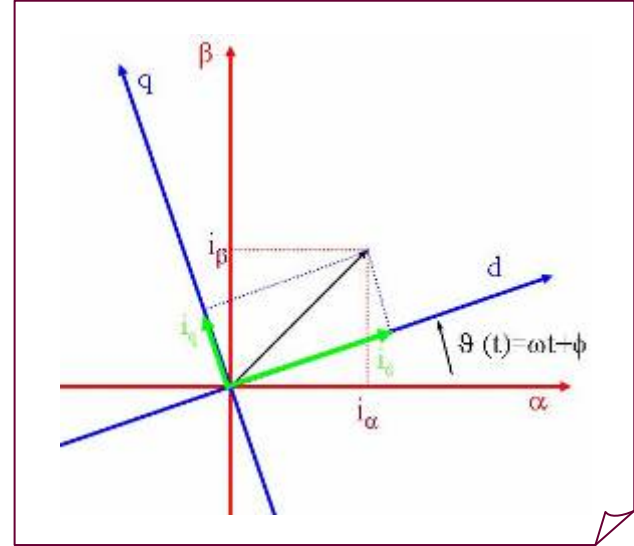
$$v_d = \text{PI}(0 - i_d)$$

$$v_q = \text{PI}(i_{q\text{ref}} - i_q)$$

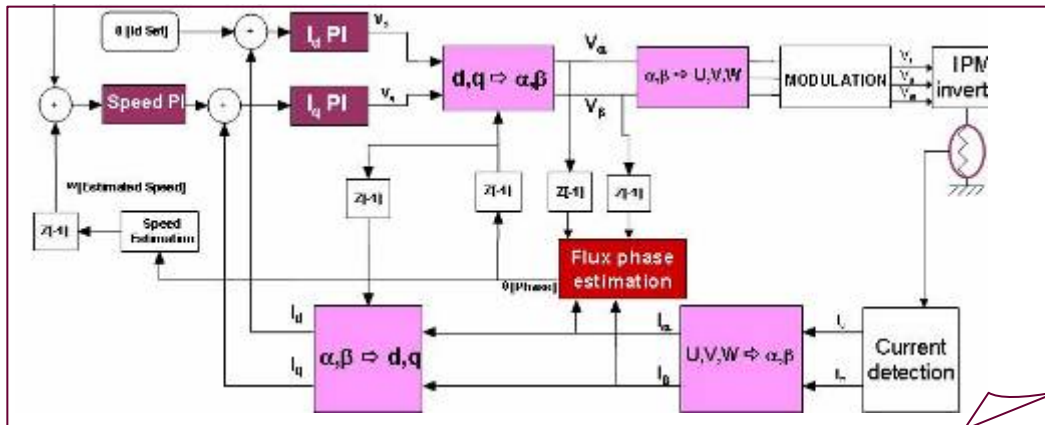
Fast rotor angle calculation

$$\theta = \arctan \left[\frac{\Lambda_m \sin(\theta)}{\Lambda_m \cos(\theta)} \right]$$

Enable quick vectors rotations



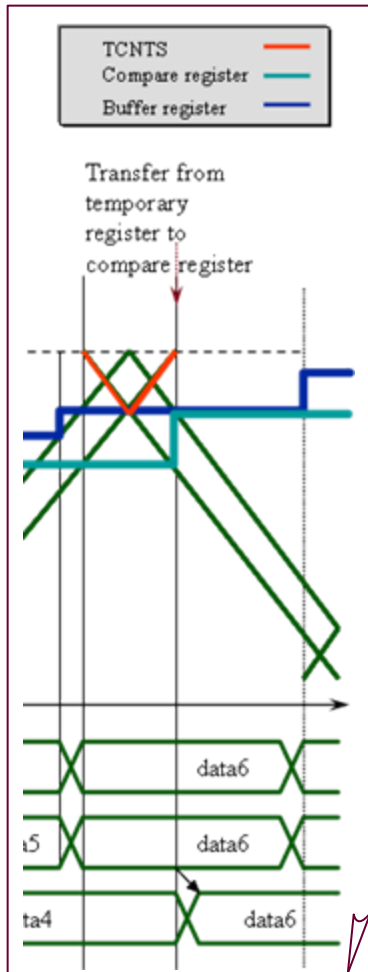
Guarantee real-time sensorless FOC algorithm



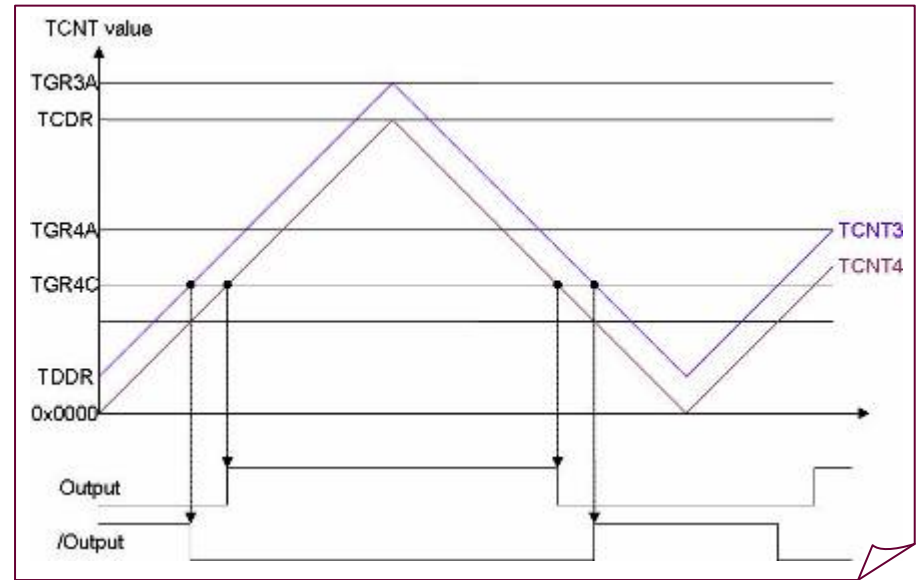
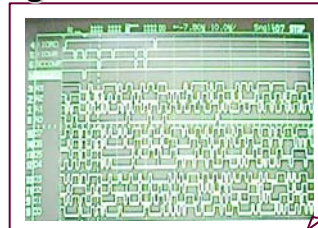
3. SH Tiny: MTU2 module

Generate six PWM in complementary mode Automatic dead-time insertion

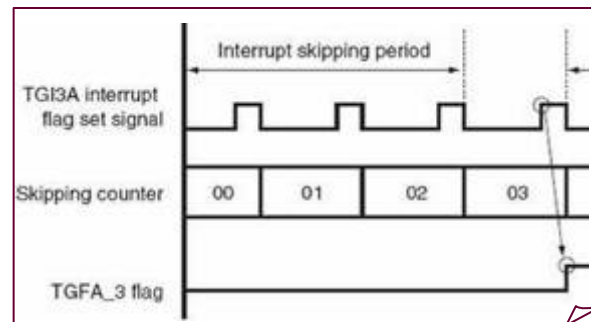
Buffers automatic reload



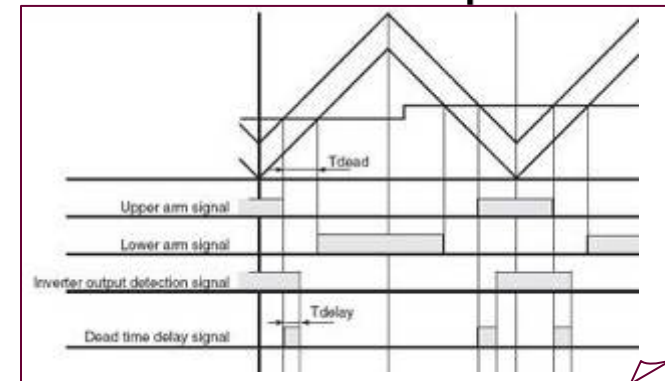
Trigger ADC to get measurements



Reduce CPU workload by INT skipping



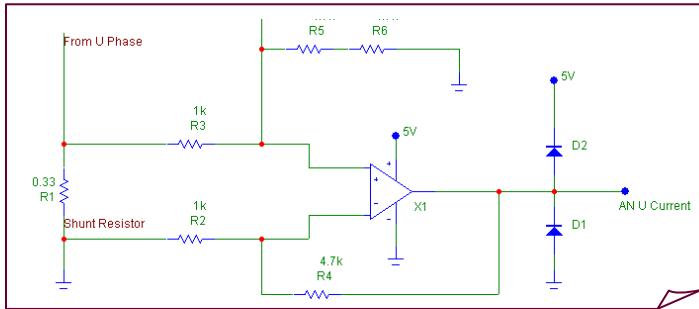
HW Dead-time compensation



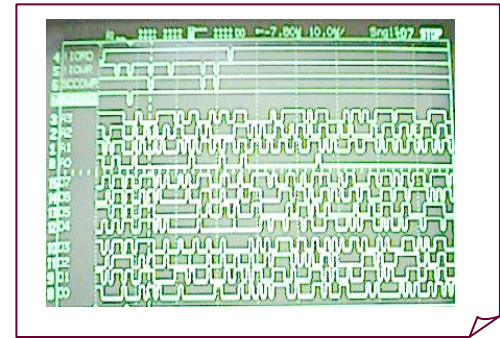
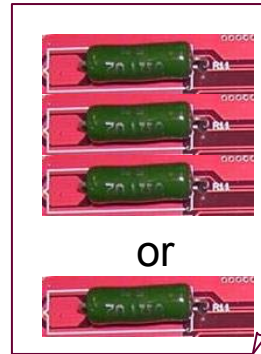
3. SH Tiny: ADC module

Fast conversion time: 2µs

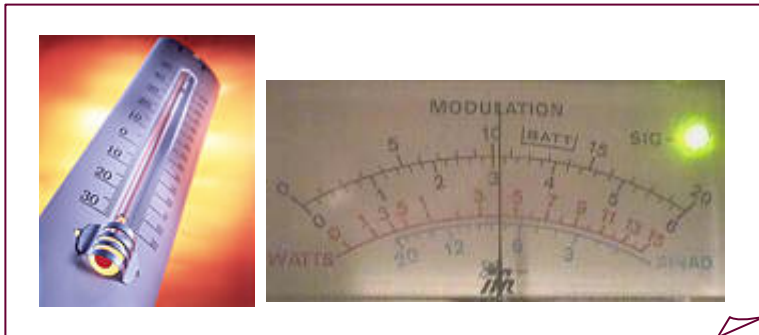
2 x modules: 10-bit resolution



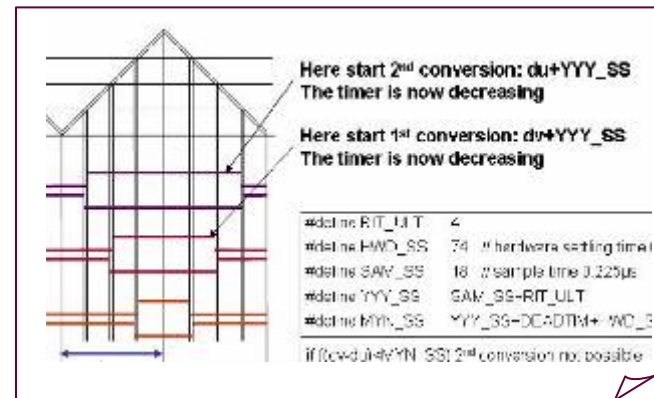
Enable 1 or 3 shunts measurements



8 inputs signals to measure U, I, Temp...

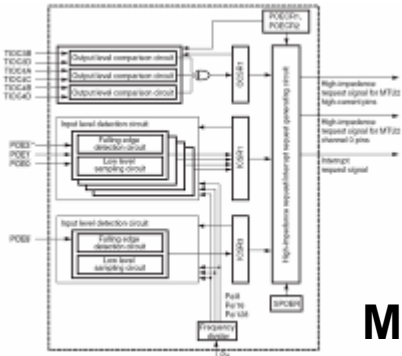


ADC synchronized with PWM signals

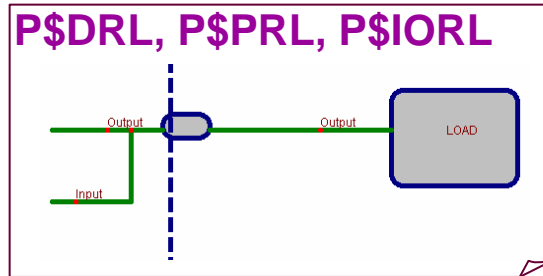


3. SH Tiny: Safety modules & protections

Port Output Enable (emergency stop)



Output level consistency check



Independent WDT with output safety signal



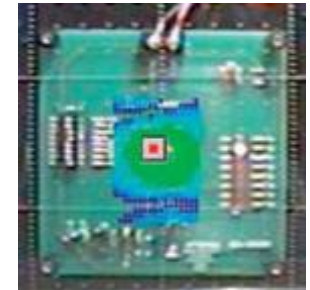
MTU2 HW shortcut protection



22 Registers Write Protected

Bit:	7	6	5	4	3	2	1	0
	-	-	-	-	-	-	-	RWE
Initial value:	0	0	0	0	0	0	0	1
R/W:	R	R	R	R	R	R	R	R/W

High robustness against burst



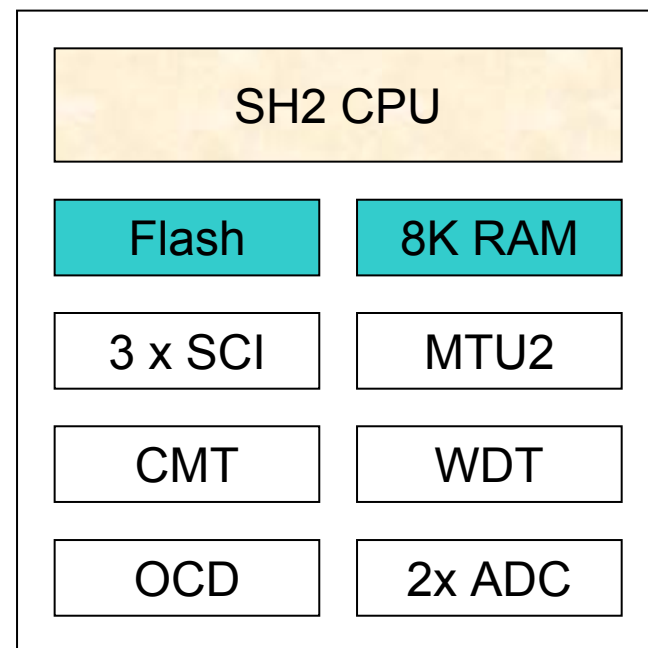
Flash protected

Bit:	7	6	5	4	3	2	1	0
	K[7:0]							
Initial value:	0	0	0	0	0	0	0	0
R/W:	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

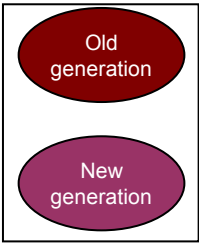
3. SH7125 Overview



- High-performance single-chip RISC with SH-2 core
 - 65 MIPS: 50MHz, 5V
 - Built-in 32-bit multiplier: MAC unit
- Built-in large capacity memory
 - 16K to 128KB Flash & 8KB RAM
 - 32-bit single cycle access
- Various peripheral functions
 - Powerful timer: MTU2 (16-bit x 6ch)
 - Compare match timer (16-bit x 2ch)
 - A/D converters: 10-bit, 8ch (4ch x 2unit)
 - Serial (SCI): 3ch
 - H-UDI: On-chip debugging functions
- Package
 - FP-48F – 48 pin (0.65mm pin pitch)
 - LQFP64 – 64 pin (0.50mm pin pitch)



4. MCRP05 – for which application?



Fridge & freezer compressor
Air conditioner



Universal motor

3ph BLDC/AC motor



Washer & dryer

3ph Induction motor

Universal motor

3ph BLAC motor

Air Extractor



Universal motor

3ph Induction motor

3ph BLDC/AC motor



Water pump

Universal motor

3ph BLDC/AC motor

▪ External power supply

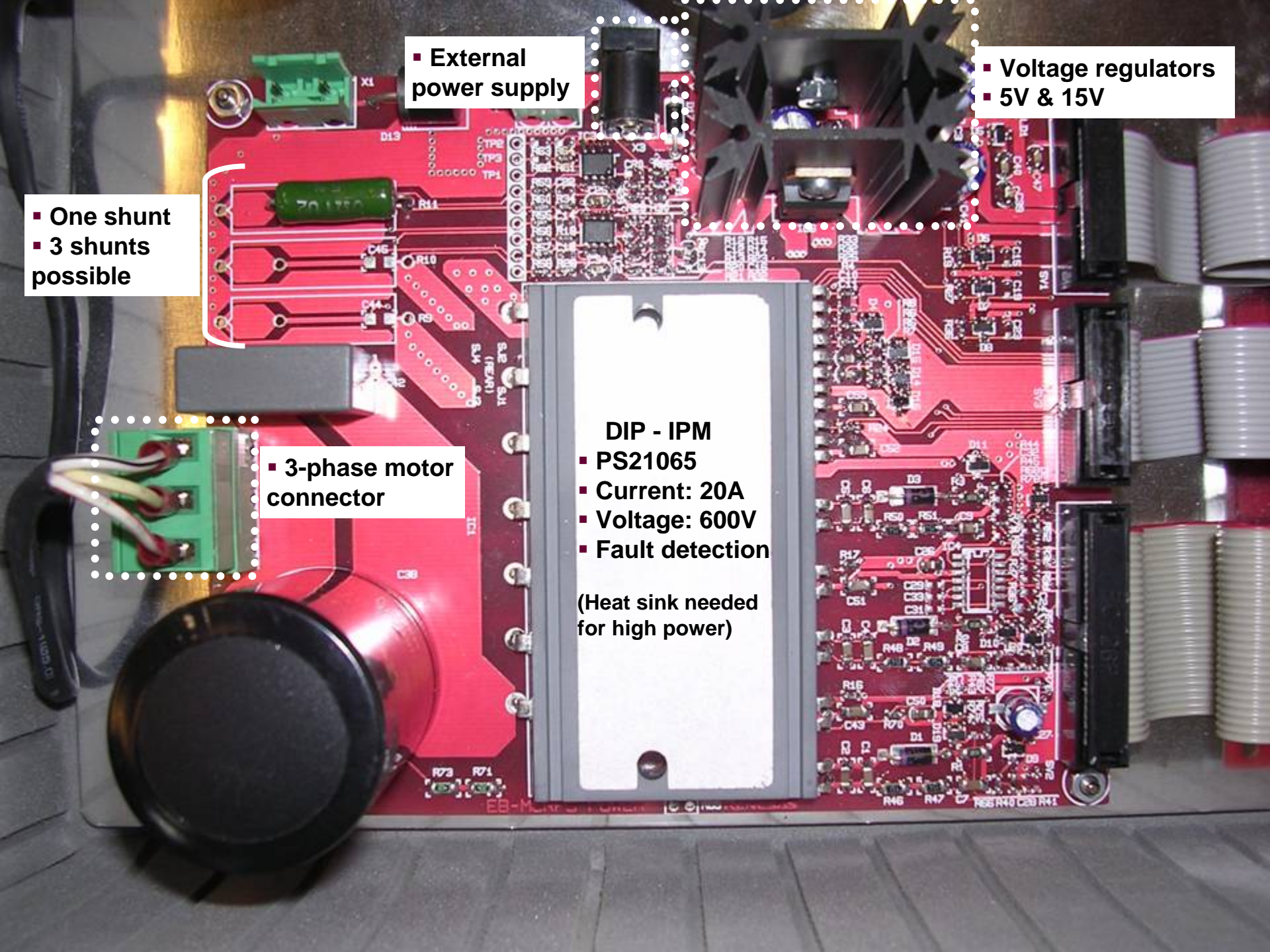
▪ Voltage regulators
▪ 5V & 15V

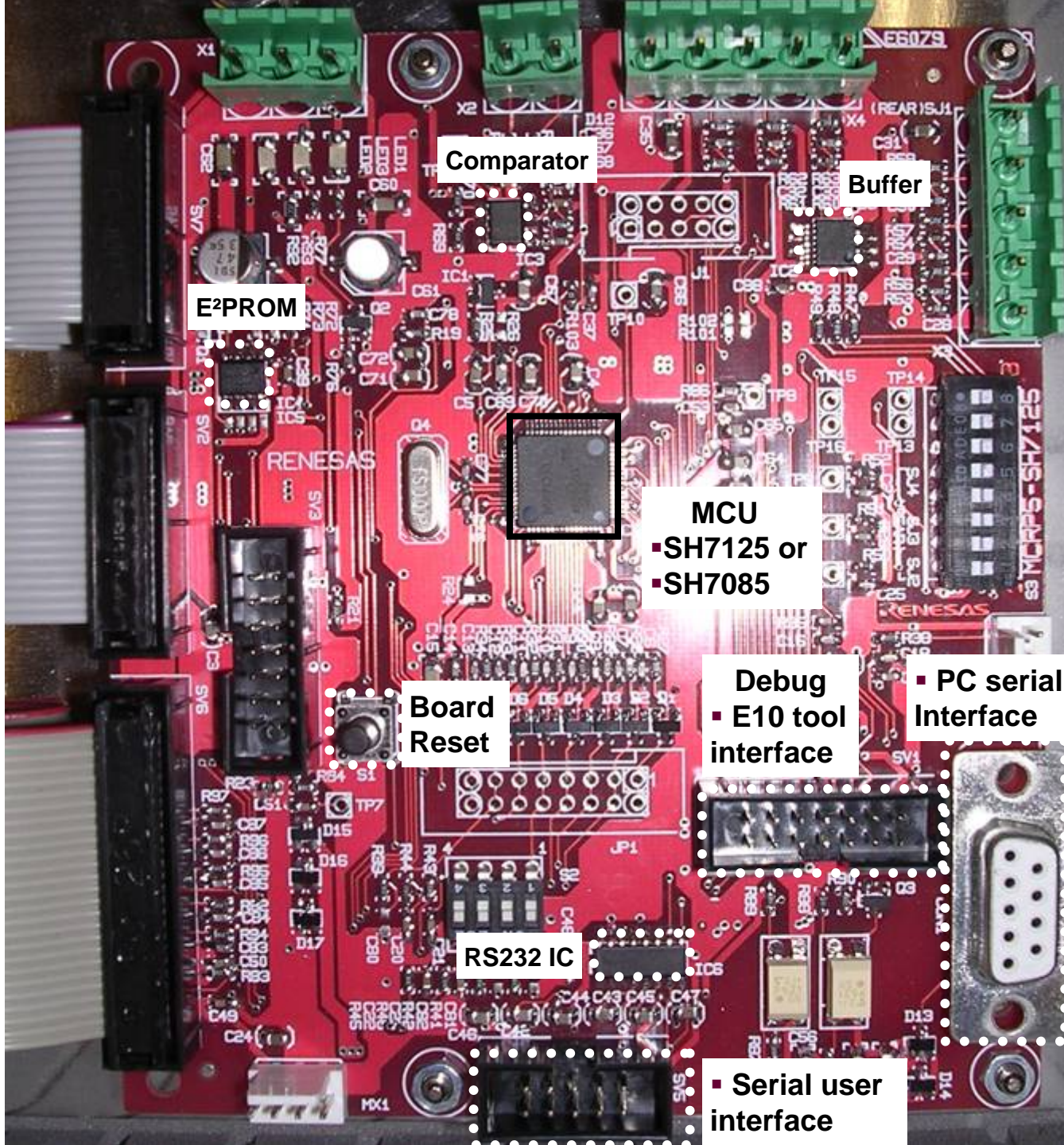
▪ One shunt
▪ 3 shunts possible

▪ 3-phase motor connector

DIP - IPM
▪ PS21065
▪ Current: 20A
▪ Voltage: 600V
▪ Fault detection

(Heat sink needed for high power)





E²PROM

Comparator

Buffer

MCU

- SH7125 or
- SH7085

Board
Reset

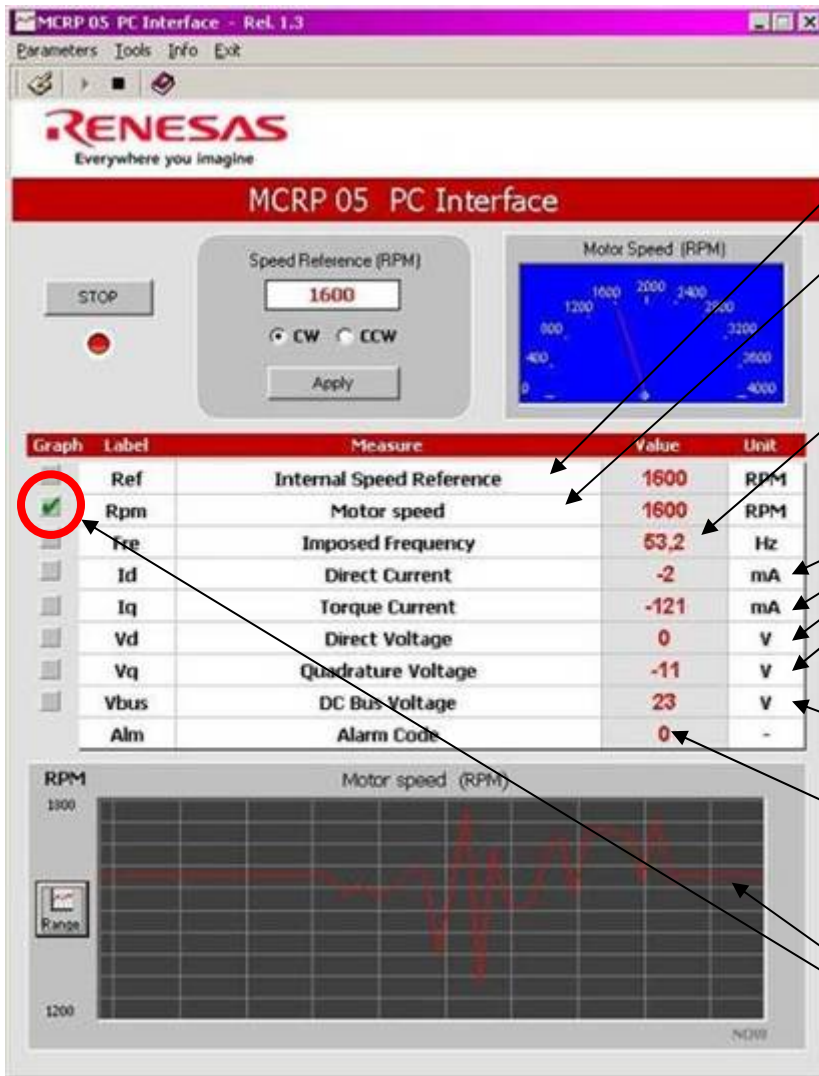
Debug
▪ E10 tool
interface

▪ PC serial
Interface

RS232 IC

▪ Serial user
interface

6. Use of PC interface



Speed value set by user
(600RPM to 1700RPM with a 24V V_{Bus})

Motor speed measured

Frequency applied

(electrical frequency of the sinusoidal 3-phase voltage waveform of the inverter impose to the motor. It's measured by the flux estimation algorithm)

I_d , I_q , V_d , V_q : are the values of the equivalent phase currents & voltages, referred to a rotating reference system aligned with the rotor.

I_q component represents the mechanical torque.

V_{Bus} voltage of the platform

Automatic Alarm Detection

(MCU detect when rotor position is lost during over-load)

Real-time graph for the selected value

6. PC interface – System Parameters

Configuration panel

RENESAS
Everywhere you imagine

Parameter Table

DESCRIPTION	UNIT	MIN	MAX	VALUE	STATUS
Default Parameters Setting	-	0	32767		
Minimum Speed	RPM	0	10000		
Maximum Speed	RPM	100	20000		
Acceleration	RPM/s	99	10000		
Deceleration	RPM/s	99	10000		
Polar Couples	-	1	4		
Nominal d Current	Amp/10	0	100		
Maximum q Current	Amp/10	0	300		
Stator Resistance	Ohm/10	0	1200		
Stator Inductance	Henry/100	0	10000		
Permanent Magnets Flux	Weber/100	0	10000		
Current Loop KP	-	0	30000		
Current Loop KI	-	0	30000		
Speed Loop KP	-	0	30000		
Speed Loop KI	-	0	30000		
Speed Loop KD	-	0	30000		
Free	-	0	32767		
Free	-	0	32767		
Free	-	0	32767		
Free	-	0	32767		

Read from board Apply Close

Max. & Min Speed

Acceleration/Deceleration

Motor parameters

PI speed & current coefficients

Load default values from the board

7. MCRP05 - Software modules

Sensorless FOC algorithm
(PI, flux estimation, filters, speed estimation, modulation routines...)

Transformations
($\alpha\beta$), (u,v,w), (d,q)

Shunt current measurement

Time delay management

Trigonometric functions

PMW generation
MTU2 handling

Communication layer

A/D converter routines

E²PROM handling layer

Interrupts vector table initi.

HW setup layer
SFRs initi.

WDT

3 x SCI

2 x ADC

32K Flash

8K RAM

CMT

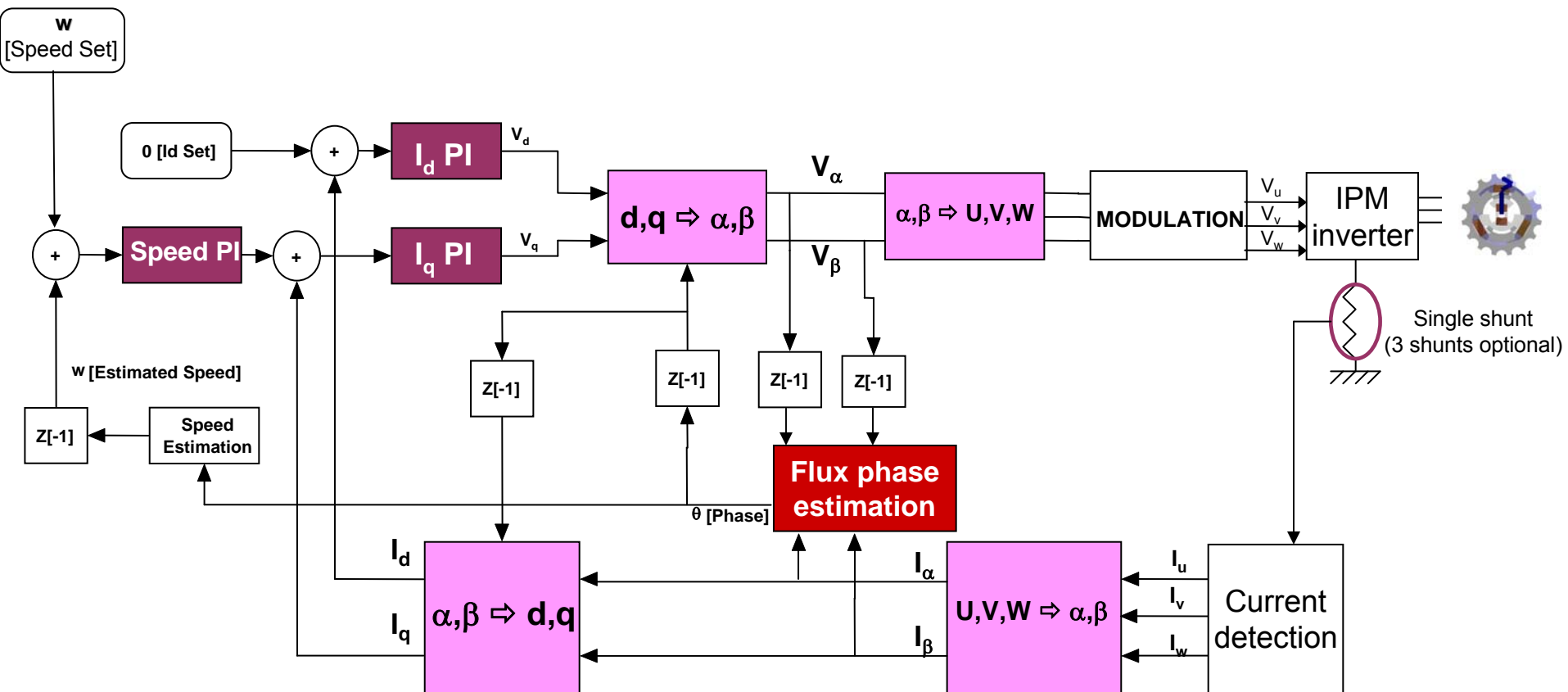
OCD

MTU2

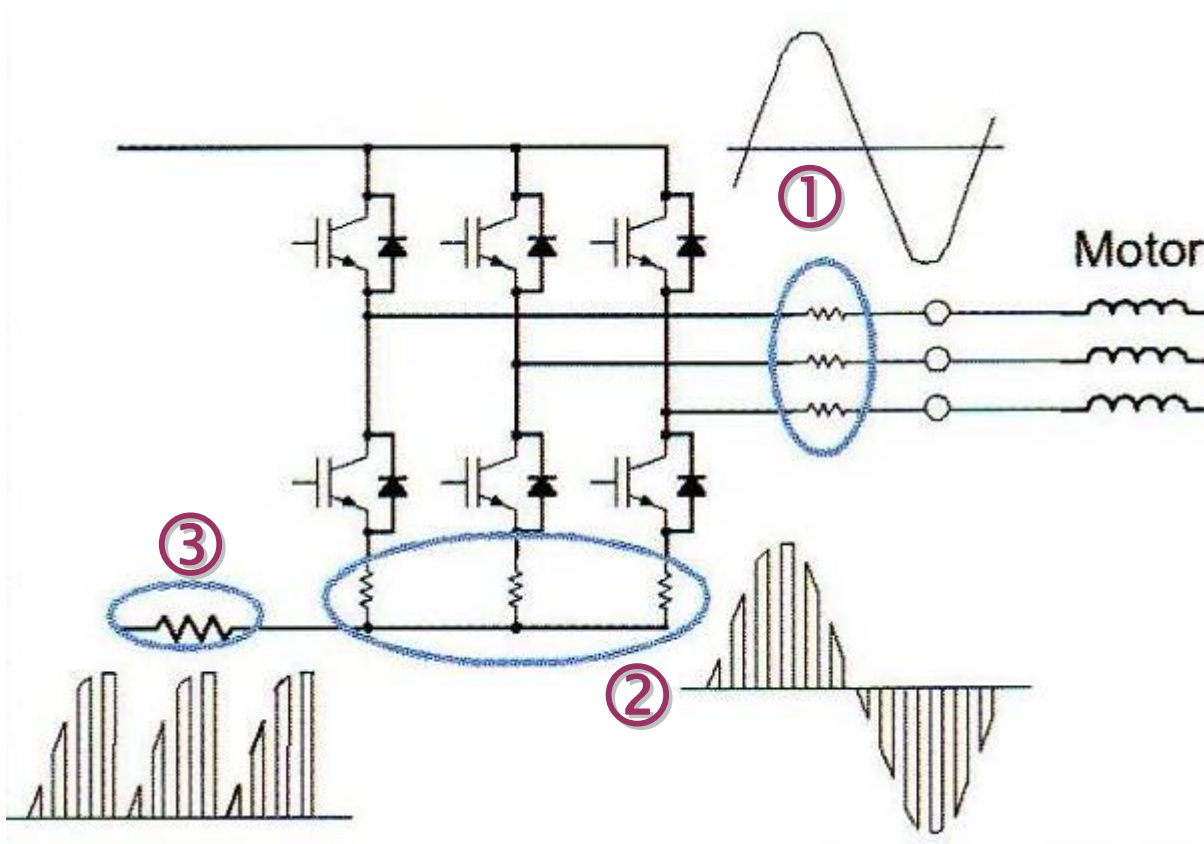
SH7125

32-bit RISC CPU

8. MCRP05 – SW functional blocks



8. Current sensing possible methods

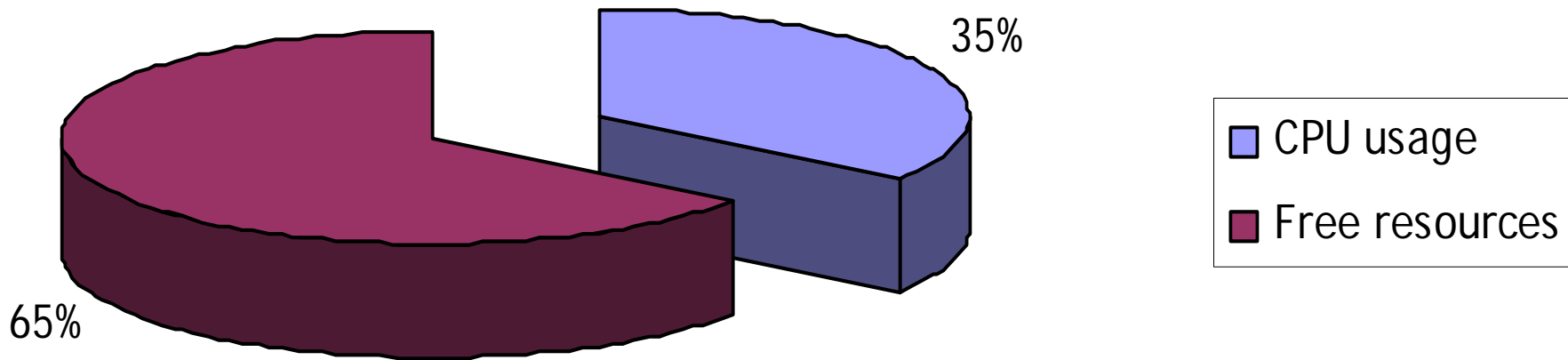


- ① Phase current sensing
- ② Three shunts current sensing
- ③ Single shunt current sensing

9. MCRP05 performances

- Motor control library memory usage:
 1. Flash < 8Kbytes
 2. RAM < 1Kbyte
 3. Interrupt Service Routines : < 35 μ s @ 80MHz

SH7085 performances @ 80MHz Switching frequency of 20KHz



9. MCRP05 performances

- The motor control algorithm is **vector controlled & fully sensorless**

		SH7125 running @ 50MHz clock cycle: 20ns	SH7085 running @ 80MHz clock cycle: 12.5ns
One shunt current detection	Switch. Freq. = 10KHz	✓	✓
	Switch. Freq. = 20KHz	-	✓
Three shunts current detection	Switch. Freq. = 10KHz	✓	✓
	Switch. Freq. = 20KHz	✓	✓

- No audible noise, high accuracy, high system dynamic

9. Motor Control Platform - Benefits

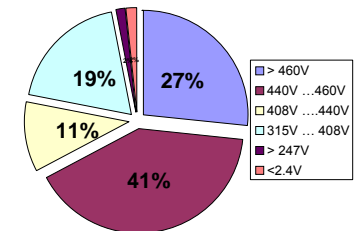
- Low-cost solution & reduced BOM

	MCU part	Power stage	Total
Capacitor	26	35	61
Resistor	24	65	89
Diode	6	16	22
ICs Misc.	2	3	5

- Self-Test MCU Software to support IEC 60730 & IEC 61508 requirements

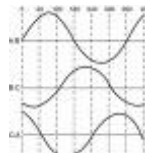


- SH offers very high EMI & robustness (Langer Test results)



- MCRP05 ensures no torque ripple, no noise and high efficiency at all speeds & good dynamics.

Short Table summary

Motor Type	Brushless AC (Permanent Magnet AC) or ACIM Low & high voltage
Control Method	Sinusoidal waveform control Field Oriented Controlled (FOC) 
Current measurement	Single Shunt Three Shunts
MCU type	SH7124 (32-bit, 50MHz) or SH7085
Flash usage	8KB flash (6KB for algorithm)
RAM usage	<1KB RAM
Available CPU time	>60%
Switching Frequency	20KHz or less
Communication	Serial: PC GUI interface or LCD display