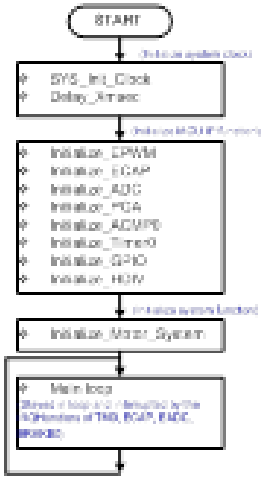
Introduction to Basic Motor Control System by NM1530

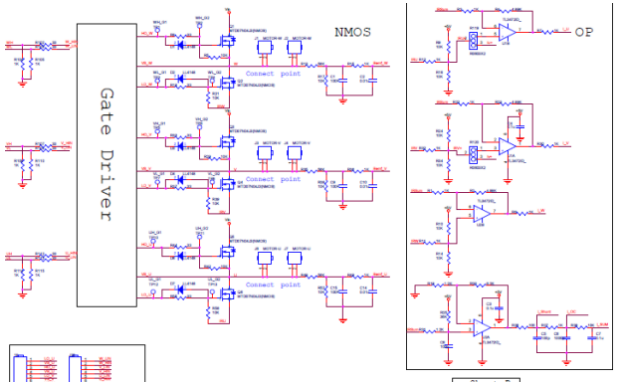
2019/June

Demo Purpose

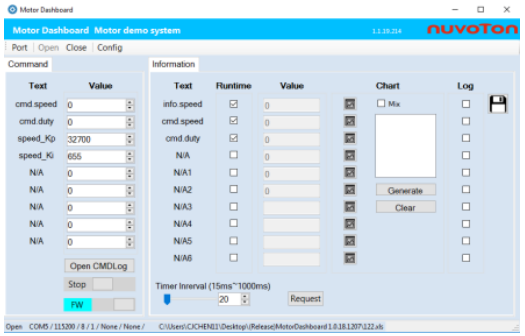
- **Easily & Rapidly Start Coding for Motor Application**
  - Provide demo system for reference design

- **Motor Drive System**
  - Basic S/W flow
  - Reference H/W circuit





- **Friendly GUI Interface Linking PC and System Board through UART(COM port)**
  - User can easily demo motor behavior



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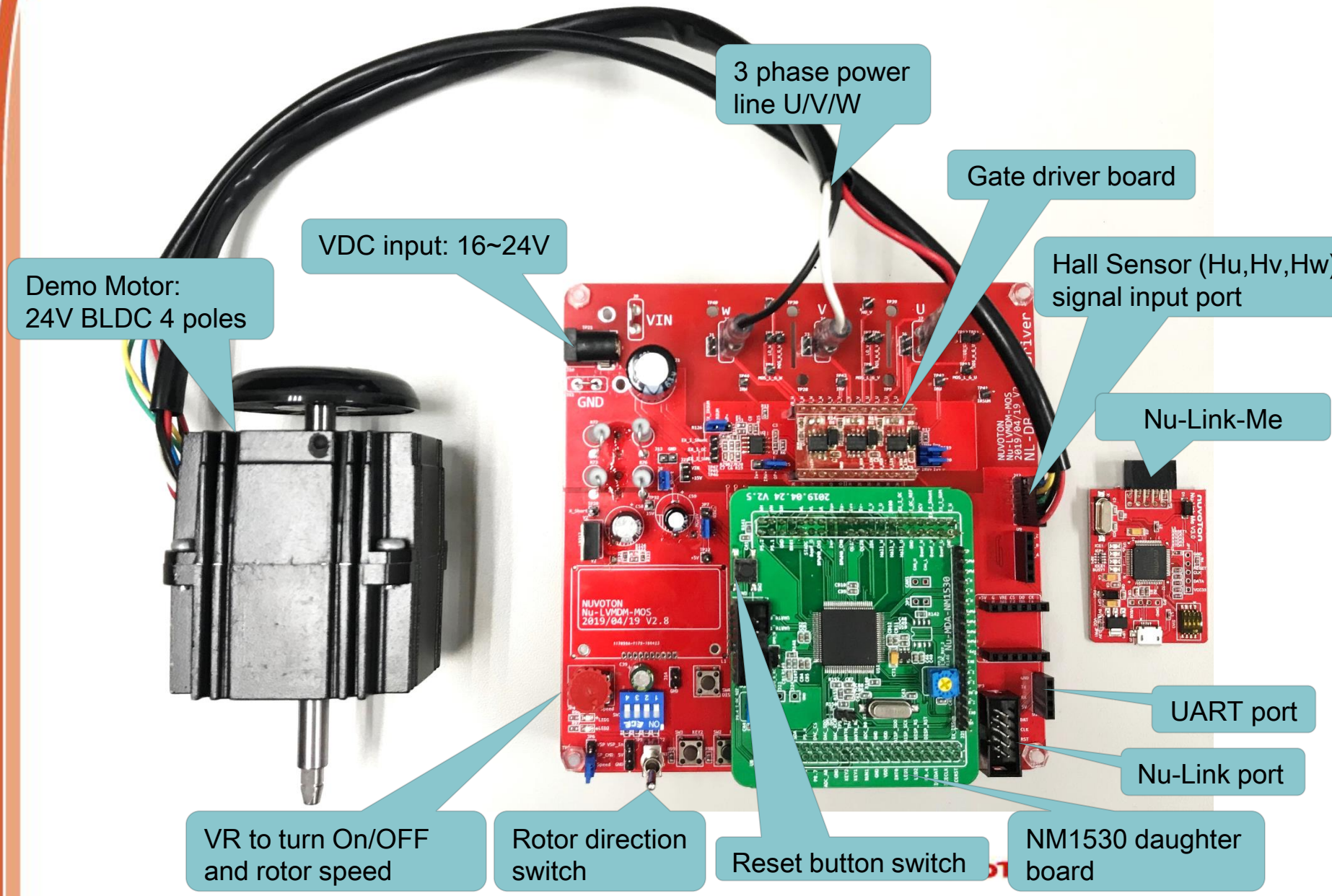
Demo System


3 phase power line U/V/W
Gate driver board
VDC input: 16~24V
Hall Sensor (Hu,Hv,Hw) signal input port
Demo Motor: 24V BLDC 4 poles
Nu-Link-Me
UART port
Nu-Link port
VR to turn On/OFF and rotor speed
Rotor direction switch
Reset button switch
NM1530 daughter board
VIN
GND
NUVOTON Nu-LVMDM-MOS 2019/04/19 V2.8

Quick Start to Motor Drive by NM1530

- **Demo how to use NM1530 to implement a basic motor drive system with**
  - Hall + FOC + 2-shunt R
  - Hall + FOC + 1-shunt R
  - Hall + Six step square wave control
    - Duty open loop
    - Speed close loop
- **Customer may refer this demo system to develop own specific system.**

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Demo Function

- ✓ **Demo NM1530 MCU basic setting**
  - Initialize MCU
  - Timer
  - Interrupt
  - ECAP (Enhance Capture Timer/Counter)
  - Complementary PWM0~5 setting
  - 2 set of 12-bit ADC
  - **MDU(Motor driver unit)**
  - ACMP (Analog Comparator)
  - OPA(NM1530 internal OPA)
- ✓ **Basic PI control** (Proportional and Integral control) for speed and current control
- ✓ **Basic FOC + SVPWM (By MDU)**

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Demo Function

- ✓ 6-Step square wave control
- ✓ Basic motor speed estimation by ECAP
- ✓ System control mode
  - VSP control mode : External VR to turn on/off the motor and adjust speed
  - UART control mode : Set command from PC to MCU through UART protocol.

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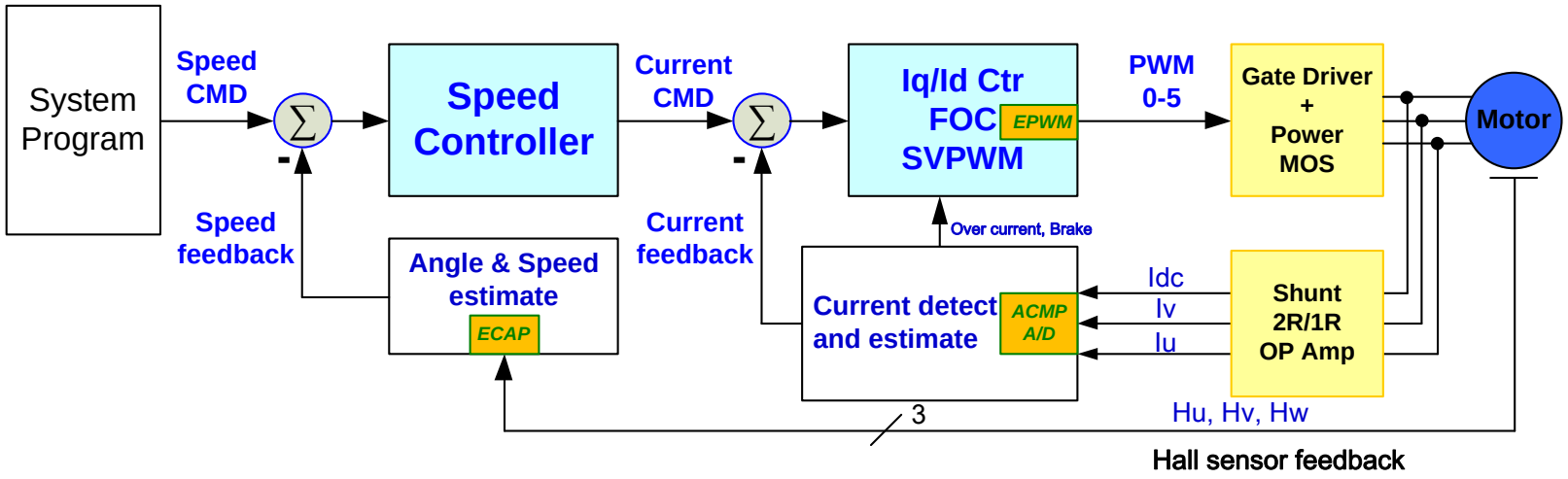
Speed Control by FOC

- Demo System : Hall + FOC
- Control mode : 2R / 1R (R : current shunt resistance)



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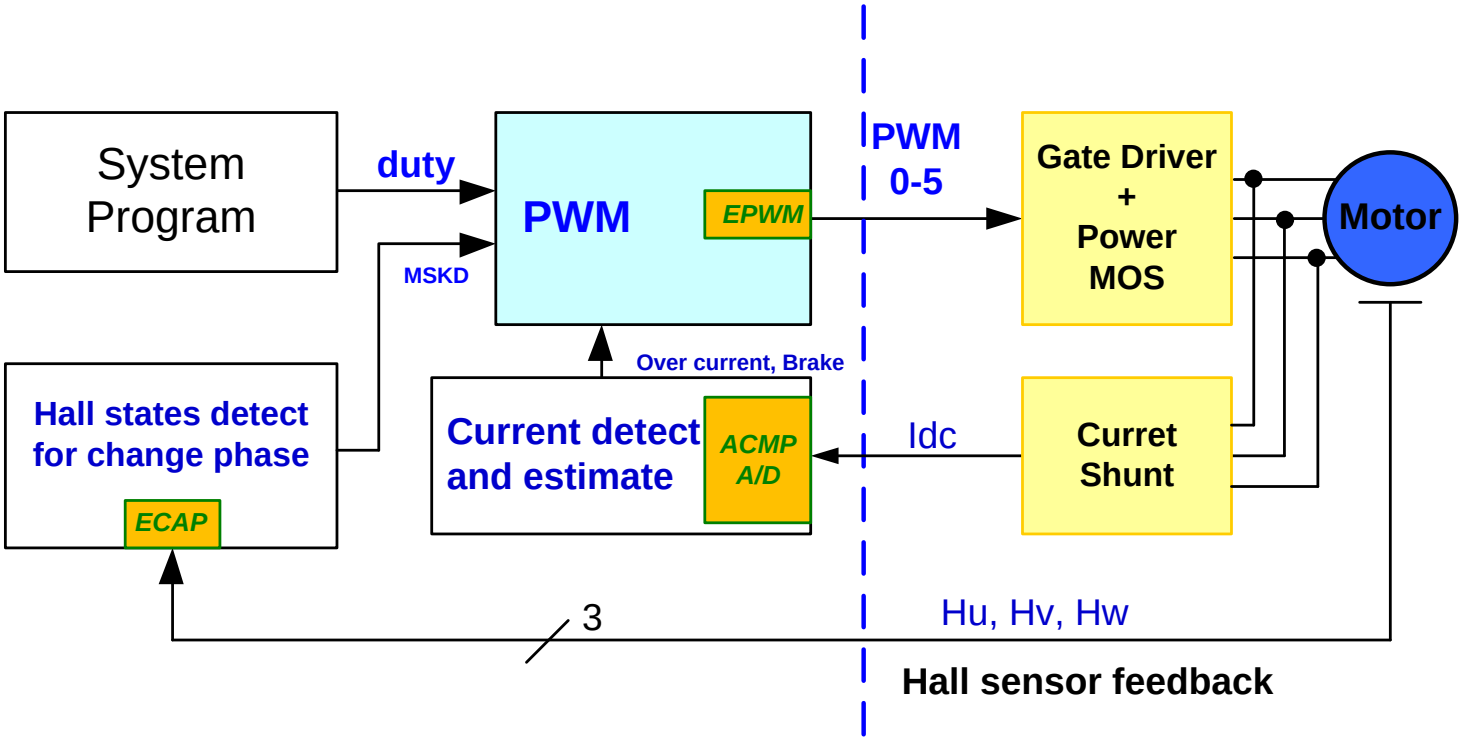
PWM Duty Control by 6-Step

- Demo System : Hall + Six Step square wave control
- Control mode : Duty open loop



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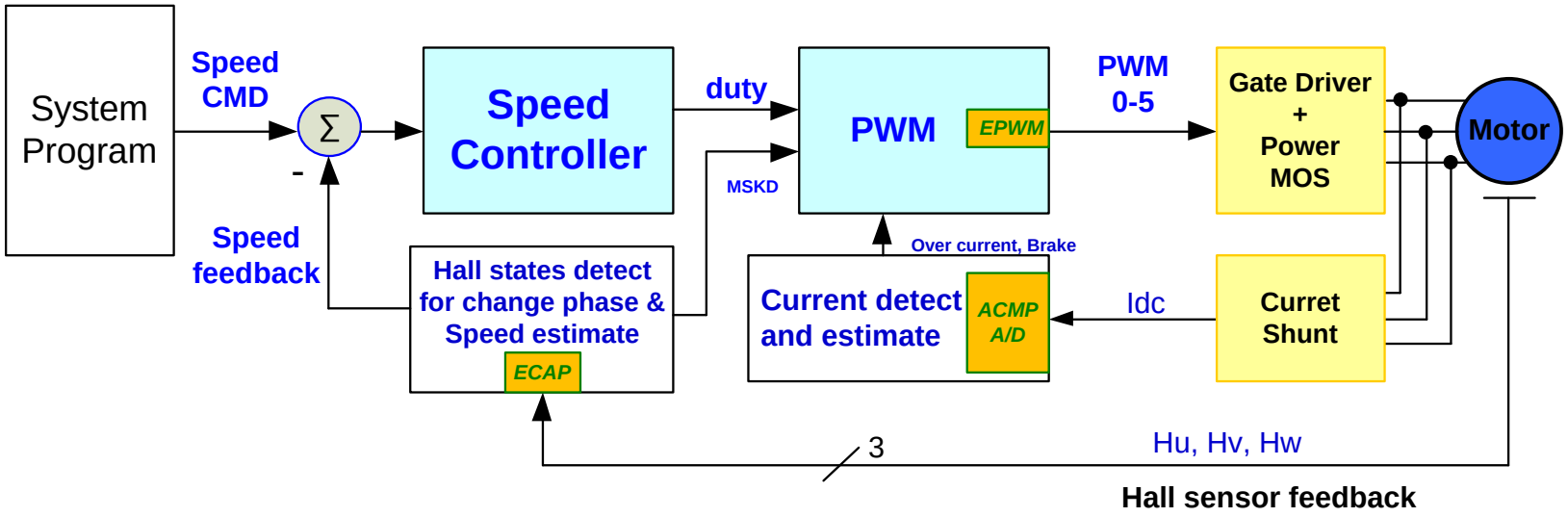
Speed Control by 6-Step

- Demo System : Hall + Six Step square wave control
- Control mode : Speed close loop



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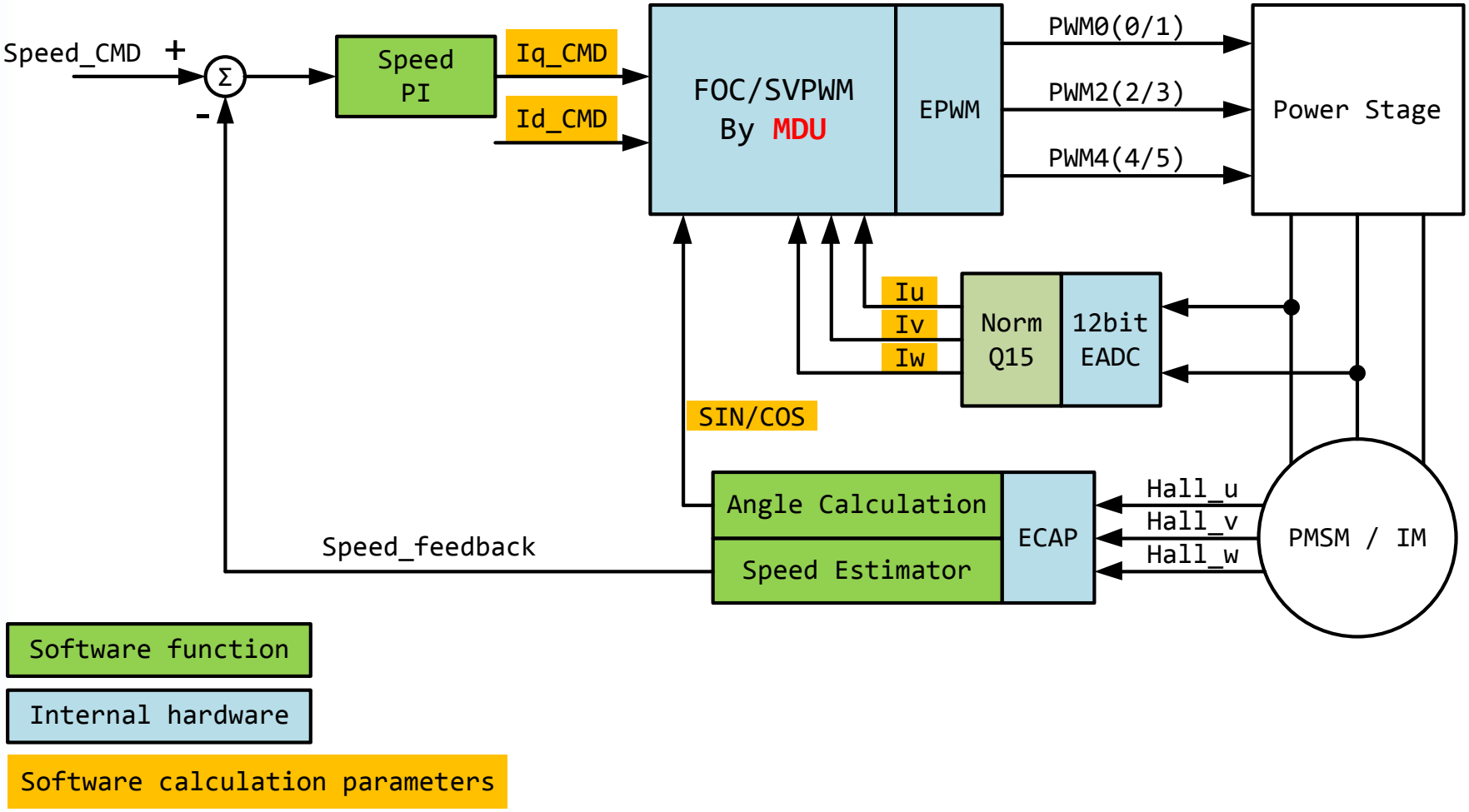
FOC control block

- It takes about **1.5us** to do all of the FOC function by MDU



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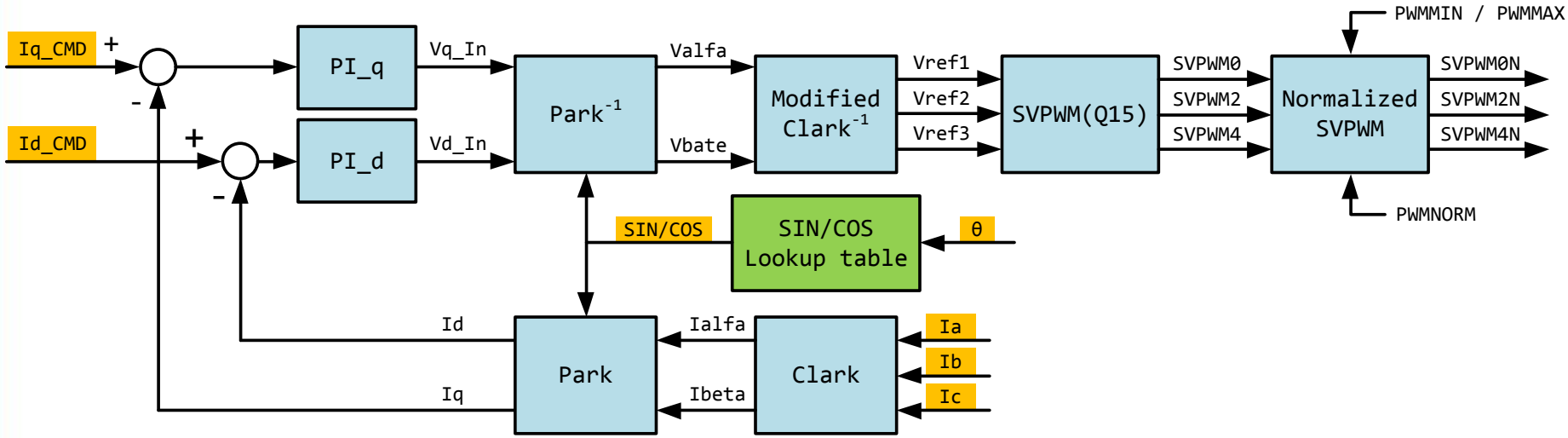
FOC by MDU



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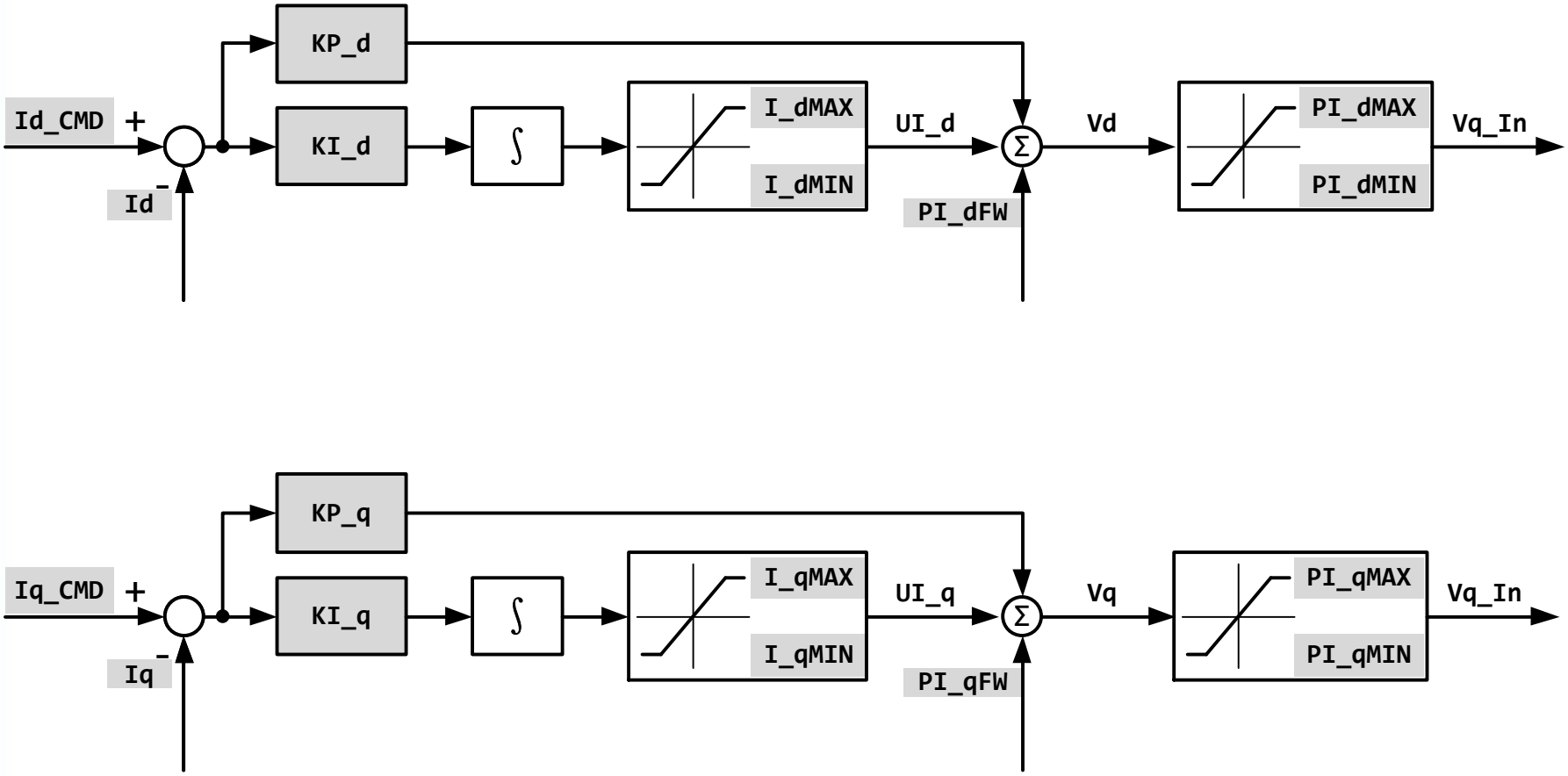
PI controller by MDU



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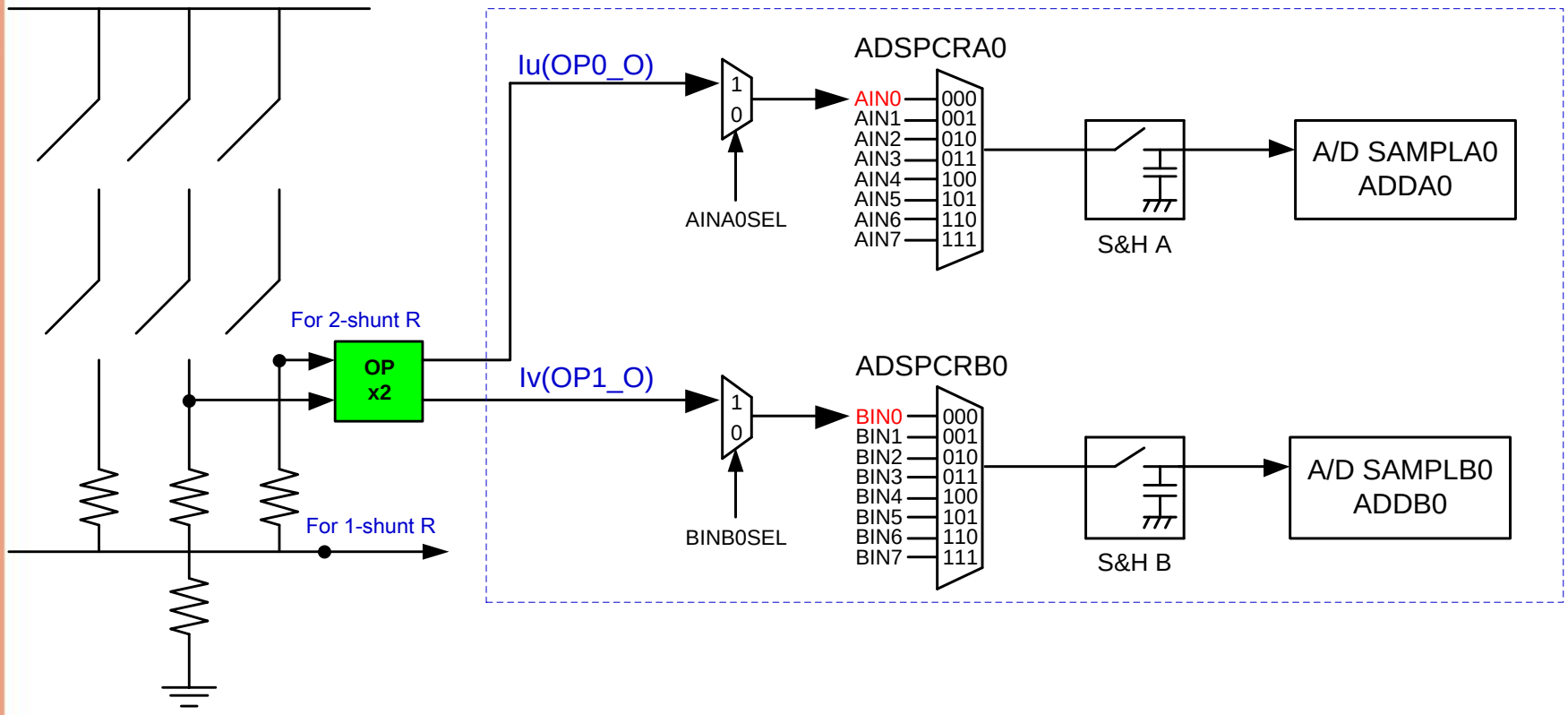
Phase Current Detection by ADC(2R)

- 2-shunt R : Iu / Iv from internal OP



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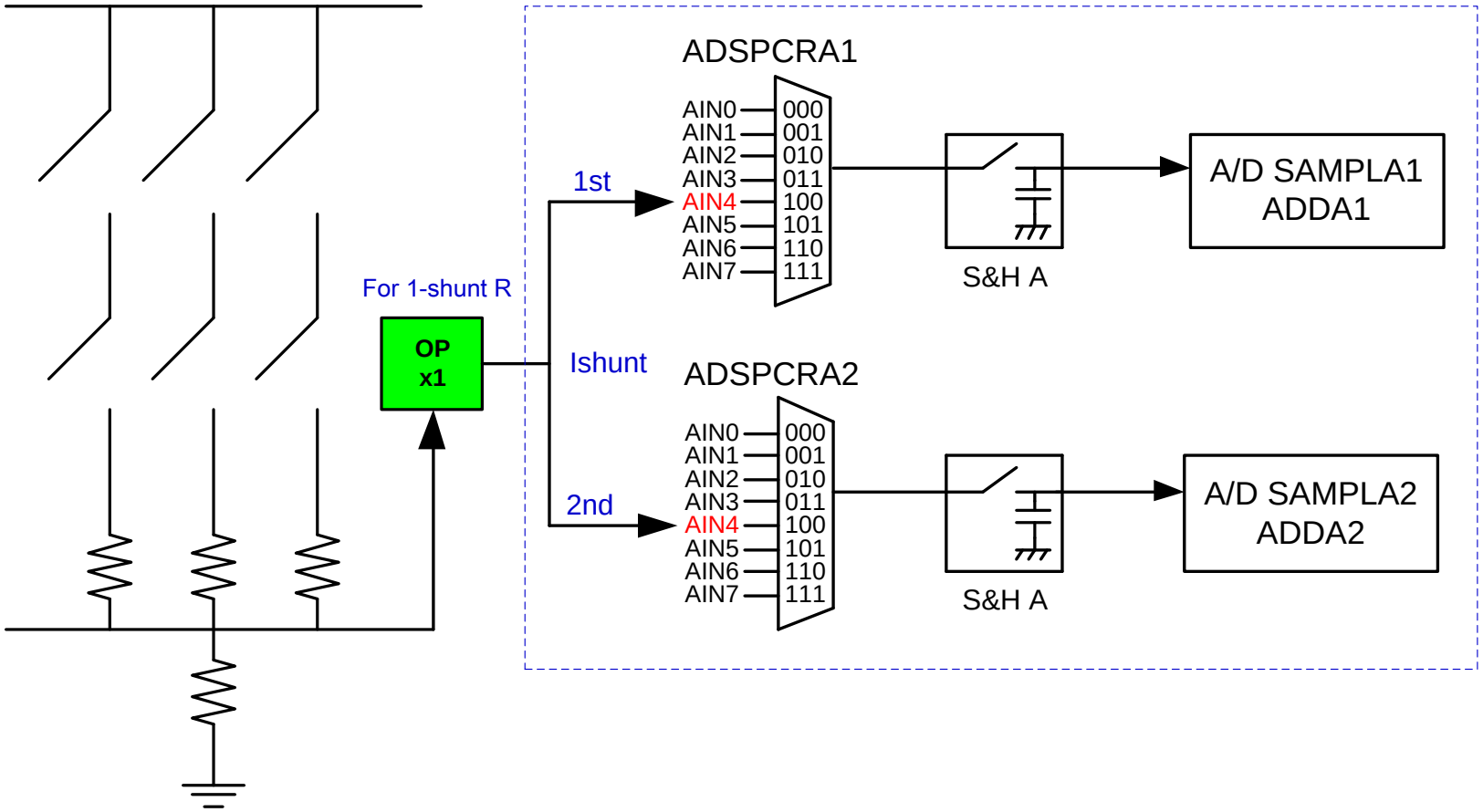
Phase Current Detection by ADC(1R)

- 1-shunt R : Iu / Iv / Iw from external OP



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Six Step square wave control

- The gate drive signal of the MOSFET is as follows.
- Using EPWM Mask mode Register (EPWM_PMSKD) to control the each of MOSFET.

Forward

STAGE FW	HALL STATES	HW P21	HV P22	HU P23	Exciting phase	Gate signal					
						U_H	U_L	V_H	V_L	W_H	W_L
1	5	1	0	1	u→w	PWM	0	0	0	0	1
2	1	0	0	1	v→w	0	0	PWM	0	0	1
3	3	0	1	1	v→u	0	1	PWM	0	0	0
4	2	0	1	0	w→u	0	1	0	0	PWM	0
5	6	1	1	0	w→v	0	0	0	1	PWM	0
6	4	1	0	0	u→v	PWM	0	0	1	0	0

Reverse

STAGE RW	HALL STATES	HW P21	HV P22	HU P23	Exciting phase	Gate signal					
						U_H	U_L	V_H	V_L	W_H	W_L
1	3	0	1	1	u→v	PWM	0	0	1	0	0
2	1	0	0	1	w→v	0	0	0	1	PWM	0
3	5	1	0	1	w→u	0	1	0	0	PWM	0
4	4	1	0	0	v→u	0	1	PWM	0	0	0
5	6	1	1	0	v→w	0	0	PWM	0	0	1
6	2	0	1	0	u→w	PWM	0	0	0	0	1

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Six Step square wave Function Call

- void SIX_STEP_CHANGE_PHASE_FW(void)
  - Do phase change function for rotor forward
  - Using EPWM Mask mode Register (EPWM_MSKD) to change phase

- void SIX_STEP_CHANGE_PHASE_RW(void)
  - Do phase change function for rotor reverse
  - Using EPWM Mask mode Register (EPWM_MSKD) to change phase

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Motor Variable Structure

```
typedef struct tag_Motor
 {
    AMotorSpec          spec;    馬達系統基本規格, ex: PWM 頻率
    AMotorInfo          info;    即時的data, ex: Iu, Iv, Iw, rotor_speed
    AMotorCommand       cmd;     馬達驅動的命令, ex:轉子速度命令rpm
    AMotorController    ctrl;    控制器的最大限制值
    AMotorSym           sym;     系統資訊, ex: 過流錯誤回報資料
    AMotorOther         other;   一些系統程式執行時需要的變數或flag
 } AMotor;
```

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PI Controller Variable Structure

```
typedef struct
 {
    INT32          e1;          Error = cmd – info, Q15 format
    INT32          ui_31;       Accumulated integrator, Q31 format
    INT32          kp_31,ki_31;  Parameters of Kp & Ki, Q31 format
    INT32          kp_17,ki_17;  Parameters of Kp & Ki, Q17 format(For MDU)
 }PICs;
```

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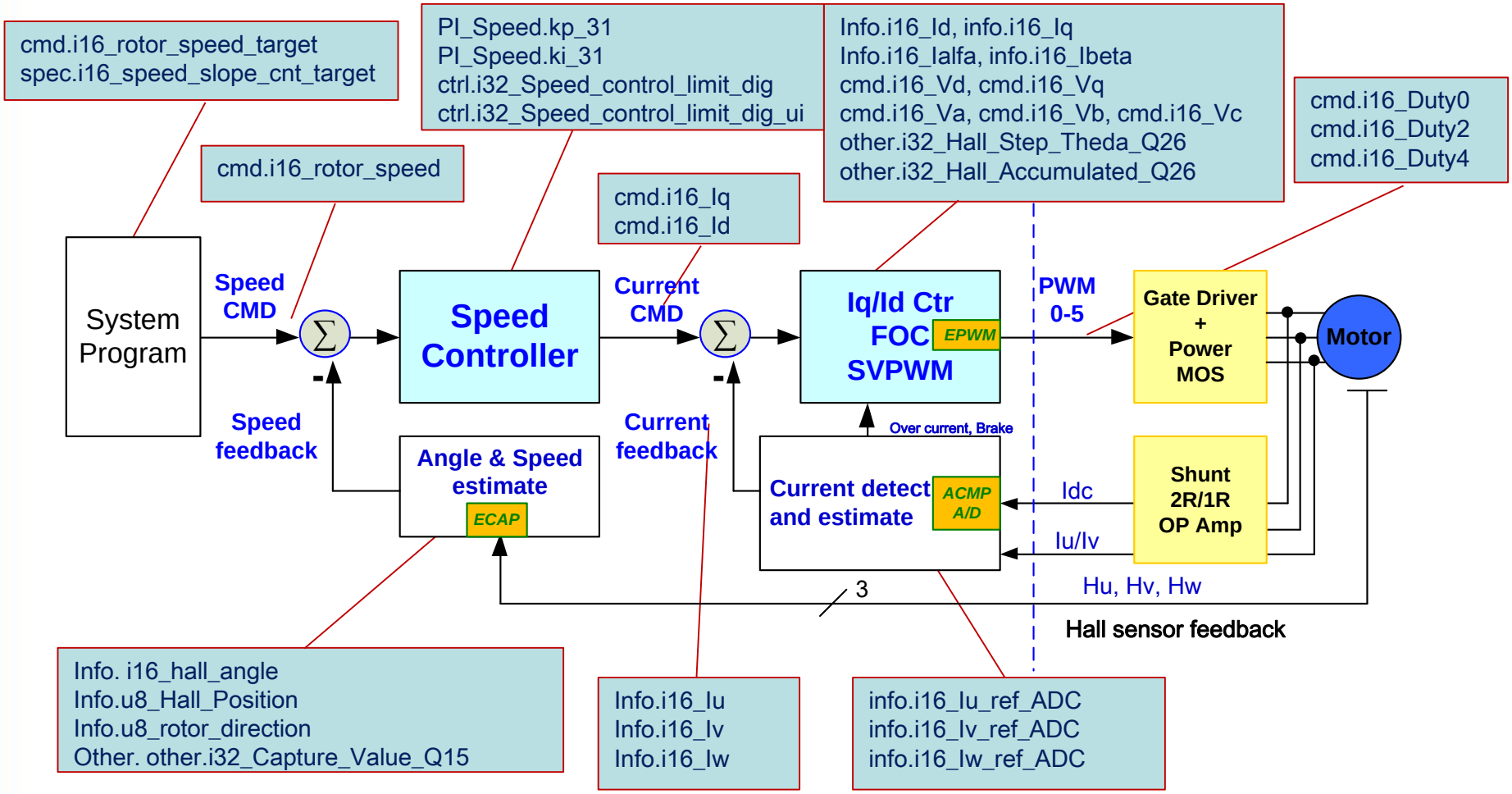
Key Variables



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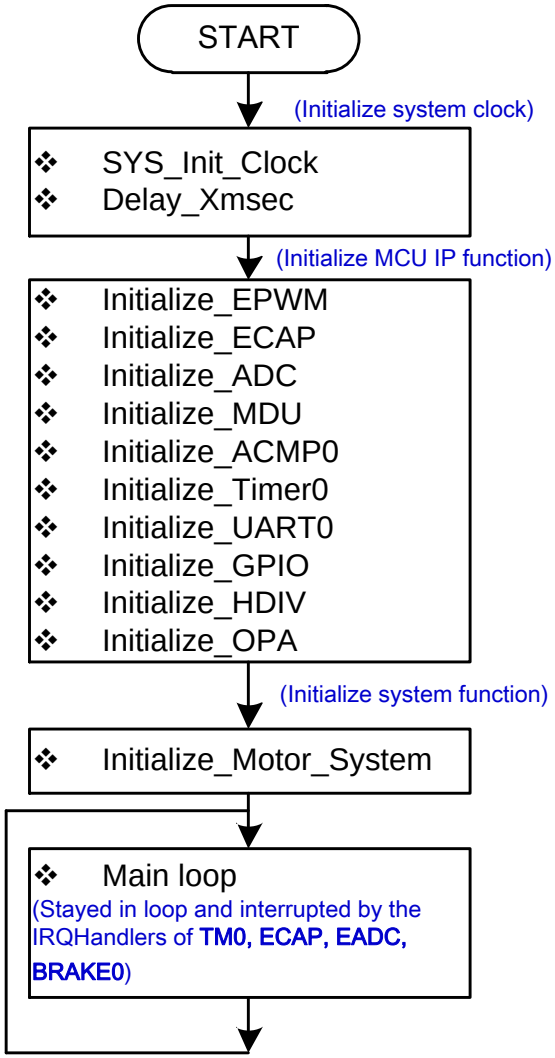
Flow Chart of main.c

- Main program to initialize MCU and system



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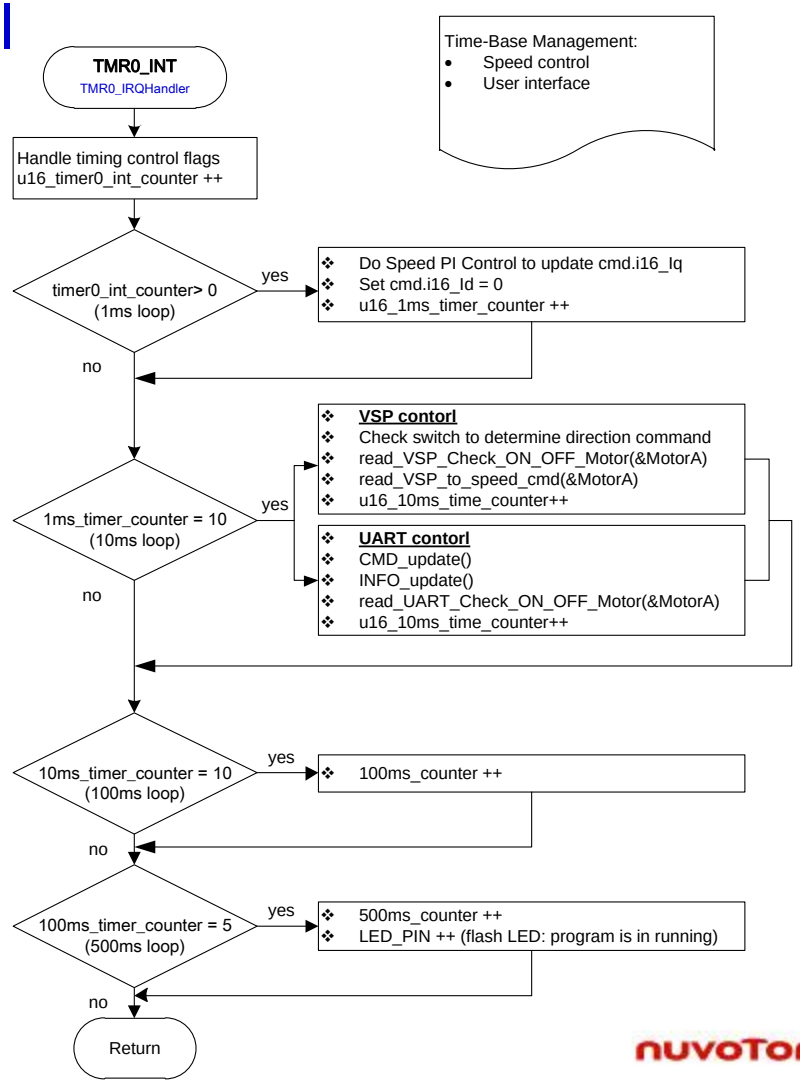
Flow Chart of TMR0_INT (for FOC)

- Timer0 INT for system timer handles the user interface and speed control



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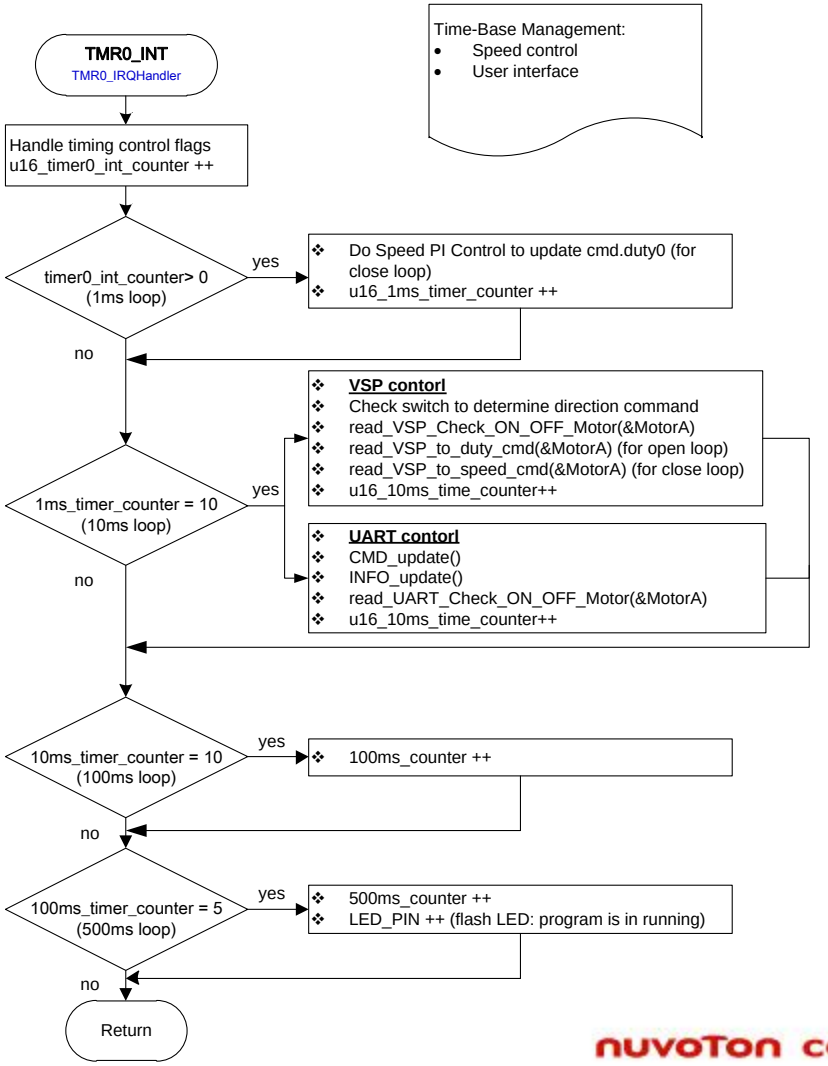
Flow Chart of TMR0_INT (for Six step)

- Timer0 INT for system timer handles the user interface and speed control



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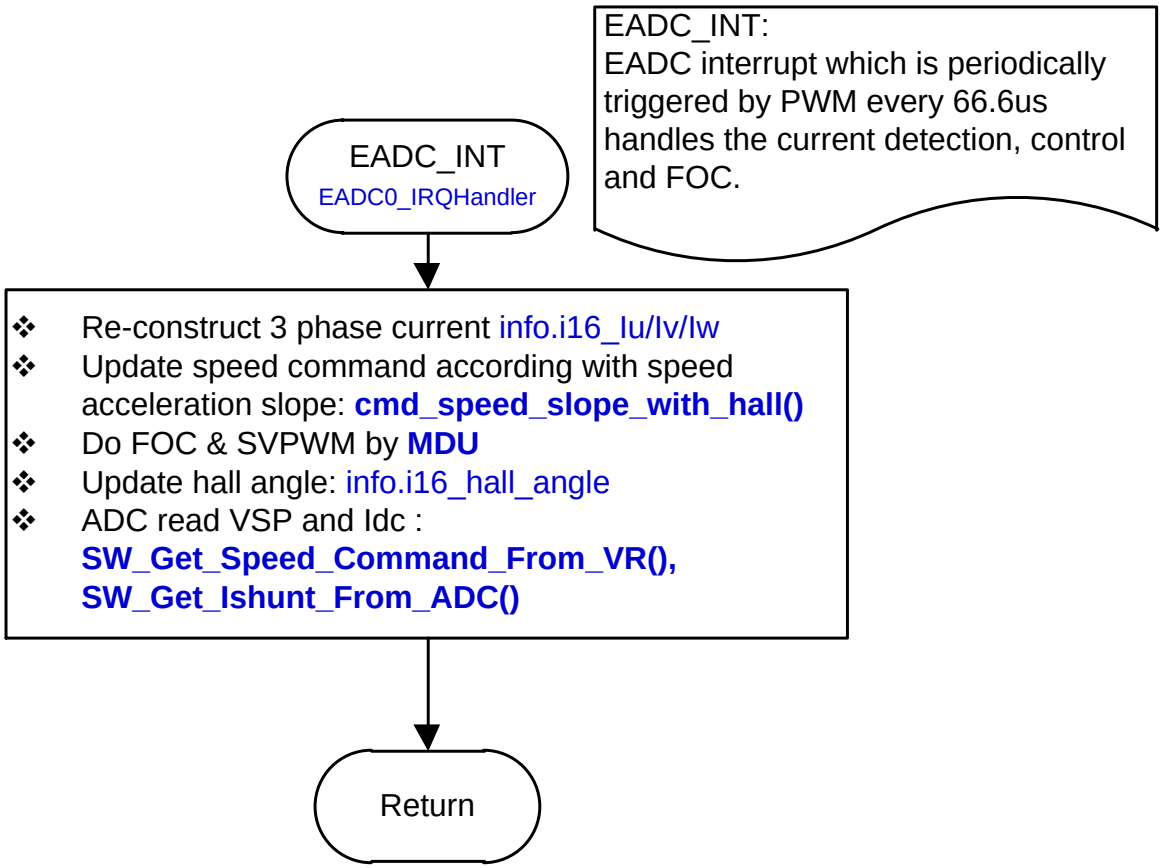
Flow Chart of EADC_INT (for 2R)

- EADC INT: for current control and FOC



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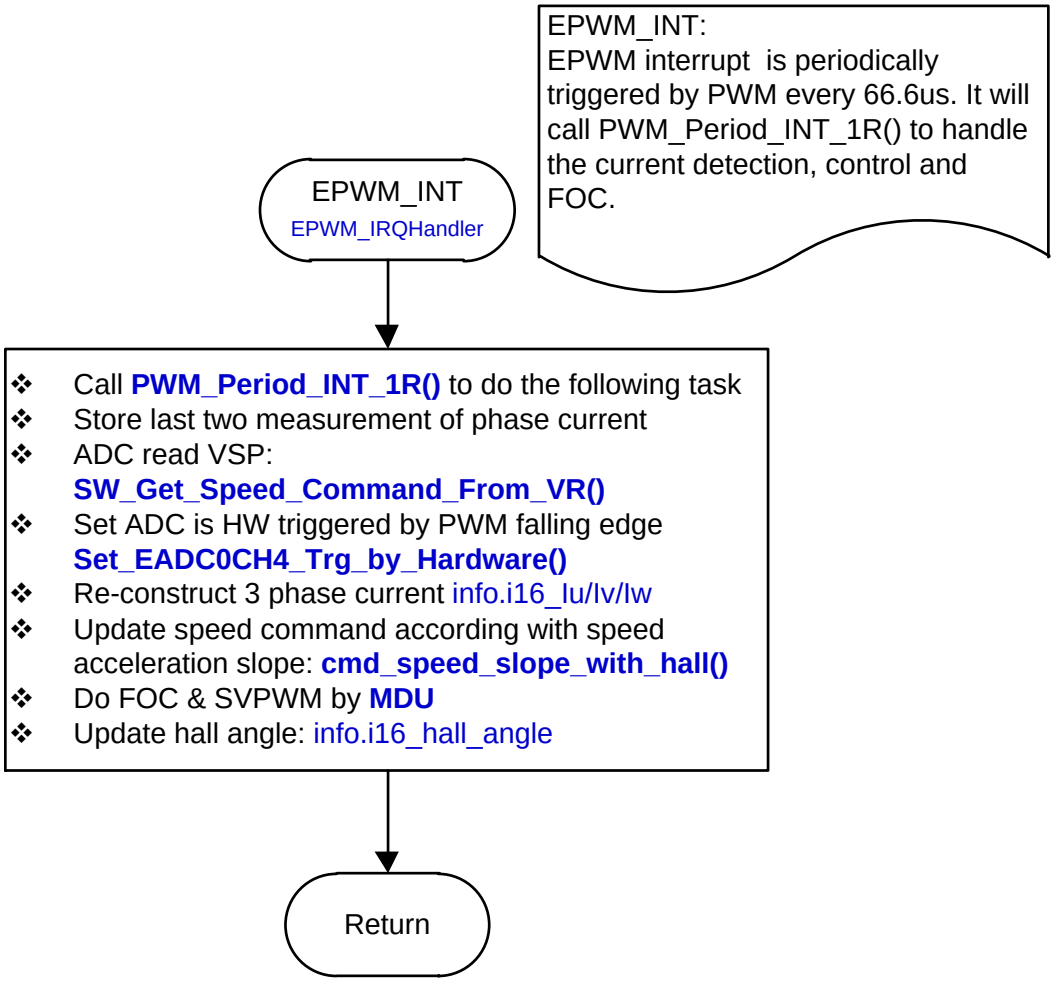
Flow Chart of EPWM_INT (for 1R)

- EPWM INT: for current control and FOC (1R)



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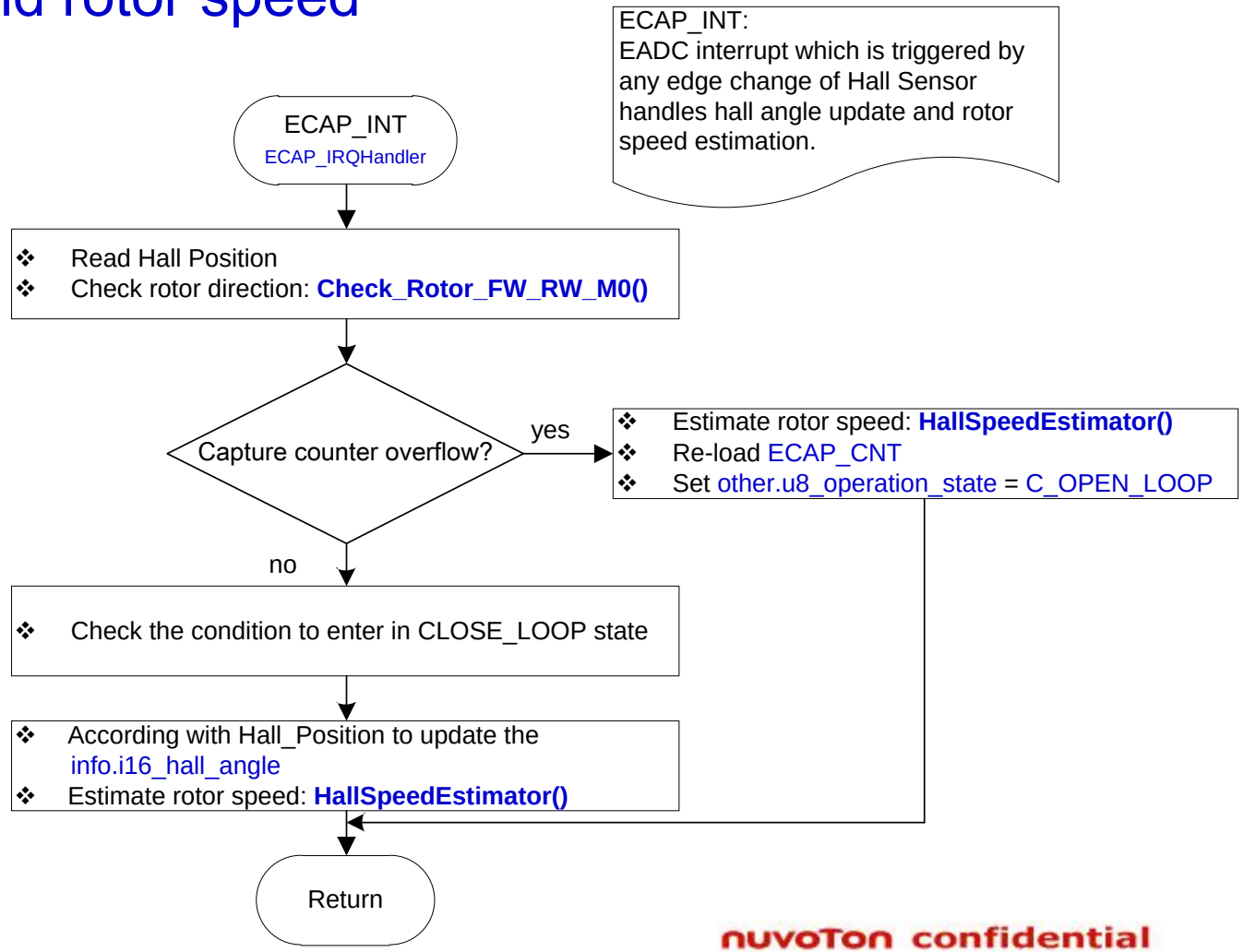
Flow Chart of ECAP_INT(for FOC)

- ECAP INT for capturing hall sensor signals to update the hall angle and rotor speed



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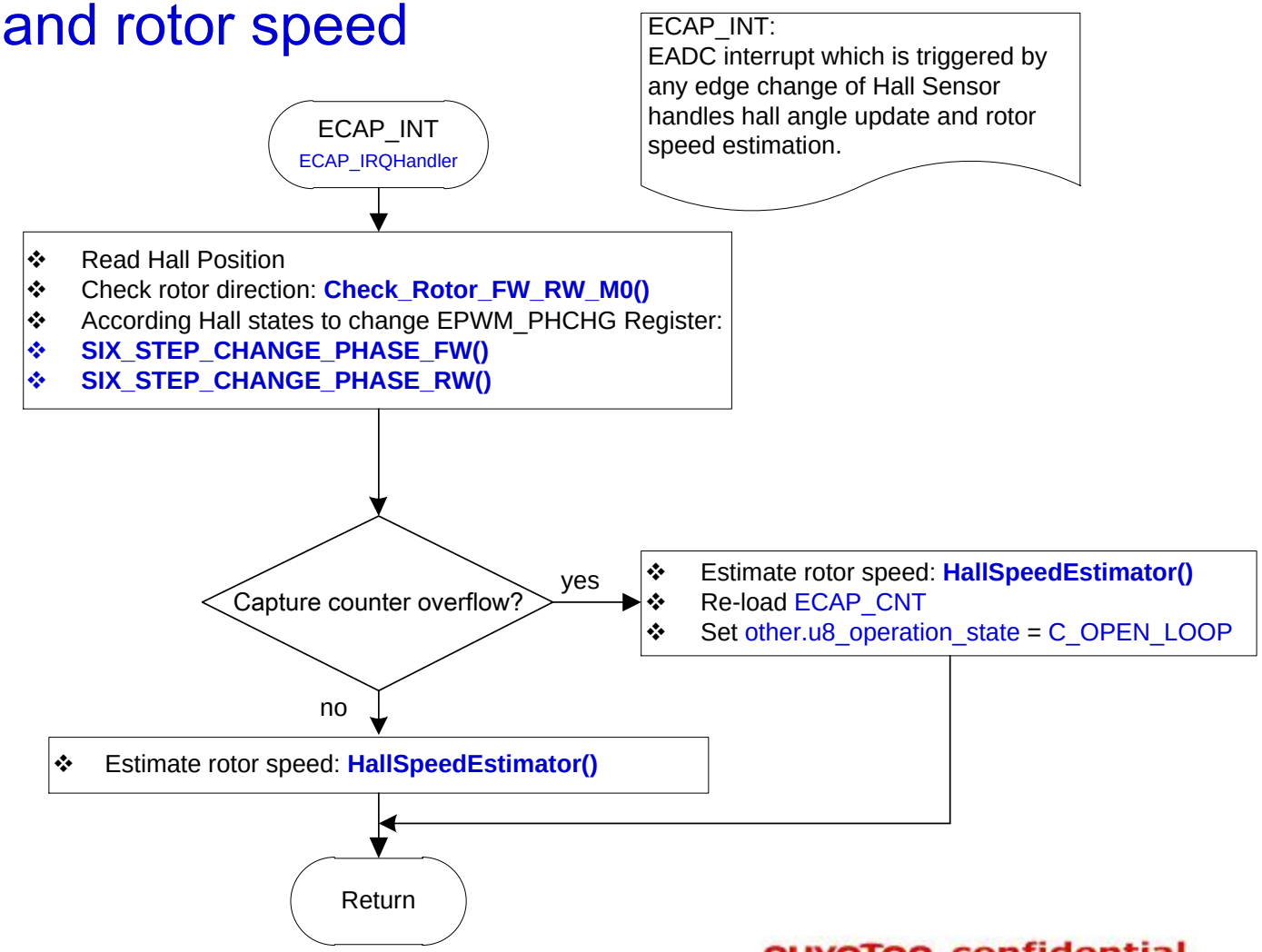
Flow Chart of ECAP_INT(for Six step)

- ECAP INT for capturing hall sensor signals to update the hall angle and rotor speed



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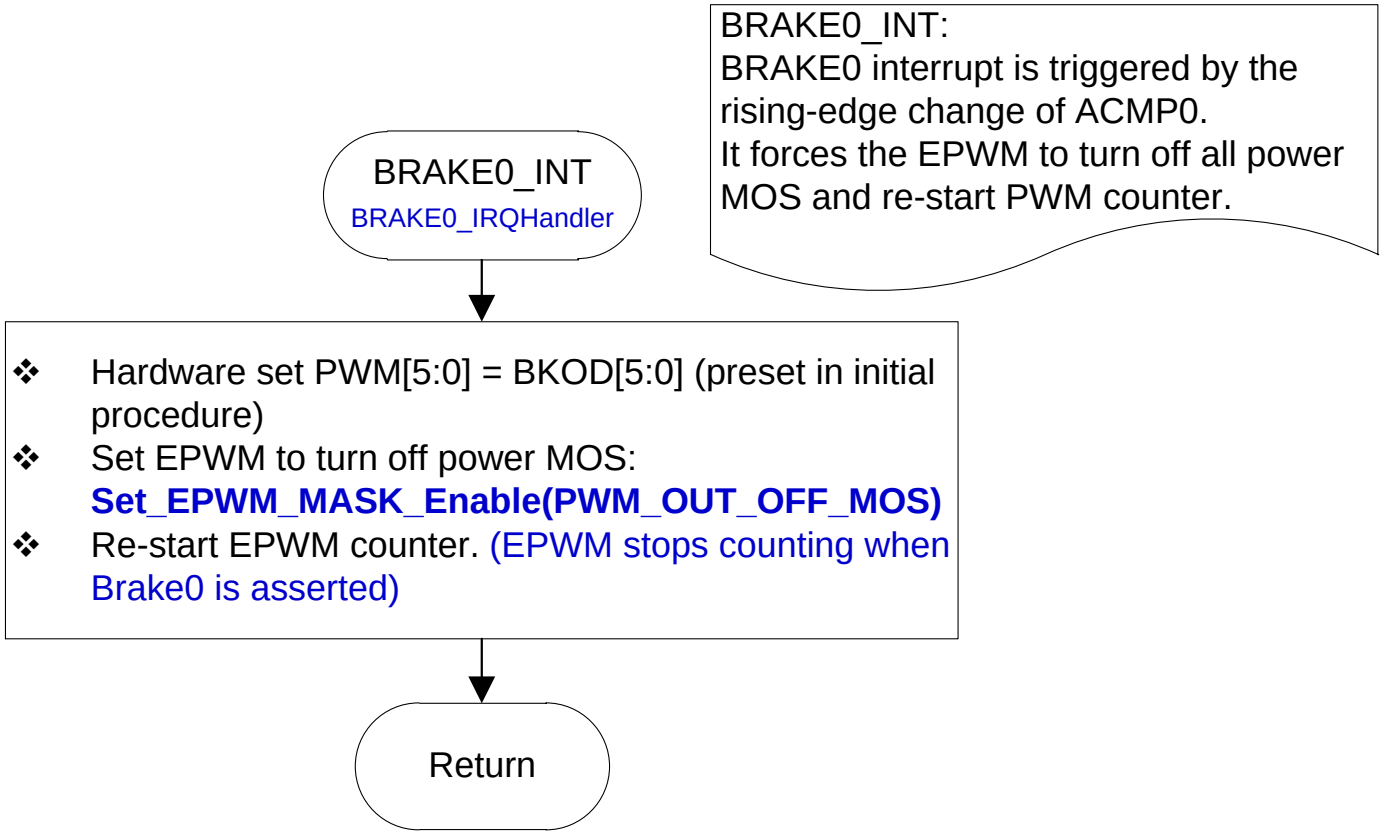
Flow Chart of BRAKE0_INT

- BRAKE0 INT to STOP PWM and turn off MOS when over current



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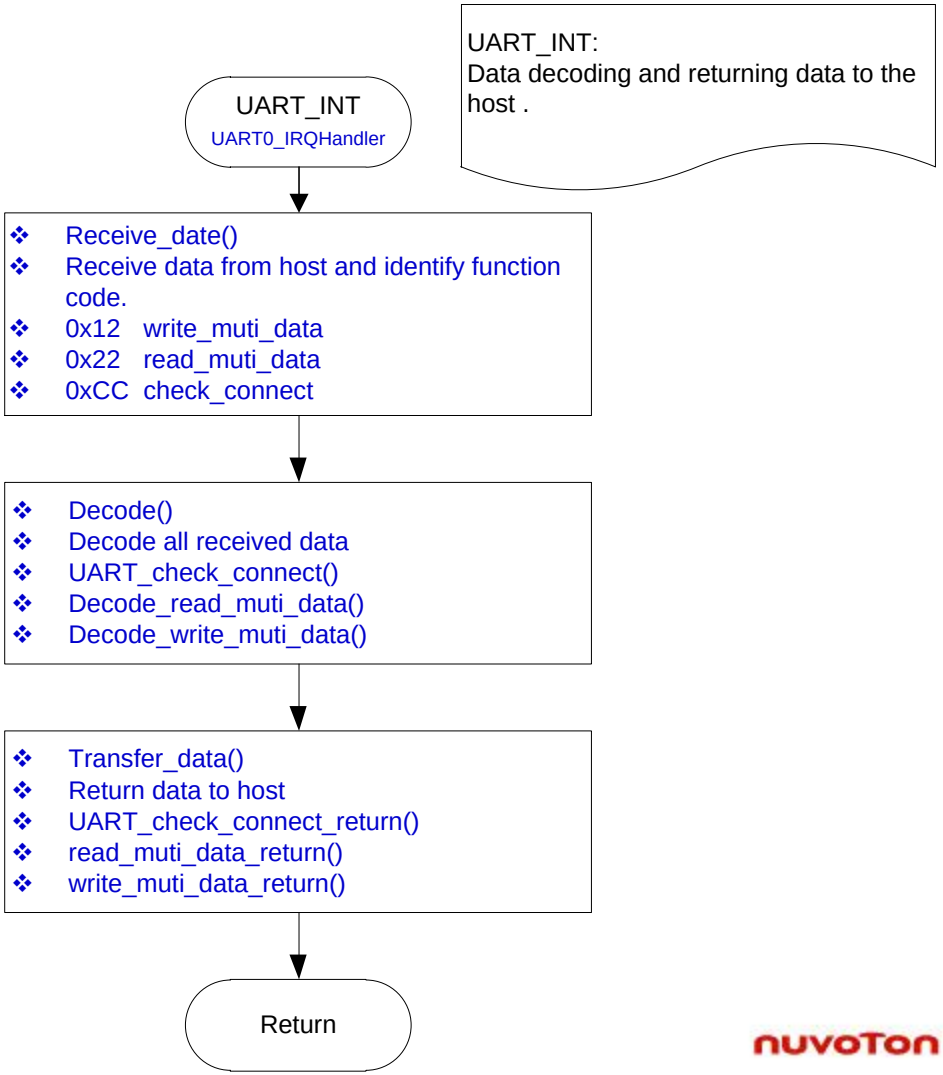
Flow Chart of UART_INT

- UART INT for data decoding and returning data to the host



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Pin Configure in Demo System (I)

- ✓ **Hall sensor (3 pins) by ECAP**
  - (Hw, Hv, Hu) = (P21, P22, P23) = (ECAP2, ECAP1, ECAP0)
- ✓ **Phase current feedback (4 pins) by ADC (for 2-shunt R)**
  - Iu: OP0 = P80(Iu+)，P81(Iu-)
  - Iv: OP1 = P92(Iv+)，P91(Iv-)
- ✓ **Total current feedback (1 pins) by ADC (for 1-shunt R)**
  - Ishunt: ADC0_CH4(AIN4) = P64
- ✓ **Over current detect (1 pin) by ACMP0**
  - I_OC = ACMP0_N = P83
  - I_OC_ref = ACMP0_P = P84
  - Overcurrent point adjust by external VR (R145)
- ✓ **Speed command from VR (1 pin) by ADC**
  - Speed = ADC1_CH3 = P73

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Pin Configure in Demo System (II)

- ✓ **PWM output (6 pin) by EPWM**
  - (PWM5~PWM0) = (P05~P00)
- ✓ **Direction command from RUN switch (1 pin) by GPIO**
  - P85: read the state of RUN switch
- ✓ **Light LED (1 pin) by GPIO**
  - P33: control LED on/off
- ✓ **UART port (2 pin) by UART0**
  - UART0_RXD = P30
  - UART0_TXD = P31
- ✓ **Nu-Link ICE port by SWD**
  - ICE_DAT = P96
  - ICE_CLK = P97

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Pin Configure in Demo System (III)

- ✓ (Optional) DAC module by SPI0
  - SPI0_MOSI = P50
  - SPI0_CLK = P27
  - CS = P47 (GPIO mode)

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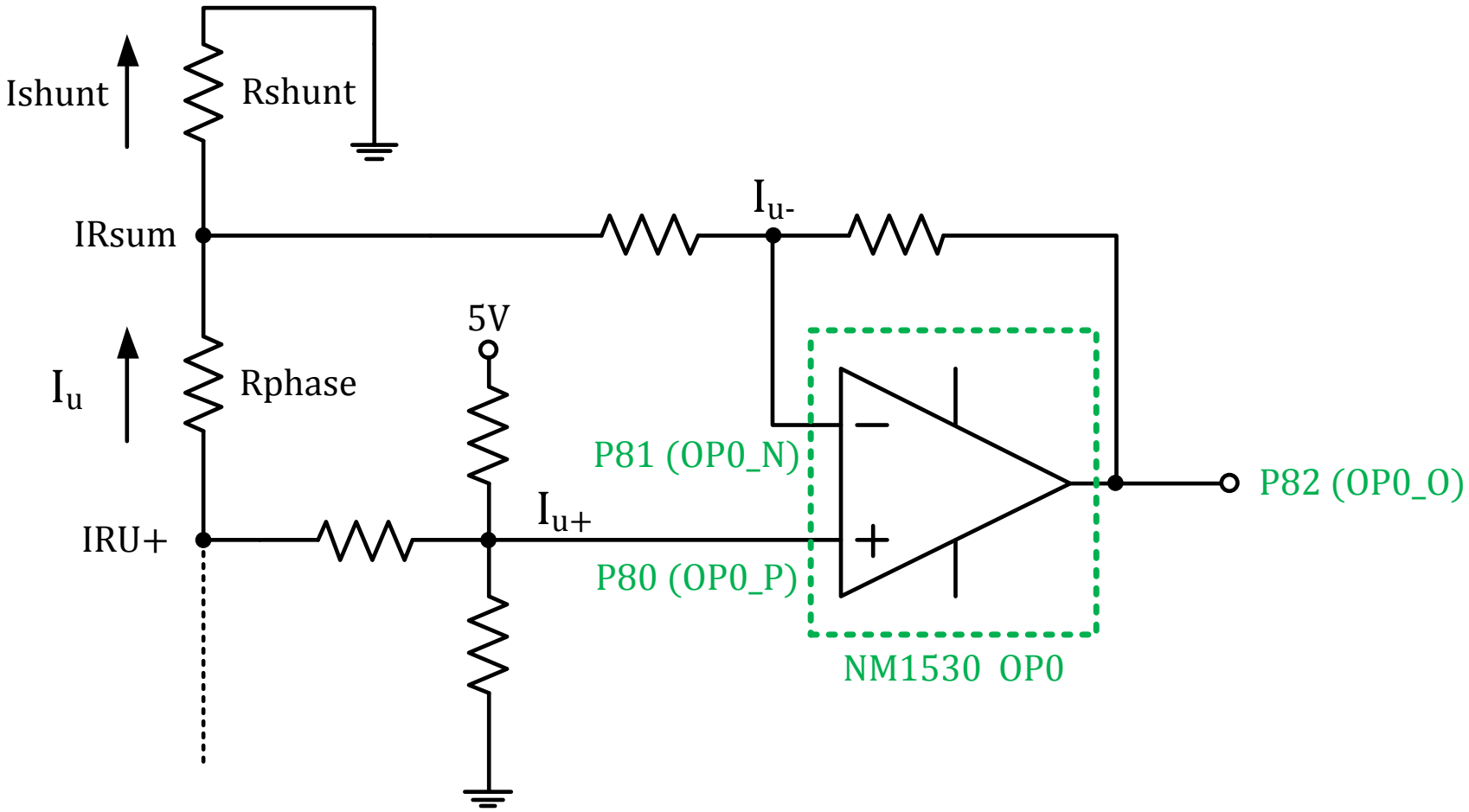
Phase current feedback circuit



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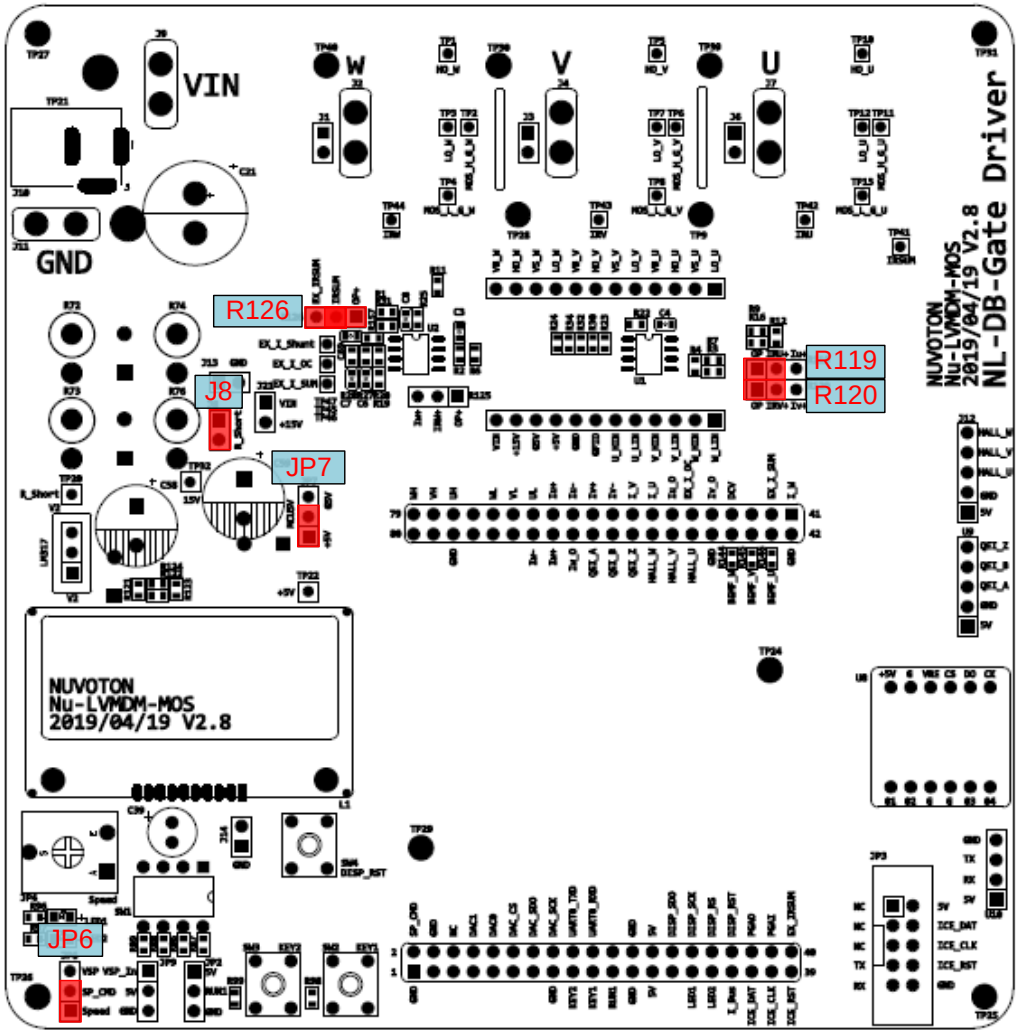
Demo board jumper layout

- R126 : Both OP+ and EX_IRsum short to IRsum



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Control mode selection

- VSP control mode : Rotate VR to make VSP initial voltage < 2.5V before power on .
- UART control mode : Rotate VR to make VSP initial voltage > 2.5V before power on .

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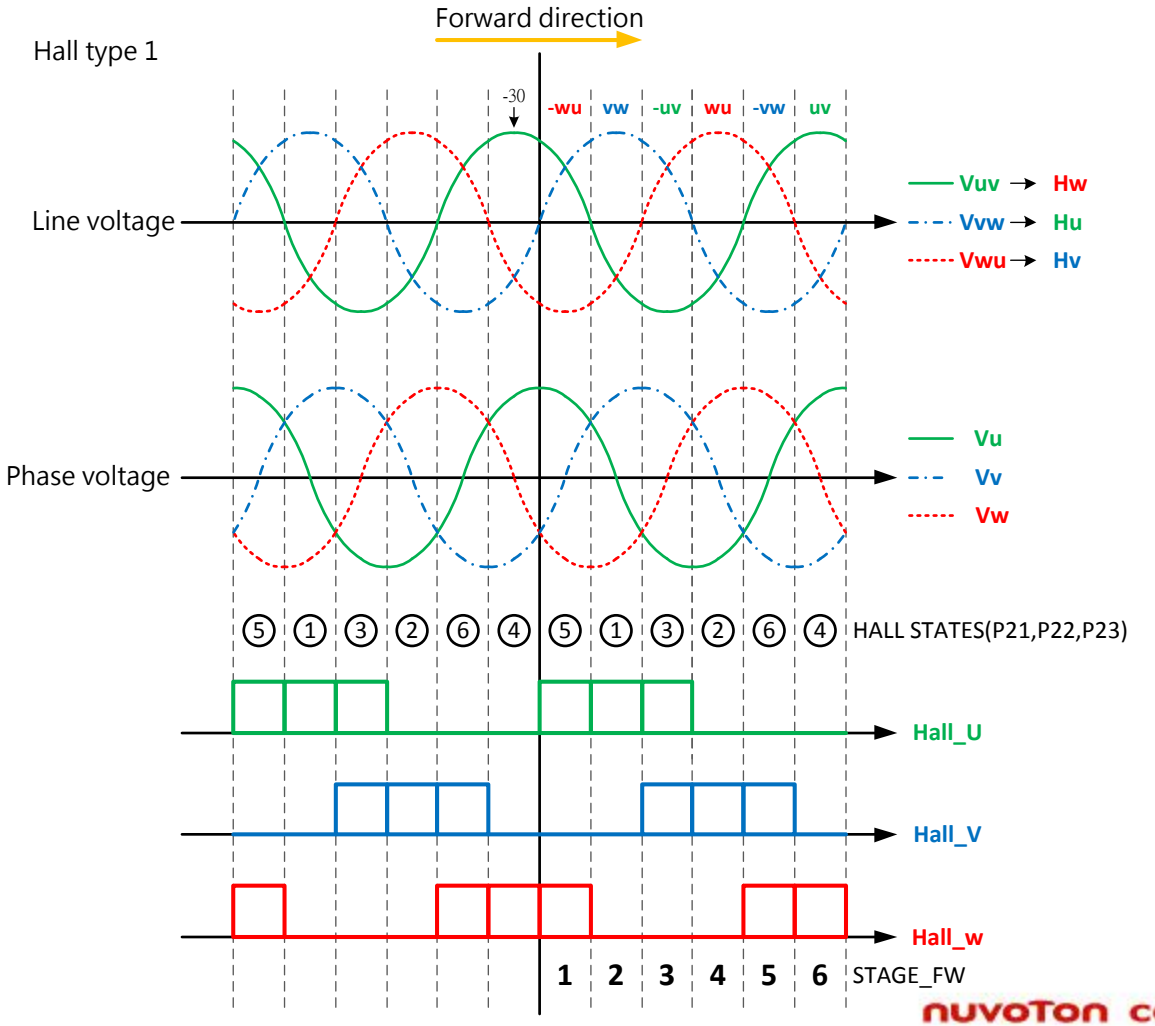
Hall signal correction

- The correspondence between BEMF & hall signal as bellow
- User can correct with line or phase voltage (example: Type 1)



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Hall signal correction

- User can select hall type 0 or type 1 in the example code
- Hall type 0 mean the falling edge of hall signal align phase voltage peak
- Hall type 1 mean the rising edge of hall signal align phase voltage peak

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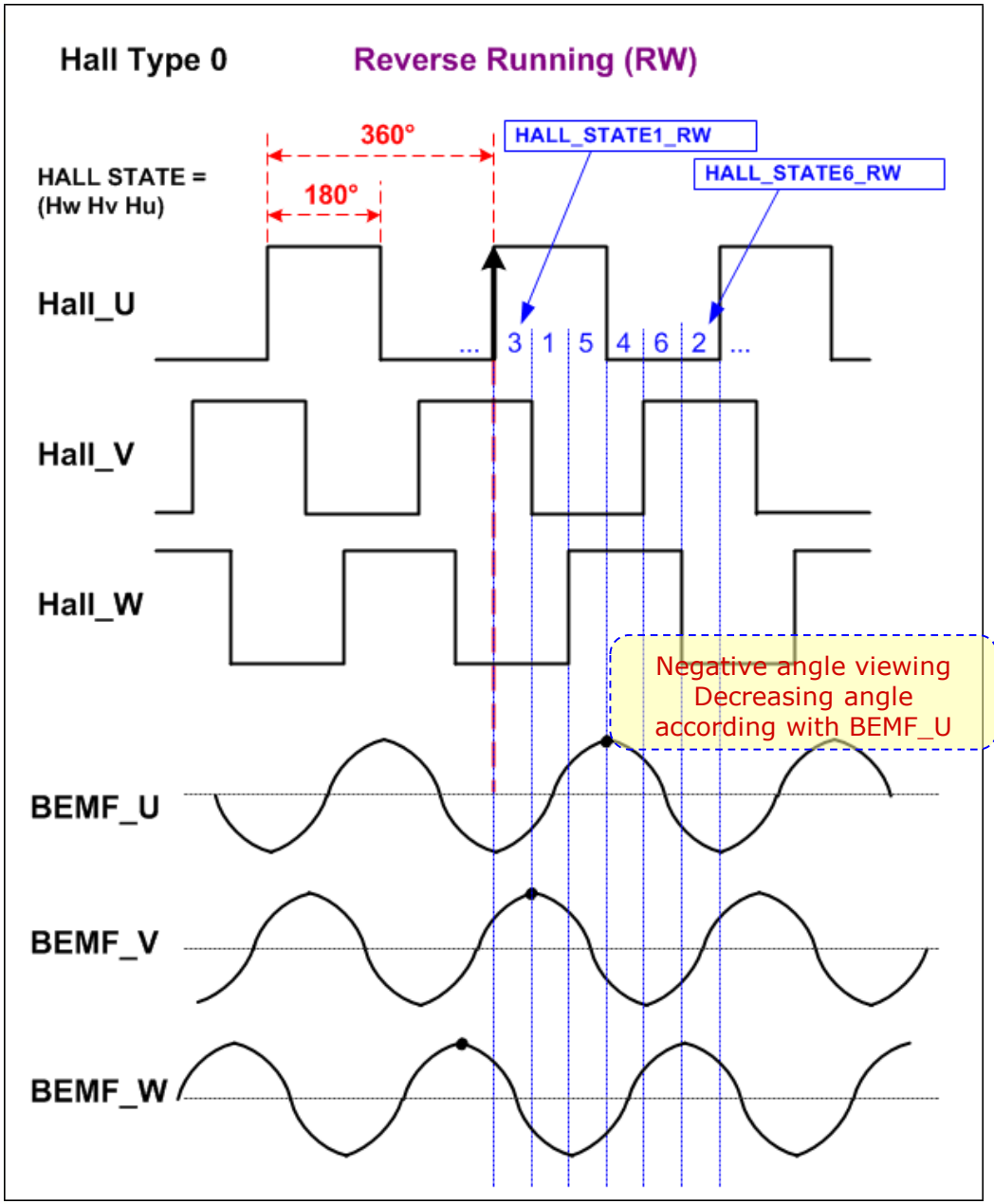
Type0 : Hall and BEMF for RW



Define the 1st hall state right after the rising edge at IC0 as "HALL_STATE1_RW"

Hall Sensor (W,V,U) =
Input Capture (IC2, IC1, IC0) =
I/O Port (P21, P22, P23) =
3, 1, 5, 4, 6, 2…for CCW

```
#define HALL_STATE1_RW  3
#define HALL_STATE2_RW  1
#define HALL_STATE3_RW  5
#define HALL_STATE4_RW  4
#define HALL_STATE5_RW  6
#define HALL_STATE6_RW  2
```

```
#define HALL_STATE1_R_ANGLE
1024*(-90+0)/360

#define HALL_STATE2_R_ANGLE
1024*(-150+0)/360

#define HALL_STATE3_R_ANGLE
1024*(-210+0)/360

#define HALL_STATE4_R_ANGLE
1024*(-270+0)/360

#define HALL_STATE5_R_ANGLE
1024*(-330+0)/360

#define HALL_STATE6_R_ANGLE
1024*(-30+0)/360
```

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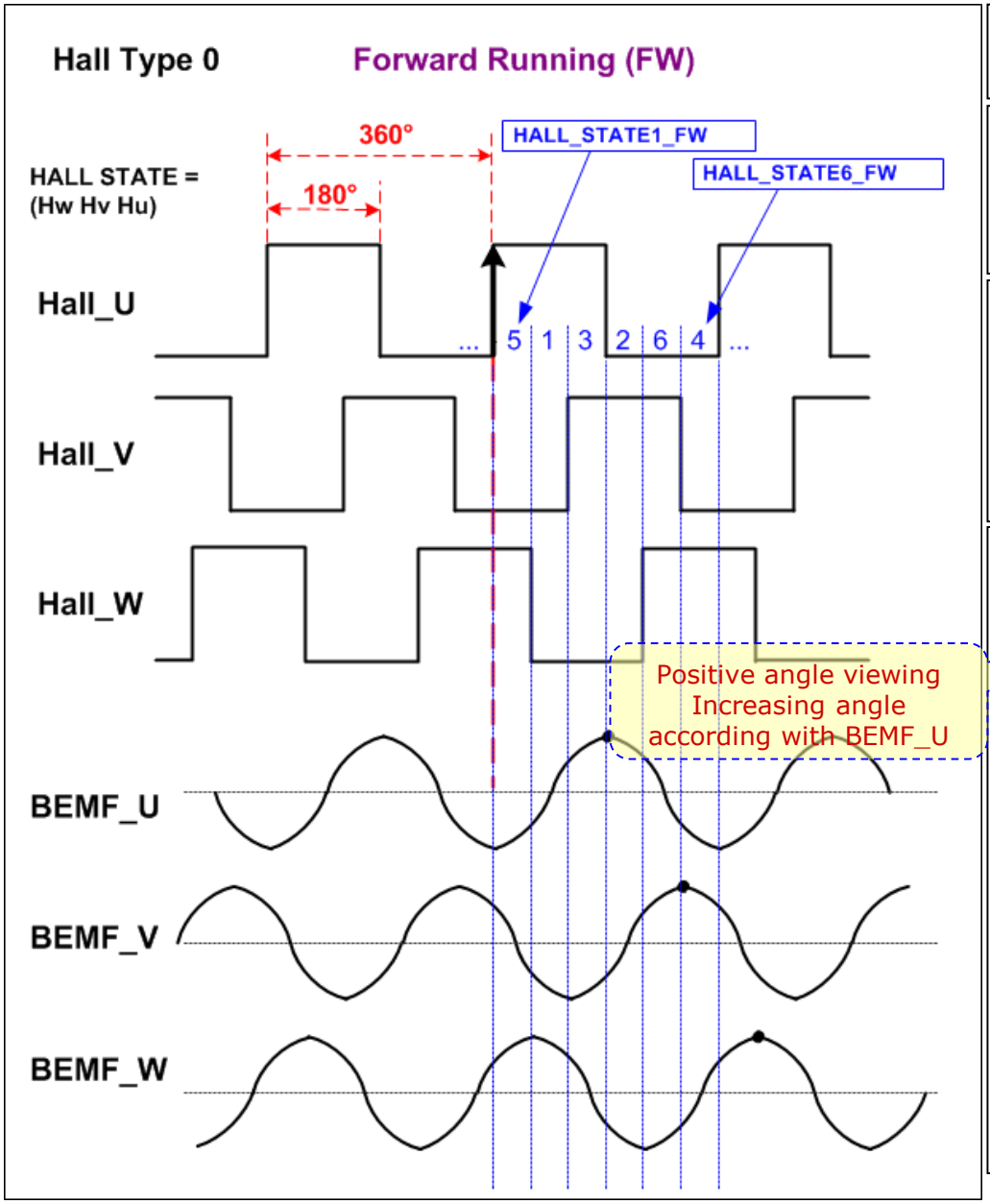
Type0 : Hall and BEMF for FW



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Hall Sensor (W,V,U) =
Input Capture (IC2, IC1, IC0) =
I/O Port (P21, P22, P23) =
5, 1, 3, 2, 6, 4…for FW

```
#define HALL_STATE1_FW  5
#define HALL_STATE2_FW  1
#define HALL_STATE3_FW  3
#define HALL_STATE4_FW  2
#define HALL_STATE5_FW  6
#define HALL_STATE6_FW  4
```

```
#define HALL_STATE1_F_ANGLE
1024*(270+0)/360 + SHIFT_180

#define HALL_STATE2_F_ANGLE
1024*(330+0)/360 + SHIFT_180

#define HALL_STATE3_F_ANGLE
1024*(30+0)/360  + SHIFT_180

#define HALL_STATE4_F_ANGLE
1024*(90+0)/360 + SHIFT_180

#define HALL_STATE5_F_ANGLE
1024*(150+0)/360 + SHIFT_180

#define HALL_STATE6_F_ANGLE
1024*(210+0)/360 + SHIFT_180
```

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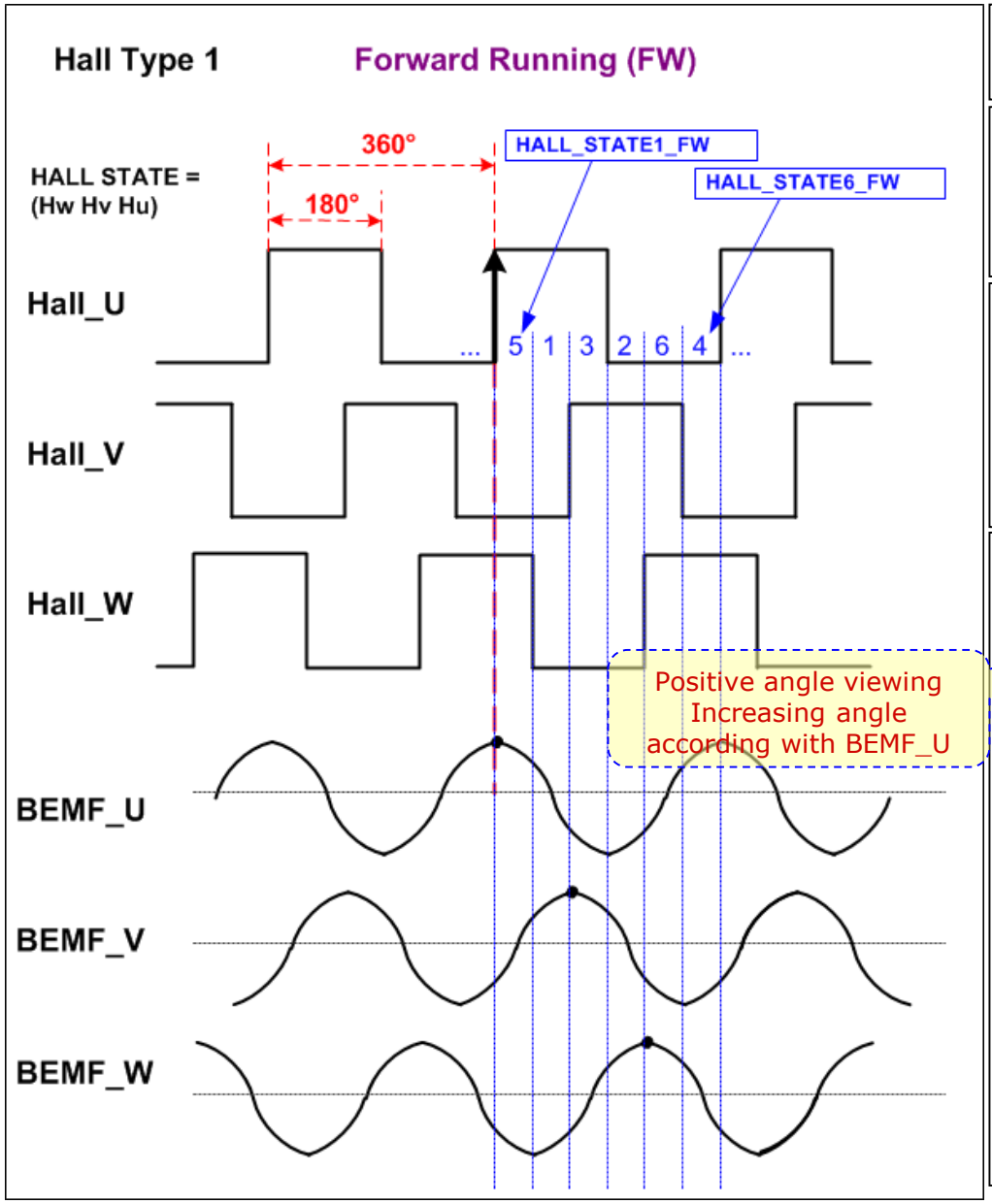
Type1 : Hall and BEMF for FW



Define the 1st hall state right after the rising edge at IC0 as "HALL_STATE1_FW"

Hall Sensor (W,V,U) =
Input Capture (IC2, IC1, IC0) =
I/O Port (P21, P22, P23) =
5, 1, 3, 2, 6, 4…for FW

```
#define HALL_STATE1_FW  5
#define HALL_STATE2_FW  1
#define HALL_STATE3_FW  3
#define HALL_STATE4_FW  2
#define HALL_STATE5_FW  6
#define HALL_STATE6_FW  4
```

```
#define HALL_STATE1_F_ANGLE
1024*(90+0)/360 + SHIFT_180

#define HALL_STATE2_F_ANGLE
1024*(150+0)/360 + SHIFT_180

#define HALL_STATE3_F_ANGLE
1024*(210+0)/360  + SHIFT_180

#define HALL_STATE4_F_ANGLE
1024*(270+0)/360 + SHIFT_180

#define HALL_STATE5_F_ANGLE
1024*(330+0)/360 + SHIFT_180

#define HALL_STATE6_F_ANGLE
1024*(30+0)/360 + SHIFT_180
```

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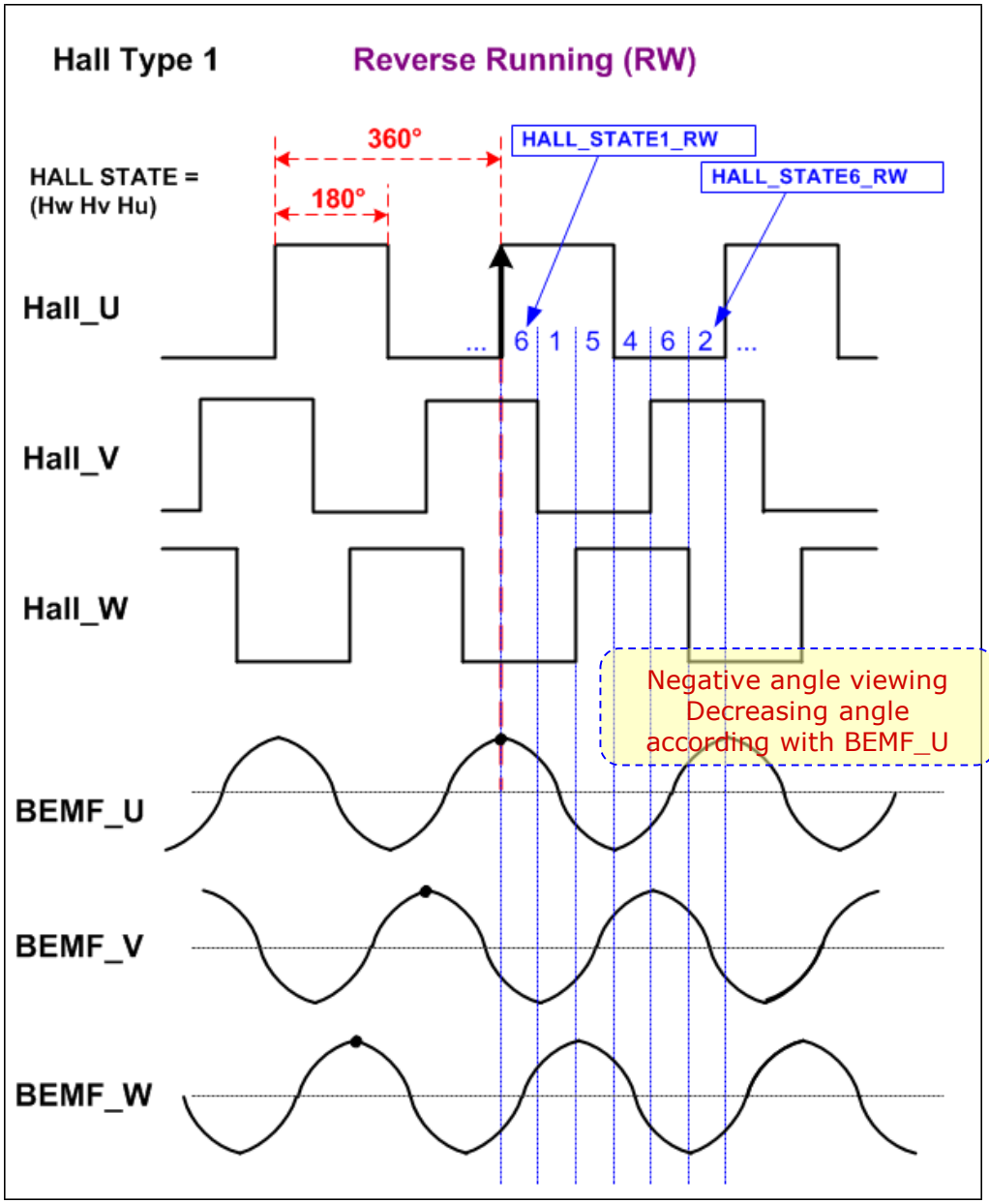
Type1 : Hall and BEMF for RW



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Input Capture (IC2, IC1, IC0) =
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3, 1, 5, 4, 6, 2…for CCW

```
#define HALL_STATE1_RW  3
#define HALL_STATE2_RW  1
#define HALL_STATE3_RW  5
#define HALL_STATE4_RW  4
#define HALL_STATE5_RW  6
#define HALL_STATE6_RW  2
```

```
#define HALL_STATE1_R_ANGLE
1024*(-270+0)/360

#define HALL_STATE2_R_ANGLE
1024*(-330+0)/360

#define HALL_STATE3_R_ANGLE
1024*(-30+0)/360

#define HALL_STATE4_R_ANGLE
1024*(-90+0)/360

#define HALL_STATE5_R_ANGLE
1024*(-150+0)/360

#define HALL_STATE6_R_ANGLE
1024*(-210+0)/360
```

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END