Application Note

16

RL78
BLDC Motor Control

16-bit Single-Chip Microcontroller

RL78/G14
RL78/F13
RL78/F14

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1. Handling of Unused Pins
   Handle unused pins in accord with the directions given under Handling of Unused Pins in the manual.
   - The input pins of CMOS products are generally in the high-impedance state. In operation with an unused pin in the open-circuit state, extra electromagnetic noise is induced in the vicinity of LSI, an associated shoot-through current flow internally, and malfunctions occur due to the false recognition of the pin state as an input signal become possible. Unused pins should be handled as described under Handling of Unused Pins in the manual.
2. Processing at Power-on
   The state of the product is undefined at the moment when power is supplied.
   - The states of internal circuits in the LSI are indeterminate and the states of register settings and pins are undefined at the moment when power is supplied.
     In a finished product where the reset signal is applied to the external reset pin, the states of pins are not guaranteed from the moment when power is supplied until the reset process is completed.
     In a similar way, the states of pins in a product that is reset by an on-chip power-on reset function are not guaranteed from the moment when power is supplied until the power reaches the level at which resetting has been specified.
3. Prohibition of Access to Reserved Addresses
   Access to reserved addresses is prohibited.
   - The reserved addresses are provided for the possible future expansion of functions. Do not access these addresses; the correct operation of LSI is not guaranteed if they are accessed.
4. Clock Signals
   After applying a reset, only release the reset line after the operating clock signal has become stable. When switching the clock signal during program execution, wait until the target clock signal has stabilized.
   - When the clock signal is generated with an external resonator (or from an external oscillator) during a reset, ensure that the reset line is only released after full stabilization of the clock signal. Moreover, when switching to a clock signal produced with an external resonator (or by an external oscillator) while program execution is in progress, wait until the target clock signal is stable.
5. Differences between Products
   Before changing from one product to another, i.e. to one with a different part number, confirm that the change will not lead to problems.
   - The characteristics of MPU/MCU in the same group but having different part numbers may differ because of the differences in internal memory capacity and layout pattern. When changing to products of different part numbers, implement a system-evaluation test for each of the products.

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Chapter 1 Overview

1.1 Abstract

This Application Note shows the implementation of 3-phase BLDC motor drive by 120-degree trapezoidal wave commutation using Renesas MOSFET pre-driver R2A25104KFP and Motor Control Timer RD. The method shown utilizes the HALL sensors in the motor to determine the motors rotor position.

This example applies to MCUs in the RL78/G14, *RL78/F13, *RL78/F14 Group.

* RL78/F13, RL78/F14 are under development.

1.2 Conditions

The explanation of this issue is applied to the following condition:

Applicable MCU: RL78/G14 Group (Device R5F104LE-TB)

MCU operational frequency: 32 MHz

Memory size: ROM 64 KB, RAM 5,5 KB

MCU Supply Voltage: 5V

Peripherals: Timer RD for PWM motor drive

MOSFET Inverter pre-driver: R2A25104KFP

1.3 Introduction

Brushless DC motors (BLDC-motors) are controlled using a three phase power semiconductor inverter bridge. The motor controller requires a rotor position feedback signal for providing the proper commutation sequence to the motor via the power devices in the inverter bridge. Hall sensors are typically used to provide the rotor position feedback.

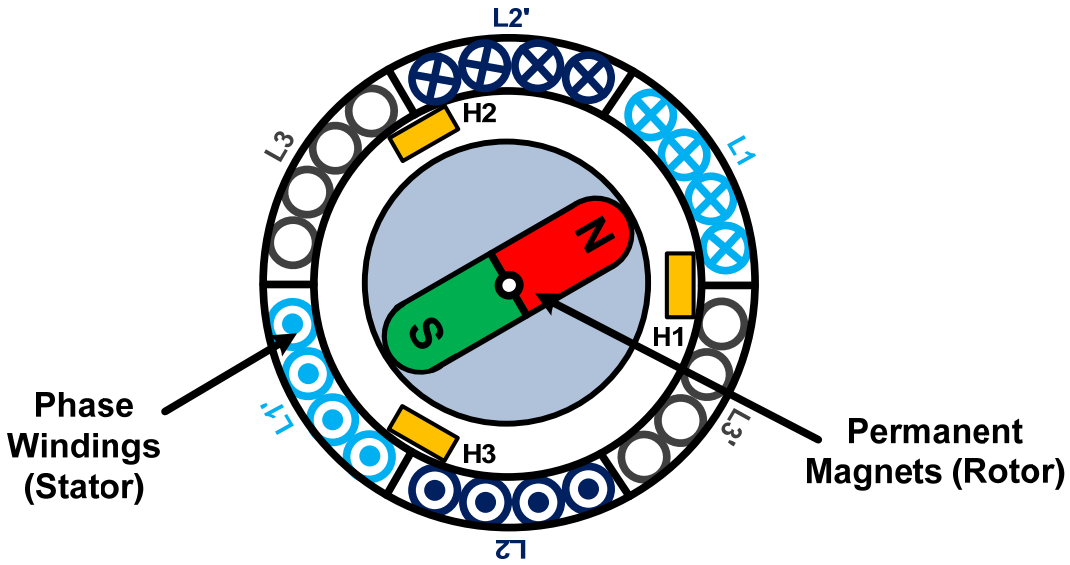
In this application note we will take a look at the RL78/G14 Group driving a 3-phase BLDC motor using the 120° trapezoidal method, also referred to a 6-step. The 6-step method is one of the simplest methods for driving 3-phase BLDC motors. In the past it was done by using discrete logic gates but with the more powerful peripherals available in today's microcontrollers, such as the RL78 family, we can provide more functionality, better energy usage and higher safety level when driving motors.

The inverter bridge is pre-driven by an intelligent Power Device R2A25104KFP.

Chapter 2 3-Phase BLDC Motor Basics

The structure of the BLDC motor is divided into two parts: The moving part, the rotor, consists of a permanent magnet, and the fixed part, the stator, consisting of phase windings for generating an electromagnetic field.

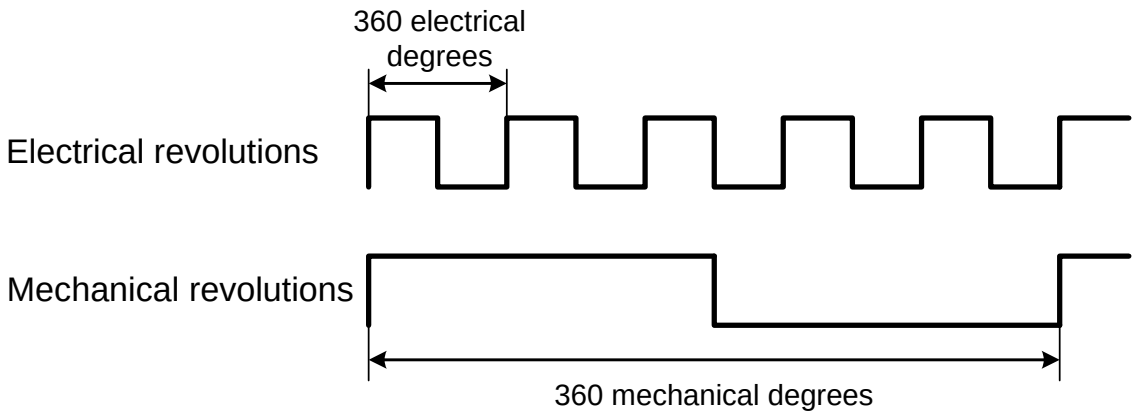
Figure 1 3-Phase BLDC motor with one pole pair permanent magnet



The rotor is attracted to the electromagnetic field caused by the energized stator windings and starts to rotate. With an appropriate electromagnetic rotating field on the stator, the rotor follows the electromagnet poles and a rotation of the permanent magnet is created and maintained.

The number of the permanent magnet poles can vary. A greater number of poles creates a greater torque for the same current level. For this Application Note a motor with 10 poles is used which means 5 pole pairs (2 poles = 1 pole pair). It defines also the ratio between electrical and mechanical revolution of the motor, which is described in Figure 2.

Figure 2 Relationship between the electrical and mechanical revolution of the motor (5 pole pairs)



The relationship between the electrical and mechanical revolution is given in equation **(1)**.

$$\omega e = p * \omega m \qquad \textbf{(1)}$$

In this equation p is the number of pole pairs of the motor, ωe the electrical speed and ωm the motor speed or speed of the rotor. For example a BLDC motor with 5 pole pairs comes to following equation **(2)**.

$$\omega m = \frac{\omega e}{5} \qquad \textbf{(2)}$$

This means the electromagnetic field in the stator has to rotate five times to produce one mechanical turn of the rotor as shown in **figure 2** above.

The rotor position, which is needed for the synchronization between rotor and rotating field, can be detected using 3 Hall sensors (sensored mode) or Back-EMF detection of the motor (sensorless mode).

In this Application Note we use the sensored mode in which the Hall sensors H1, H2, H3 in the motors are displaced by 120° to each other.

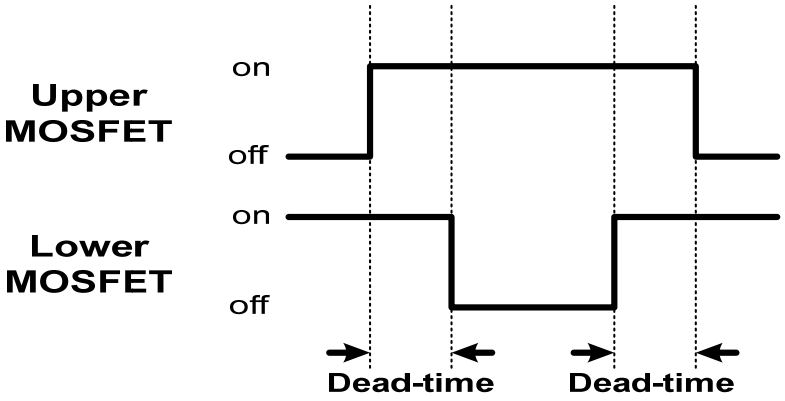
The lack of the brushes in the BLDC motor requires electronic commutation to produce the rotating field on the stator. An external circuit, known as an Inverter circuit, performs the electronic commutation. The topology and the function of the Inverter are described in the next section.

Chapter 3 3-Phase Inverter Topology

3.1 General Inverter Topology

Figure 4 shows the basic Inverter topology for driving 3-phase motors. In case of this application note the control electronics is the RL78/G14. It is important to note that it requires 6 outputs to drive the Inverter section. Timer RD in the RL78 family is perfectly suited for this task and supports “dead-time” to prevent “shoot-through” current on the MOSFETs (figure 3).

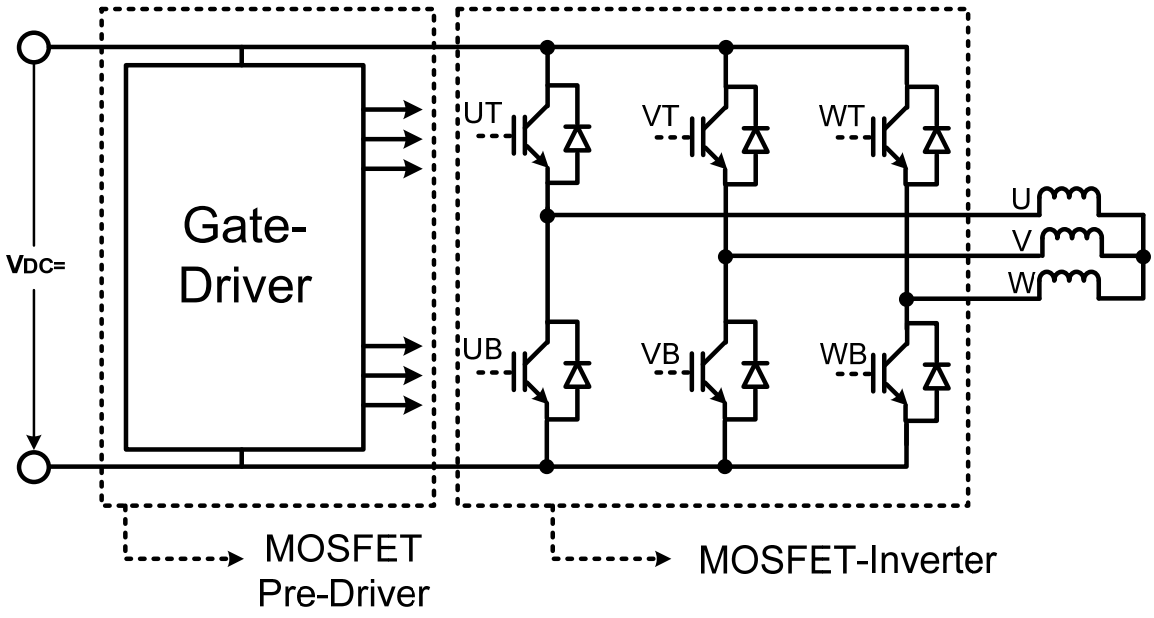
Figure 3 Dead-time



If Inverter is build on MOSFETs it is necessary to pre-drive the gates, because every MOSFET has an oxide-insulated gate electrode which builds a capacitor into the transistor. At every changing process this internal capacitor has to be reloaded as fast as possible. For this task the intelligent pre-driver R2A25104KFP suits ideally.

The main parts of the R2A25104KFP are described in the next section.

Figure 4 Three-Phase Inverter and motor connections



The circuit contains 6 MOSFETs connected to the high and low side of the DC supply. UT, VT and WT are the high side (upper) transistors and UB, VB and WB are the low side (lower) transistors of the circuit.

3.2 Intelligent Power Device for MOSFET Pre-drive (R2A25104KFP)

3.2.1 Description

R2A25107KFP device is an intelligent Power Device to pre-drive the FET inverter used to drive the three phase brushless motor. This device contains three sets of pre-drivers and is applicable to be used in systems using supply voltages between 7V and 36V.

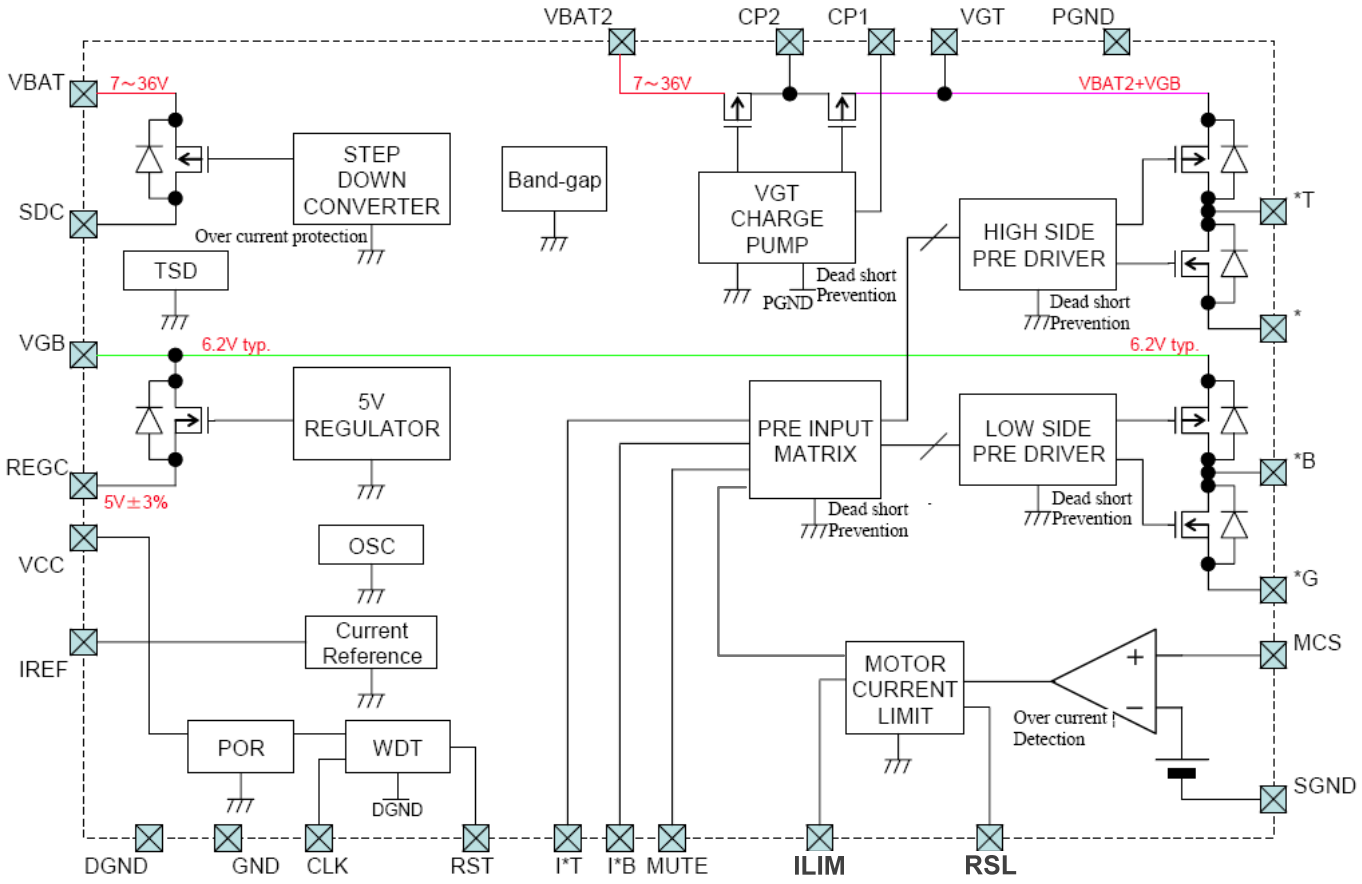
The integrated circuit contains step down converter, charge pump circuit for the power supply of upper side FET drive, 5V series regulator, watchdog timer, protection circuits as thermal shut down circuit (TSD) and over current detection circuit.

3.2.2 Features

- Wide range operating voltage; 7V to 36V (VBAT, VBAT2)
- On-chip Three phase pre-driver circuit
  - PWM control; up to 20KHz
  - Totem pole type MOSFET gate drive circuit
- On-chip power supplies
  - Step down converter; 6.2V typ.
  - Charge pump circuit for power supply of upper side FET drive; >5V
  - 5V series regulator for MCU; <70mA
- On-chip protections
  - Thermal shut down circuit (TSD)
  - Over current of step down converter
  - Over current detection of motor current
- Watchdog timer circuit (WDT)
- Bandgap reference circuit
- Internal oscillation circuit; 265KHz typ
- 48pin LQFP package

3.2.3 Structure of R2A25104KFP

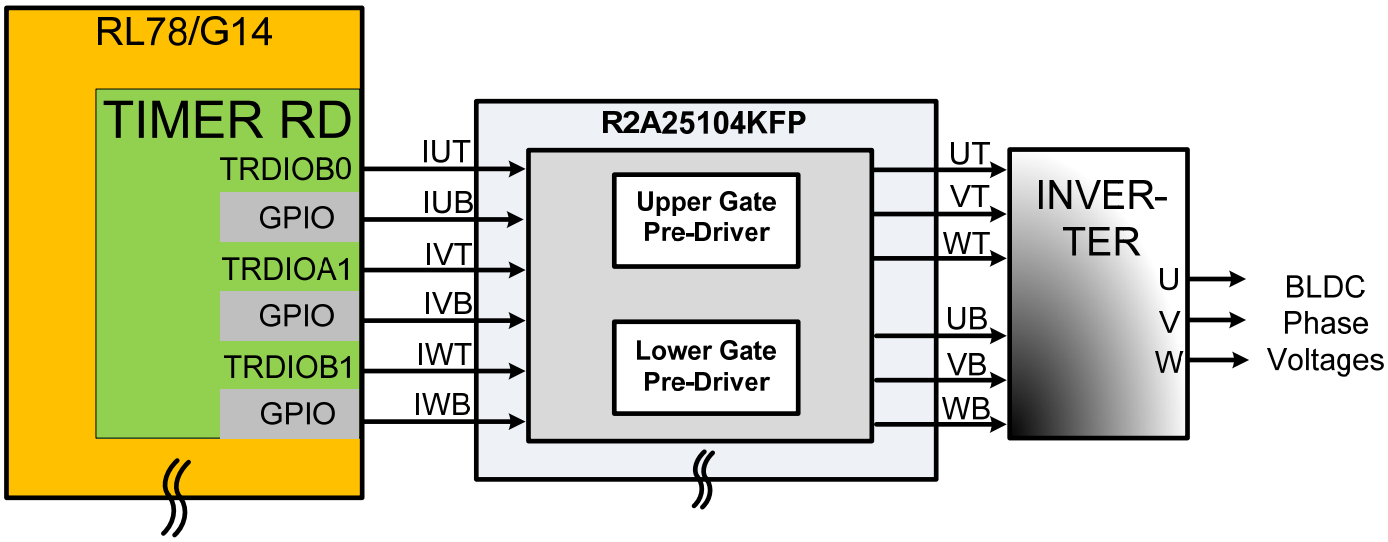
Figure 5 Block Diagram of R2A25104KFP



3.3 RL78/G14 Specific Inverter Topology

Figure 6 shows the specific architecture of the motor control board connected to the RL78/G14.

Figure 6 Block Diagram of RL78/G14 Inverter Control



Note: *Shows the pre-driver part only*

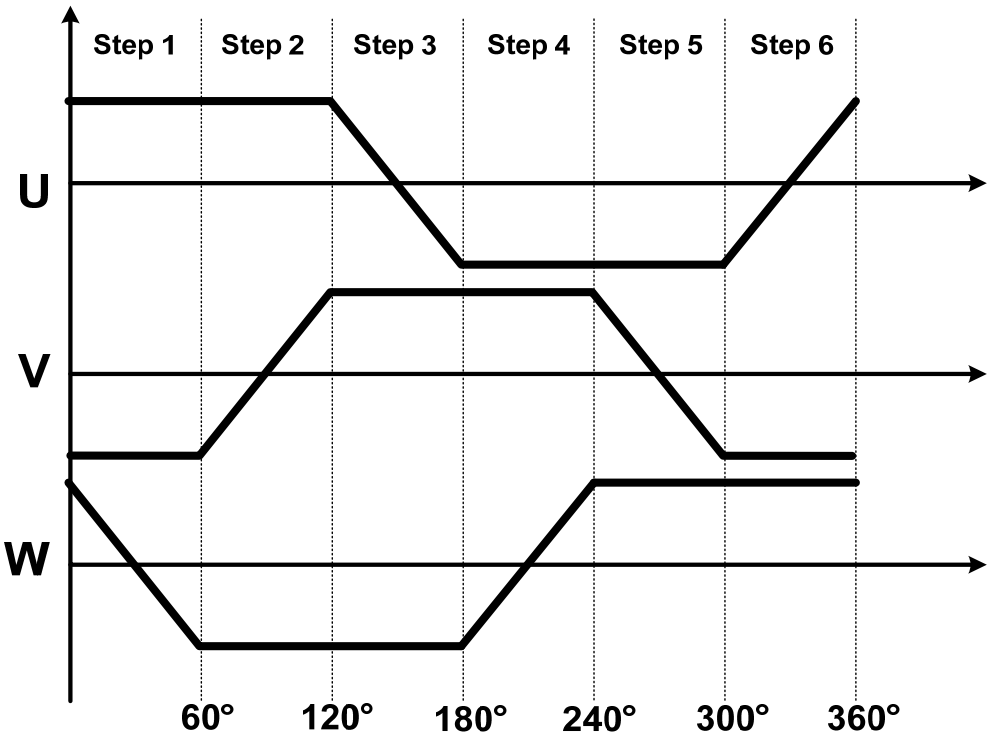
The Gates of the upper MOSFETs are modulated by Timer RD. The low site MOSFETs are driven by general I/O port (upper Modulation).

Chapter 4 Basics of Trapezoidal Commutation (6-step)

The 6-step method is one of the simplest methods for driving 3-phase BLDC motors. It is also known as 120-Degree trapezoidal, since it drives each winding for 120-degrees of the electrical rotation and leaves the winding un-driven for 60 degrees. The phase currents of trapezoidal commutation are shown in figure 7.

Please note, although the drive method is simple, this lack of drive for 60 degrees also results in higher torque ripple in the end application. The system designer must decide if this is acceptable or other drive methods should be considered.

Figure 7 Phase Currents of Trapezoidal Commutation

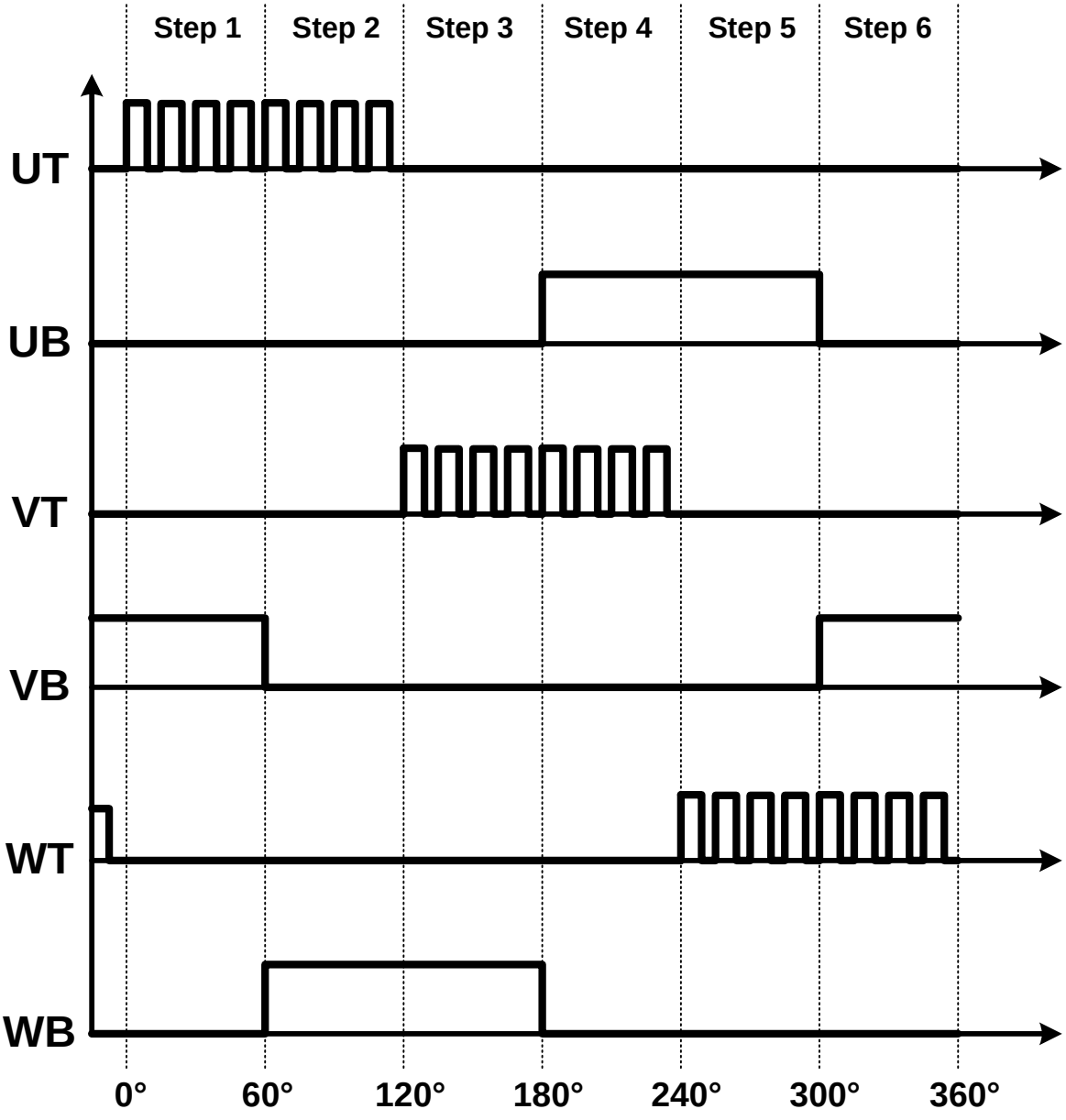


4.1 Controlling Phase Voltage

In chapter 3.3 we showed how we will connect the microcontroller to the power inverter stage to control the gates of the MOSFETs. The speed of the motor is directly proportional to the applied voltage. To vary the speed, one or both of the transistors in the excited pair can be pulse width modulated to produce a variable average DC voltage. Maximum speed is achieved when both transistors are on for 100% of the commutation period so that the full supply voltage is applied to the motor.

Typically modulation techniques are Upper modulation, Lower Modulation, Rotating Modulation or Balanced Modulation. For this application note we will be showing Upper modulation only. Figure 8 shows the basic Upper modulation waveforms. Please note that in this method only the “T” or upper MOSFETs are modulated. UT, VT, WT are the upper transistors and UB, VB, WB are the low site transistors which are set by general purpose ports. U, V, W are the resulting phase voltages.

Figure 8 Upper Modulation



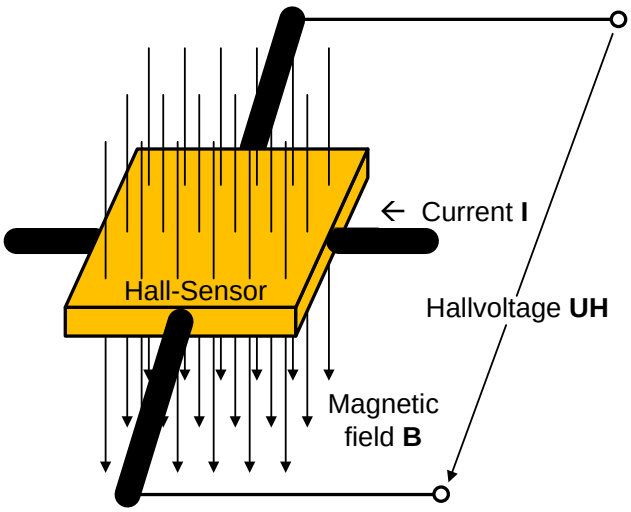
NOTE: *Timer RD in the RL78 Family can do any of the modulation techniques and is not limited to single-sided modulation techniques. This would include sinusoidal modulation for other motor types such as 3-phase induction.*

4.2 Rotor Position

We can control voltage on the windings (and indirectly the current) by using a PWM timer, but we must present these signals in the appropriate sequence to properly commutate the motor. In order to do this we must know the rotor position. We will achieve this by the Hall sensors which sense the position of the rotor by using the Hall Effect (figure 9 left site). The sensors can do this because they are positioned relatively to each motor phase winding in the stator coils (see figure 9 right site). Figure 10 shows a typical HALL cell signature. Please note that the state changes every 60° for one electrical cycle. Interrupt input pins of RL78 allow us to read the hall signal and the control software decode them into a 60° rotor position.

In the below figure a motor with 1 pole pair is used, whereas the motor in this application note has 5 pole-pairs.

Figure 9 Hall Effect Hall Positioning



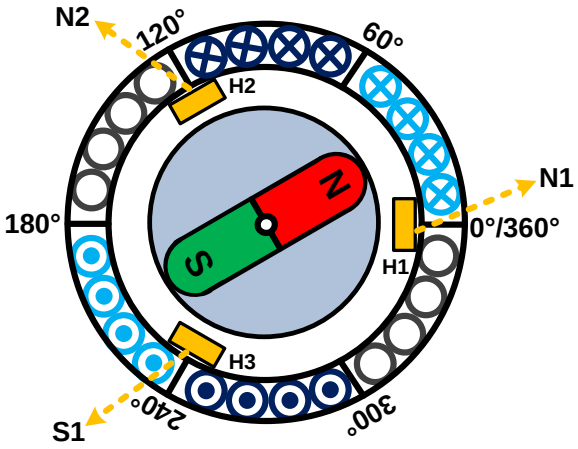
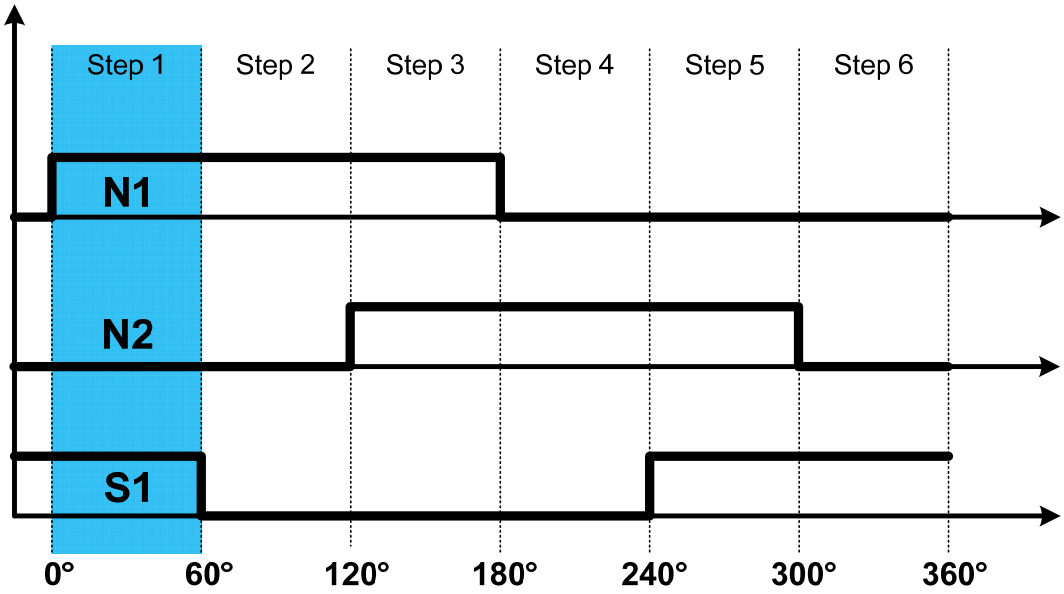


Figure 10 Typical Hall Signature



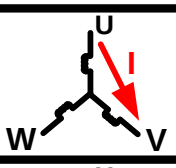
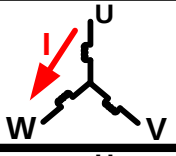
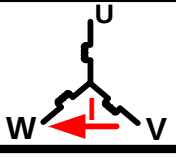
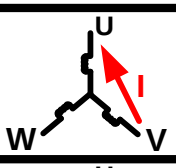
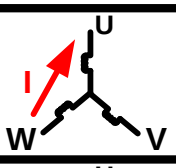
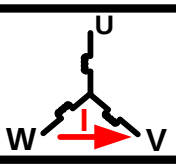
4.3 Commutating

So now we can control the voltage, we know where the rotor is so let's put them together.

A motor manufacturer's data sheet will typically tell you "…when you see this HALL signature, drive these phase windings". Figure 11 shows a typical commutation sequence. For this motor, when we see the HALL signature for STEP1, we drive UT and VB. The rotor will move because torque is being caused by the magnetic fields in the stator coils at the correct angle to the magnets on the rotor. When we see the Hall signature change state to indicate Step 2, we switch commutation sequence from UT and VB to UT and WB, and the rotor will continue to move.

This will continue for the entire cycle until we are back at step one and the process repeats.

Figure 11 Typical Commutation Sequence

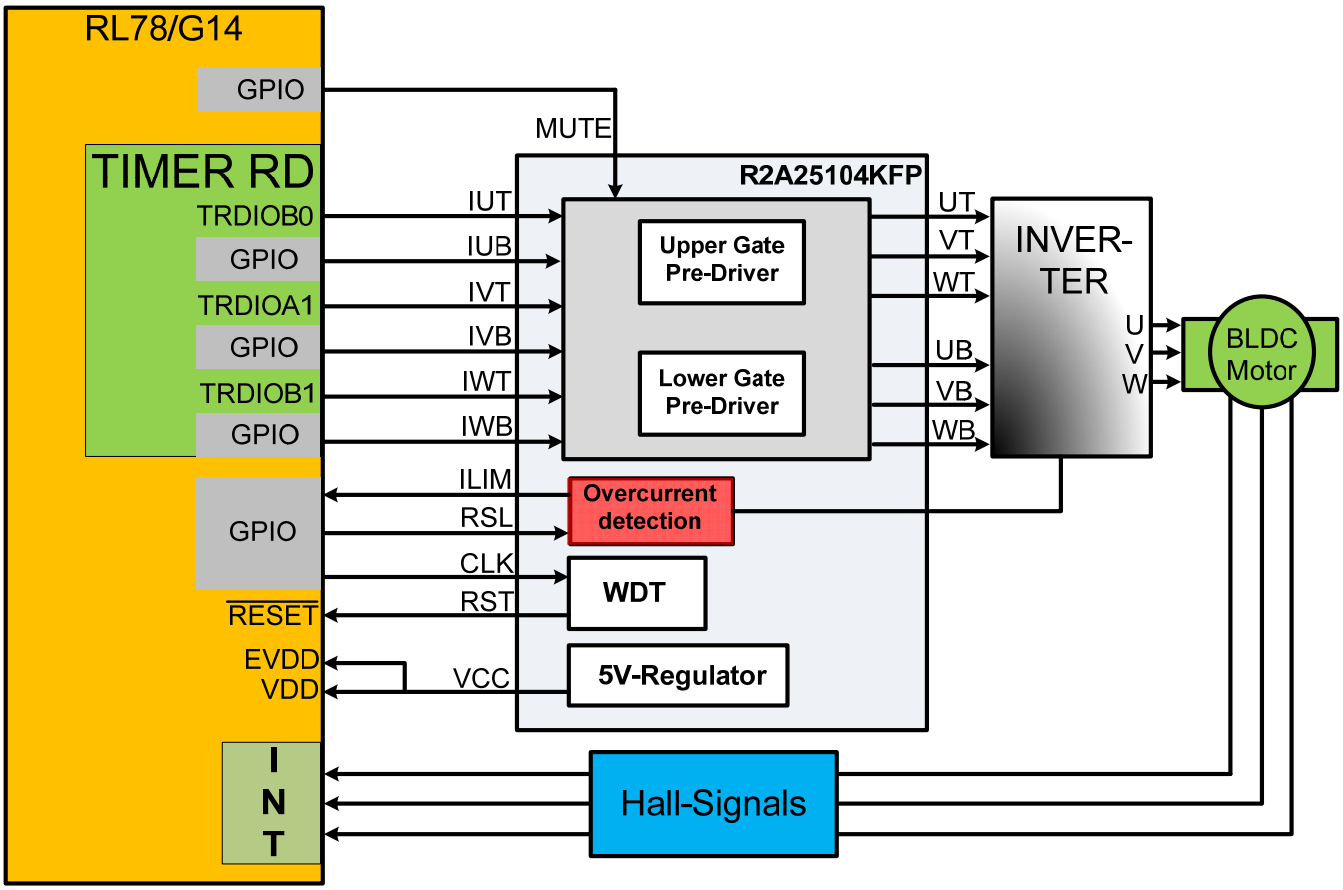
	Transistor			Graphic	Angle
Step 1	**UT**	VT	WT		0° - 60°
	UB	**VB**	WB		
Step 2	**UT**	VT	WT		60° - 120°
	UB	VB	**WB**		
Step 3	UT	**VT**	WT		120° - 180°
	UB	VB	**WB**		
Step 4	UT	**VT**	WT		180° - 240°
	UB	VB	WB		
Step 5	UT	VT	**WT**		240° - 300°
	UB	VB	WB		
Step 6	UT	VT	**WT**		300° - 360°
	UB	**VB**	WB		

= Transistor active

Chapter 5 Implementation

5.1 System configuration

Figure 12 System configuration with the peripherals of the R5F104LE-TB (RL78/G14) and R2A25104KFP



As you can see the MCU is supplied by 5V-Relulator of intelligent pre-driver R2A25104KFP. Furthermore overcurrent detection is done by this device. The external Watchdog Timer is used for software shut down. Position detection is done by Hall sensors connected to external interrupt inputs of RL78.

5.2 Configuration of Target Board R5F104LE-TB

The R5F104LE-TB device is a member of the high performance RL78 Family 16-bit microcontrollers. The configuration of the device and the operating environment used in this application is listed below:

- CPU: R5F104LE
- Operating Clock: 32MHz
- Supply Voltage: 5V
- Internal ROM: 64 KB
- Internal RAM: 5,5 KB

5.3 Motor Configuration

- Max. Speed: 4000 rpm
- Max. Voltage: 24V
- Poles: 10 (5 pole-pairs)

5.4 Peripherals I/O Assignments

Table 1 lists all the pins of the R5F104LE-TB device and the ones used in this application are described with their associated function.

Table 1 Peripheral I/O Assignment

PIN No.	PIN Name	Mode Setting	Function
1	P120/ANI19	Not used	
2	P43	Not used	
3	P42	Not used	
4	P41	Not used	
5	P40/TOOL0	TOOL0	TOOL0 (Target board)
6	RESET	RESET	RESET-Input
7	P124/XT2/EXCLKS	XT2	Subsystem Clock (Target board)
8	P123/XT1	XT1	Subsystem Clock (Target board)
9	P137/INTP0	INTP0	Test switch (Target board)
10	P122/X2/EXCLK	X2	Main System Clock (Target board)
11	P121/X1	X1	Main System Clock (Target

			board)
12	REGC	REGC	REGC (Target board)
13	VSS	VSS	GND
14	EVSS	EVSS	Connected to GND
15	VDD	VDD	Supply Voltage MCU
16	EVDD	EVDD	Connected to VDD
17	P60/SCLA0	Not used	
18	P61/SDAA0	Not used	
19	P62/SSi00	P62	Test-LED (Target board)
20	P63	P63	Test-LED (Target board)
21	P31/TI03	Not used	
22	P77/KR7/INTP11	Not used	
23	P76/KR6/INTP10	Not used	
24	P75/KR5/INTP9/SCK01/SCL01	Not used	
25	P74/KR4/INTP8/SI01/SDA01	Not used	
26	P73/KR3/SO01	Not used	
27	P72/KR2/SO21	P72/Input	ILIM (Overcurrent circuit)
28	P71/KR1/SI21/SDA21	P71/Output	RSL (Overcurrent circuit)
29	P70/KR0/SCK21/SCL21	P70/Output	MUTE
30	P06	Not used	
31	P05	Not used	
32	P30/INTP3/RTC1HZ/SCK00/SCL00/TRJO0	INTP3	HALL3
33	P50/INTP1/SI00/RxD0/TOOLRx/SDA00/TRGIOA	INTP1	HALL1
34	P51/INTP2/SO00/TxD0/TOOLTxD/TRGIOB	INTP2	HALL2
35	P52	Not used	
36	P53	Not used	
37	P54	Not used	
38	P55	Not used	
39	P17/TI02/TO02/TRDIOA0/TRDCLK0	Not used	
40	P16/TI01/TO01/INTP5/TRDIOC0	Not used	
41	P15/SCK20/SCL20/TRDIOB0	TRDIOB0	IUT (Phase U)
42	P14/RxD2/SI20/SDA20/TRDIOD0	P14/Output	IUB (Phase inv U)
43	P13/TxD2SO20/TRDIOA1	TRDIOA1	IVT (Phase V)
44	P12/SO11/TRDIOB1	TRDIOB1	IWT (Phase W)
45	P11/SI11/SDA11/TRDIOC1	P11/Output	IVB (Phase inv V)
46	P10/SCK11/SCL11/TRDIOD1	P10/Output	IWB (Phase inv W)
47	P146	Not used	
48	P147/ANI18	Not used	
49	P27/ANI7	Not used	
50	P26/ANI6	Not used	
51	P25/ANI5	Not used	
52	P24/ANI4	Not used	
53	P23/ANI3	Not used	
54	P22/ANI2	Not used	

55	P21/ANI1/AVREFM	Not used	
56	P20/ANI0/AVREFP	Not used	
57	P130	Not used	
58	P04/SCK10/SCL10	Not used	
59	P03/ANI16/Si10/RxD1/SDA10	Not used	
60	P02/ANI17/SO10/TxD1	Not used	
61	P01/TO00/TRGCLKB/TRJIO0	Not used	
62	P00/TI00/TRGCLKA	P00/Output	external WDT Clock
63	P141/PCLBUZ1/INTP7	Not used	
64	P140/PCLBUZ0/INTP6	Not used	

Chapter 6 Hardware Configuration

6.1 Motor Control Timer RD

The timer used in the RL78/G14 for 3-phase complementary PWM is Timer RD, as shown in **Figures 13 and 15**. In Complementary PWM mode, it offers three high-side and three low-side PWM outputs, each with adjustable dead-time between the upper and lower pairs. These outputs are connected to the gates of the Inverter MOSFET via the pre-driver (**figure 14**).

Figure 13 Register Diagram of Timer RD in Complementary PWM Mode

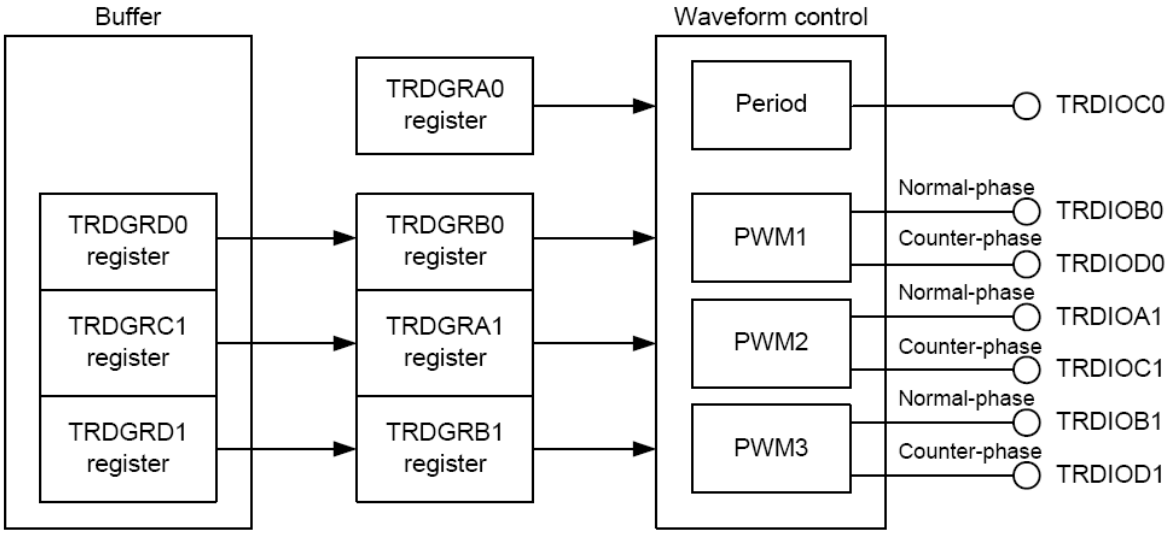
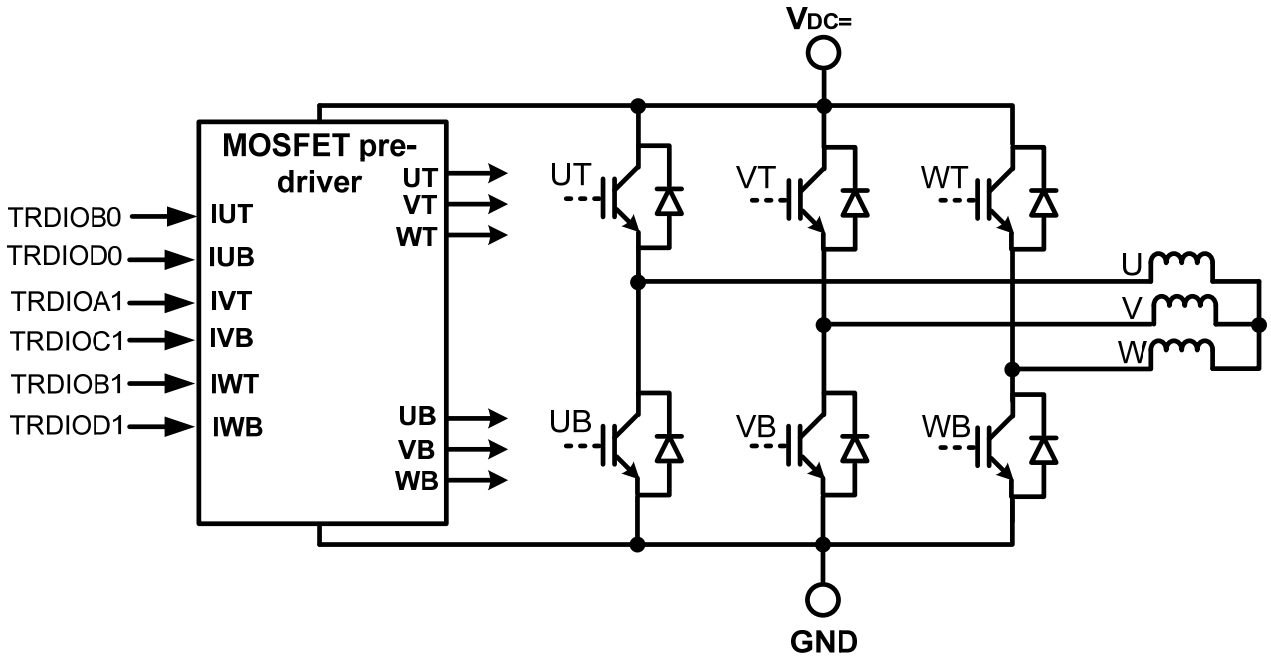
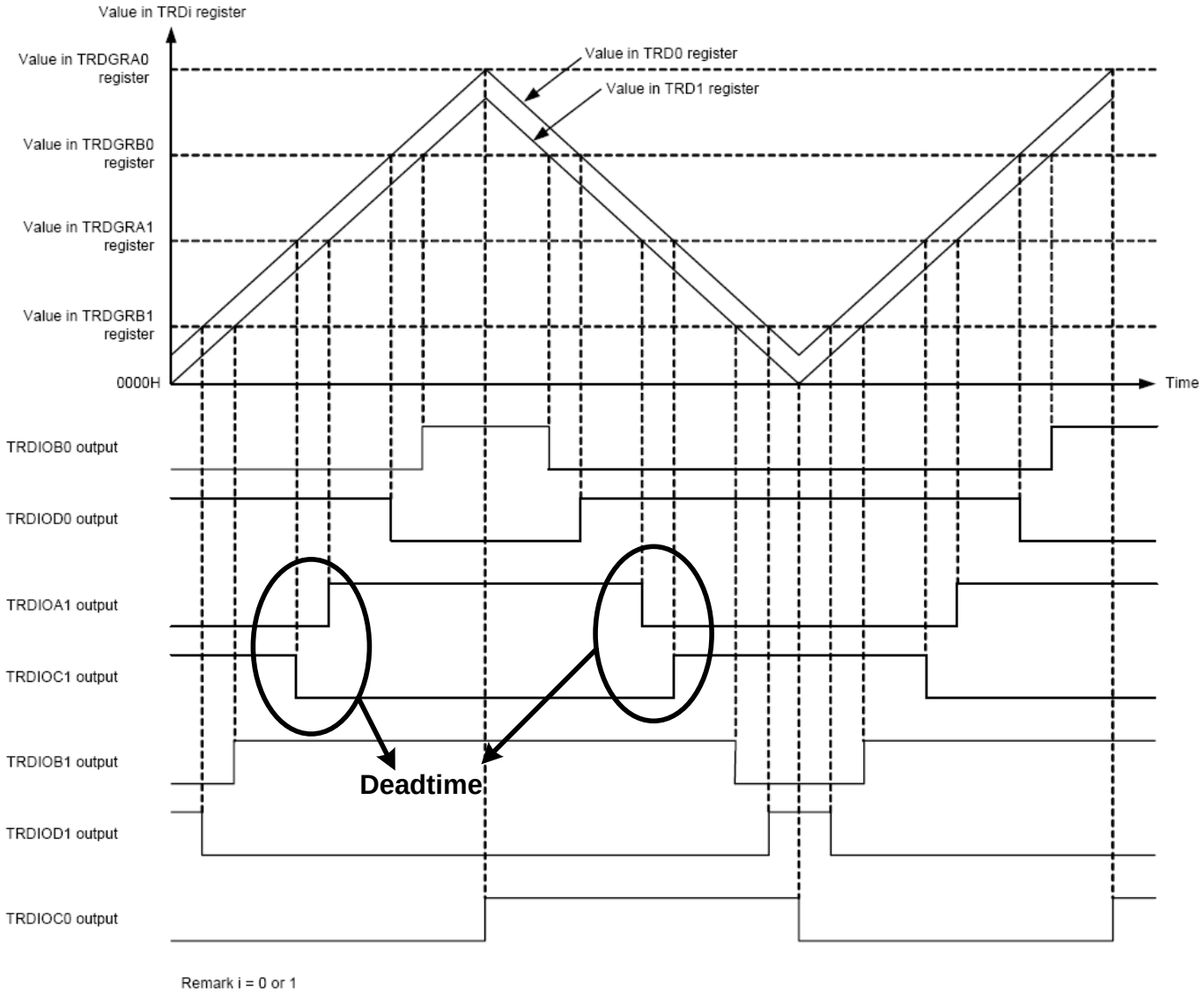


Figure 14 Connection Diagram of Timer RD



The timer is 16-bit, allowing any value up to that point for a peak value. We use a PWM maximum (TRDGRA register value) of 1662, which translates to 3324 clocks per PWM period. That count Value provides a 20 kHz PWM frequency. This frequency is chosen because it is outside the audible frequency range (> 16 kHz) and on the other hand it does not cause too high switching losses. The timer counter register, TRD0 counts up to the value of TRDGRA, then turns around and counts down until another counter, TRD1, reaches zero, then it counts up again. The difference between the two counters is the dead-time value which is preloaded before the timer is started (**figure 15**).

Figure 15 Output Model of Complementary PWM Mode

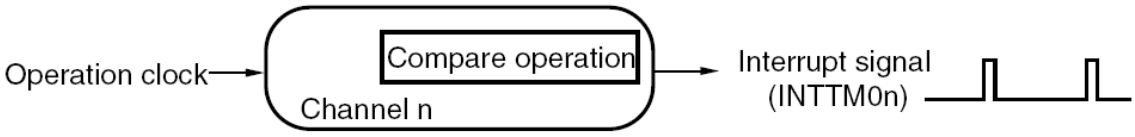


Remark i = 0 or 1

6.2 Timer Array Unit

The Timer Array Unit is used to realize a 16-bit **Interval Timer** function. This Interval Timer generates a fixed interrupt named INTTM00 every 5 ms. This Interrupt is used to generate a predefined commutation sequence for motor starting (Chapter 7.2).

Figure 16 Interval Timer operation of the Timer Array Unit



Chapter 7 Software Configuration

Required resources for the example:

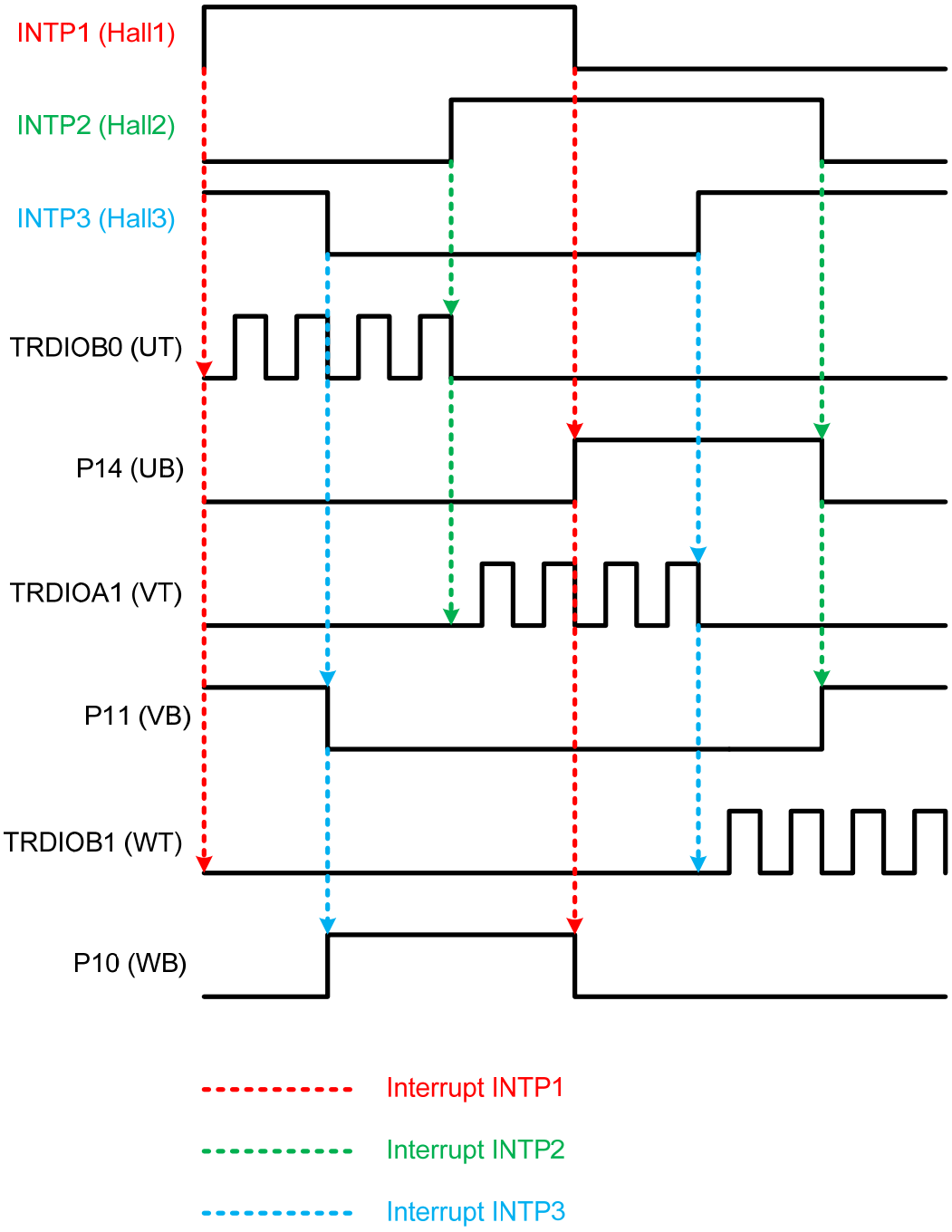
- Required RAM 220 Byte
- Required ROM 1 Kbyte
- Port 0.0 Clock for external Watchdog Timer.
- Port 1.0, 1.1, 1.4 3 Port Pins for lower Inverter MOSFETs.
- Port 7.0 MUTE Port-Pin, enables Inverter Outputs.
- Port 7.1, 7.2 2 Ports Pins for overcurrent detection.
- Port INTP (-1,-2,-3) Interrupt Inputs for Hallsensor feedback signal.
- INTP (-1,-2,-3) Interrupt generated by Hallsensors.
- Timer Channel 0 16-bit Interval Timer (200Hz), generates fixed Interrupt.
- INTTM00 Interrupt of Interval Timer (every 5 ms).
- Timer RD Motor Control Timer.
- TRDIO (-B0,-A1,-B1) 3 Timer RD Outputs for upper Inverter MOSFETs.

7.1 Commutation control

In order to obtain the points where to commutate the motor, the Halls are connected to Interrupt Input ports. At this commutation points an Interrupt (INTP1, INTP2, INTP3) is generated at every Hall change. This Interrupt is used to change the required Ports respectively to enable or disable the correct Timer RD Outputs.

For this application note the motor was driven in a counter clockwise (CCW) direction only (as viewed from the motor shaft end). The commutation sequence for the inverter transistors to achieve CCW rotation of the motor is as follows.

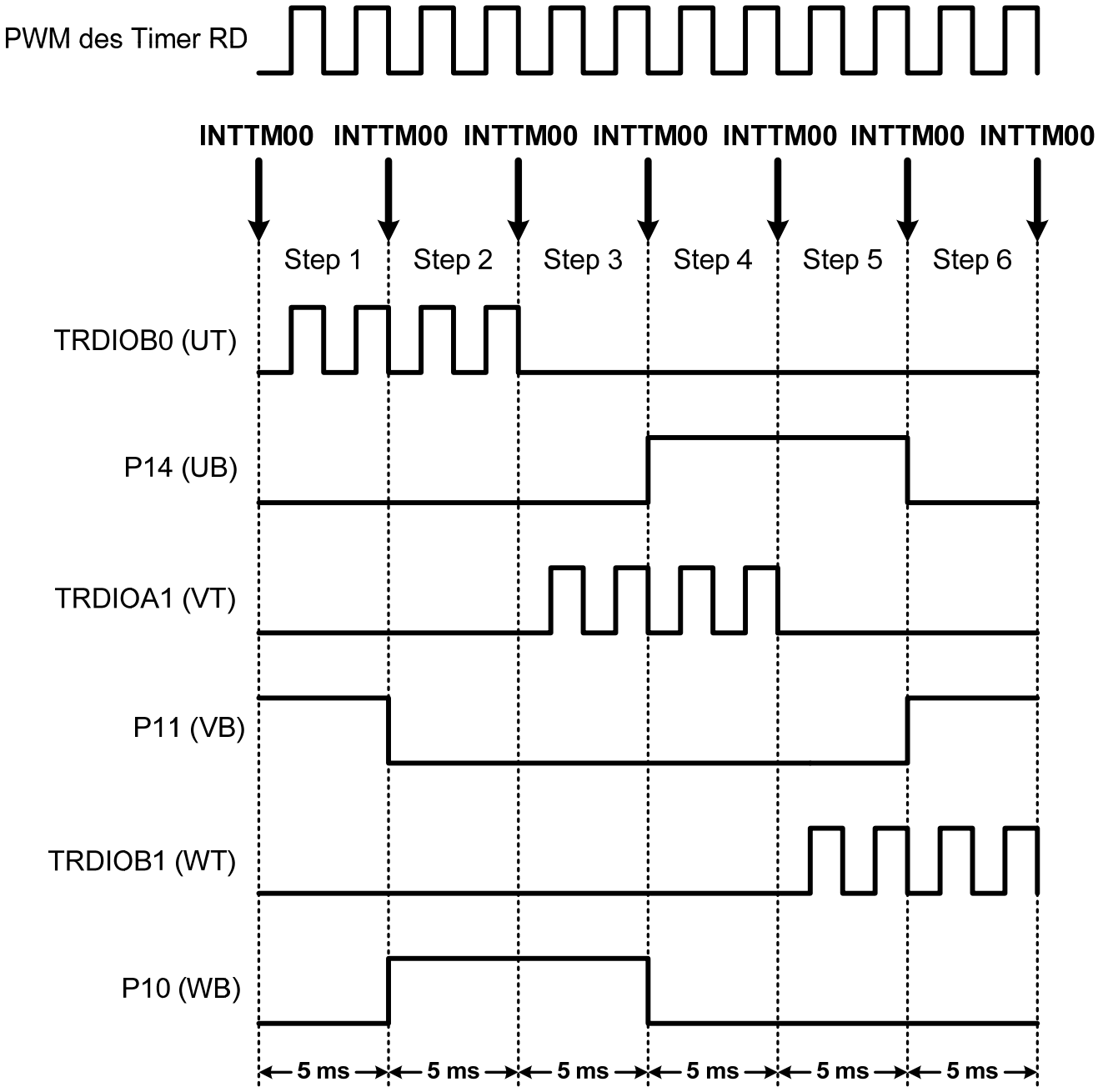
Figure 17 Commutation control while motor is running



7.2 Motor starting

As described in the previous section the control software needs an external Interrupt for commutation control. This Interrupt is generated while motor is rotating only. Therefore we have to start the motor without that external interrupt function by reading the absolute rotor position. This is done by reading Hall sensors at the beginning of program. After this is done a software state machine is entered to start the motor up to a fixed speed using a predefined commutation sequence. This is done until an external Interrupt signal is received by external Interrupt pin of MCU. If an external Interrupt is generated the motor is commutated using the Hall Interrupts (described in chapter 7.1).

Figure 18 Predefined commutation sequence to start the motor



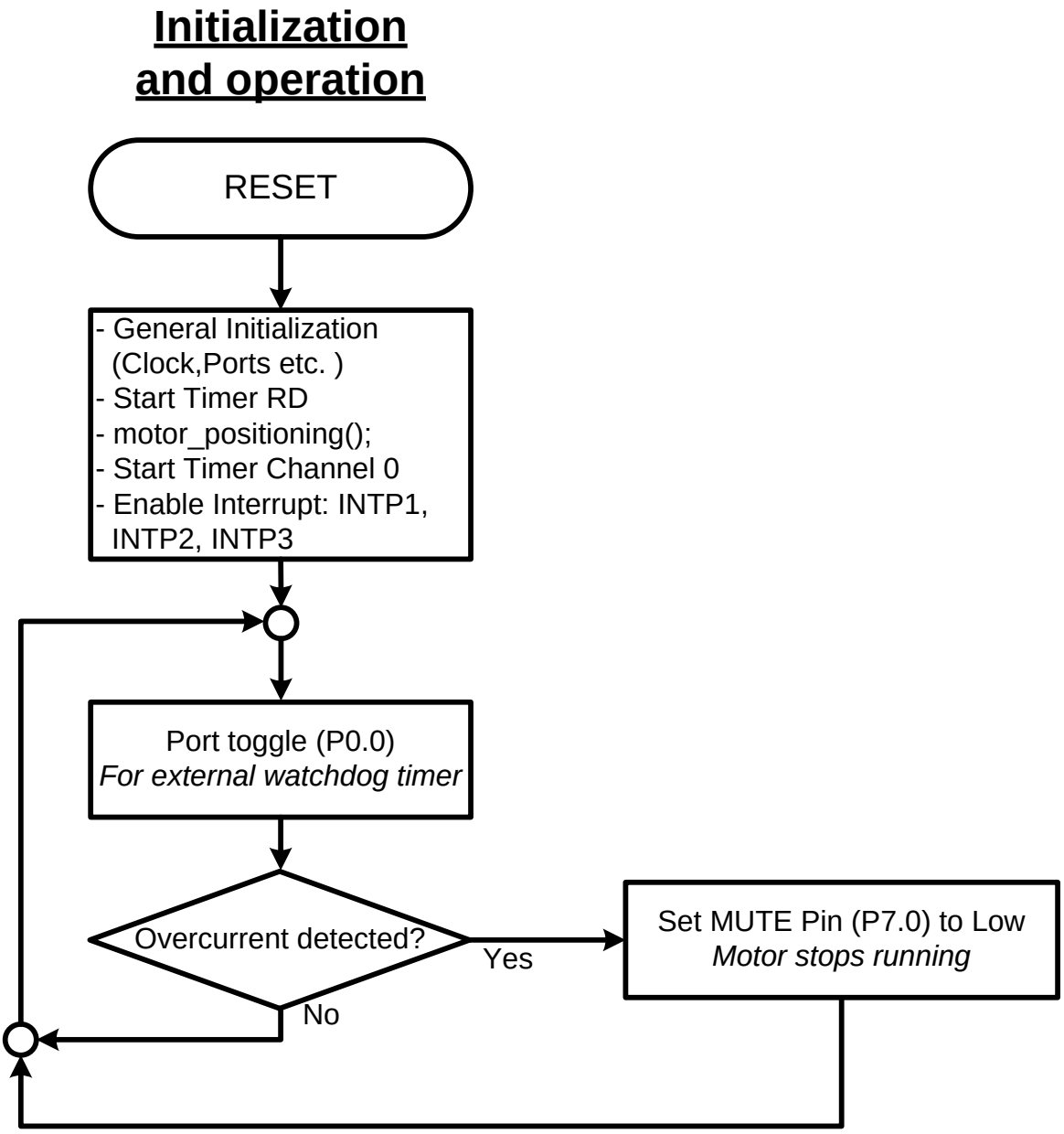
Chapter 8 Software Module Descriptions

With the use of flow charts this section describes the major processes of the software.

8.1 Main Routine

Figure 19 shows the main program loop that is entered after a system RESET.

Figure 19 Flow Chart of main



After resetting the hardware registers and the various timers are initialised and enabled before the program enters an endless loop. The function **motor_position** is used to detect the absolute rotor position for motor starting.

At start of endless loop a Port toggle for external Watchdog timer is generated. Than an overcurrent check is done: Is overcurrent detected the motor stops running and endless loop starts again, is it not detected the endless loop starts up again immediately.

8.2 INTP1, INTP2, INTP3 Interrupt Service Routine

Figures 20, 21, 22 show the Interrupt Service Routines to commutate the motor while running.

Figure 20 INTP1 Interrupt Service Routine

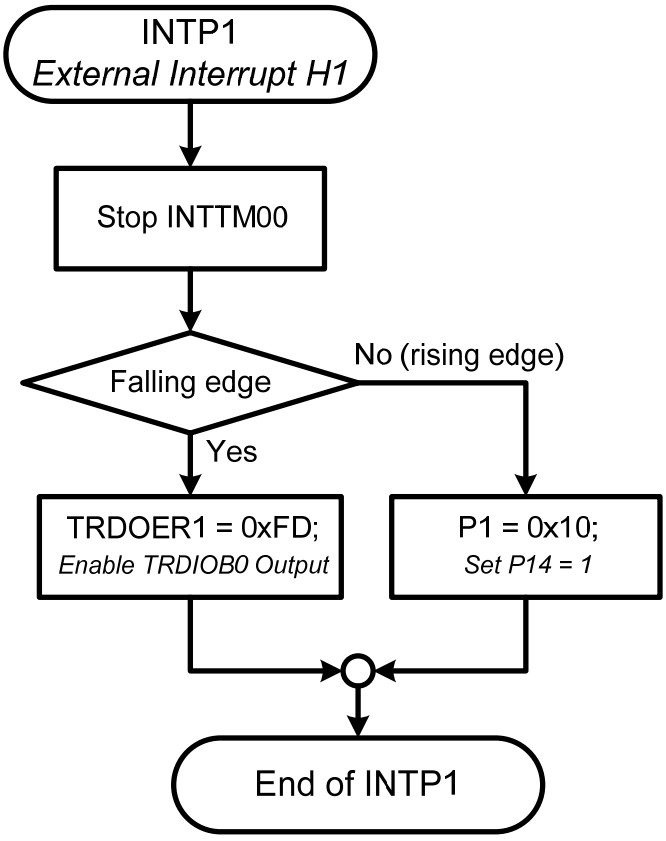


Figure 21 INTP2 Interrupt Service Routine

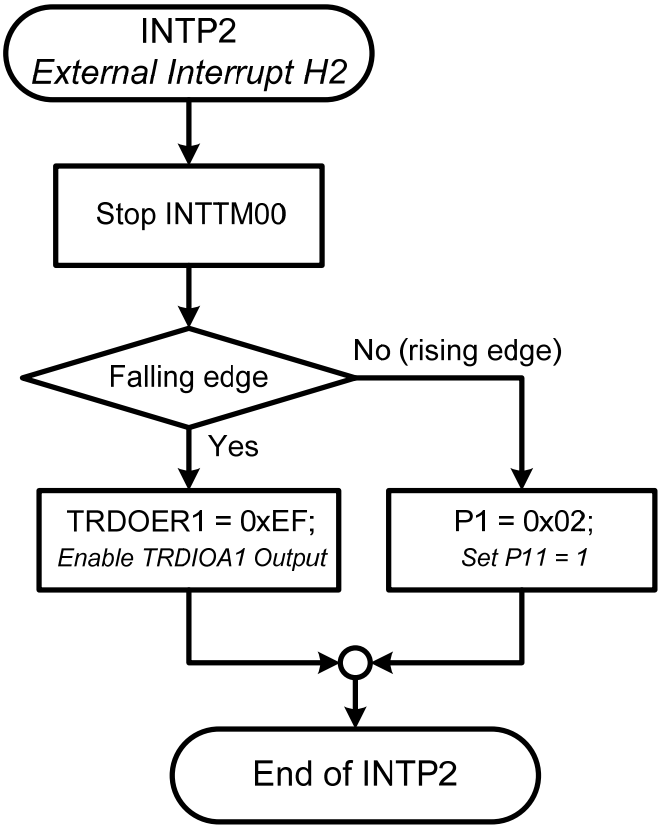
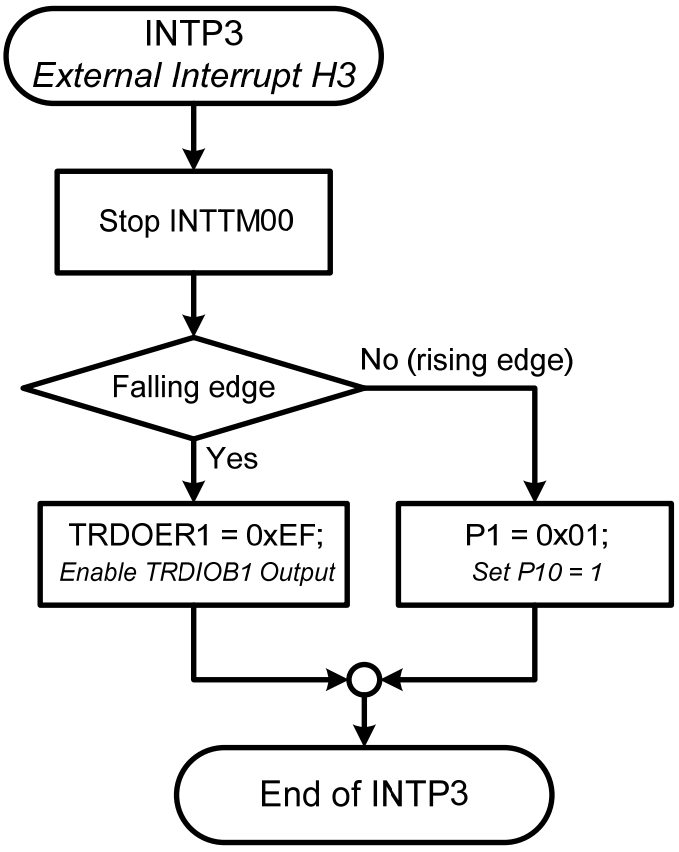


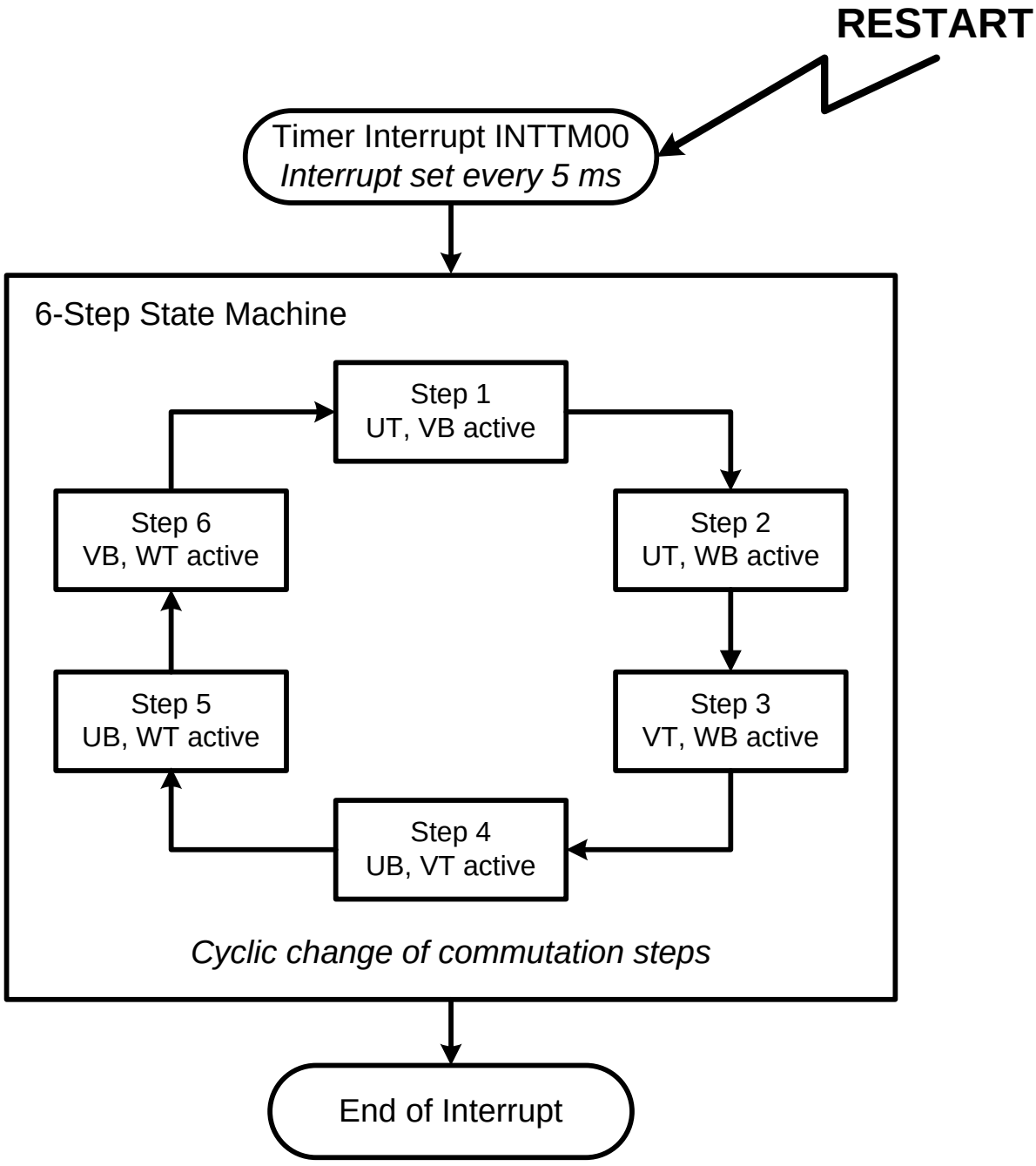
Figure 22 INTP3 Interrupt Service Routine



8.3 Interval Timer Interrupt Service Routine

Figure 23 shows a presentation of the motor state machine. Each state in the diagram represents a different pair of transistors energized in the inverter. The state machine is synchronized to an interval timer (Timer Channel 0) running at 5 ms intervals.

Figure 23 Interrupt Service Routine of Interval Timer



Chapter 9 Program Code (motor driving part only)

9.1 Main Routine

Hauptschleife

```
void  main(void)
{
      DI();   //disable all Interrupts
      P1 = 0x00;    //set Port 0 to low
      TRDOER1 = 0xff;     //disable all Timer RD outputs
      P7_bit.no0 = 1;     //set mute to high
      EI();   //enable all interrupts

      R_TMR_RD0_Start();    //start Timer RD
      R_TAU0_Channel0_Start();    //start INTM00 interrupt

      R_INTC1_Start();
      R_INTC2_Start();    //enable Hall interrupts
      R_INTC3_Start();

      while (1U)
      {
            P0_bit.no0 = ~P0_bit.no0; //Port Toggle for extern WDT
            if (P7_bit.no2 == 0)     // If overcurrent is detected...
                P7_bit.no0 = 1;      //set MUTE Pin = Low
      }
}
```

Register settings to start Timer RD

```
void R_TMR_RD0_Start(void)
{
TRDSR0 = _E0_TMRD_TRDSR0_DEFAULT_VALUR;    /* clear TRD0 each
interrupt request */
TRDSR1 = _C0_TMRD_TRDSR1_DEFAULT_VALUR;    /* clear TRD1 each
interrupt request */
TRDIF0 = 0U;    /* clear TMRD0 interrupt flag */
TRDMK0 = 0U;  /* enable TMRD0 interrupt */
TRDIF1 = 0U;    /* clear TMRD1 interrupt flag */
TRDMK1 = 0U;  /* enable TMRD1 interrupt */
TRDSTR |= _03_TRD_COUNT_STATR_INITIAL_VALUE;          /* start TMRD
counter */
}
```

Register settings to start Timer Channel 0 Interval Timers

```
void R_TAU0_Channel0_Start(void)
{
TMIF00 = 0U;    /* clear INTTM00 interrupt flag */
TMMK00 = 0U;  /* enable INTTM00 interrupt */
TS0 |= _0001_TAU_CH0_START_TRG_ON;
}
```

Register settings to start external Interrupts

```
void R_INTC1_Start(void)
{
PIF1 = 0U;      /* clear INTP1 interrupt flag */
PMK1 = 0U;      /* enable INTP1 interrupt */
}

void R_INTC1_Stop(void)
{
PMK1 = 1U;      /* disable INTP1 interrupt */
PIF1 = 0U;      /* clear INTP1 interrupt flag */
}

void R_INTC2_Start(void)
{
PIF2 = 0U;      /* clear INTP2 interrupt flag */
PMK2 = 0U;      /* enable INTP2 interrupt */
}
```

9.2 INTTM00 Interrupt Service Rountine

```
int i = 1;


#pragma vector = INTTM00_vect
__interrupt void R_TAU0_Channel0_Interrupt(void)
{
   switch(i)
      {
       case 1:
       TRDOER1 = 0xfd;          // activate TRDIOB0
       i++;                     //i = i+1
       break;
       case 2:
       P1 = 0x01;               // Set P1.0 = 1
       i++;                     //i = i+1
       break;
       case 3:
       TRDOER1 = 0xef;          // activate TRDIOA1
       i++;                     //i = i+1
       break;
       case 4:
       P1 = 0x10;               // Set P1.0 = 1
       i++;                     //i = i+1
       break;
       case 5:
       TRDOER1 = 0xdf;           // activate TRDIOB1
       i++;                     //i = i+1
       break;
       case 6:
       P1 = 0x02;               // Set P1.0 = 1
       i=1;                     //i = i+1
       break;
       default:
       TRDOER1 = 0xff;          //disable all Timer RD outputs
       P1 = 0x00;               // Set P1 to low
       break;
      }
}
```

9.3 Interrupt Service Routines of external Interrupt INTP1, INTP2, INTP3

Interruptfunction INTP1

```
#pragma vector = INTP1_vect
__interrupt void R_INTC1_Interrupt(void)
{
R_TAU0_Channel0_Stop();   // stop INTTM00
if (P5_bit.no0 == 0)        // 180°
P1 = 0x10;           // Set P1.0 = 1
else                    // 0°
TRDOER1 = 0xfd;      // activate TRDIOB0
}
```

Interruptfunction INTP2

```
#pragma vector = INTP2_vect
__interrupt void R_INTC2_Interrupt(void)
{
R_TAU0_Channel0_Stop();   // stop INTTM00
if (P5_bit.no1 == 0)         //300°
P1 = 0x02;            // Set P1.0 = 1
else                     //120°
TRDOER1 = 0xef;        // activate TRDIOA1
}
```

Interruptfunction INTP3

```
#pragma vector = INTP3_vect
__interrupt void R_INTC3_Interrupt(void)
{
R_TAU0_Channel0_Stop();   // stop INTTM00
if (P3_bit.no0 == 0)         // 60°
P1 = 0x01;            // Set P1.0 = 1
else                     // 240°
TRDOER1 = 0xdf;        // activate TRDIOB1
}
```

Register settings to stop INTTM00 Interrupt

```
void R_TAU0_Channel0_Stop(void)
{
TT0 |= _0001_TAU_CH0_STOP_TRG_ON;
/* Mask channel 0 interrupt */
TMMK00 = 1U;  /* disable INTTM00 interrupt */
TMIF00 = 0U;    /* clear INTTM00 interrupt flag */
}
```

Chapter 10 Principle Circuit and Schematics

Figure 24 Picture of the Motor Control Circuit

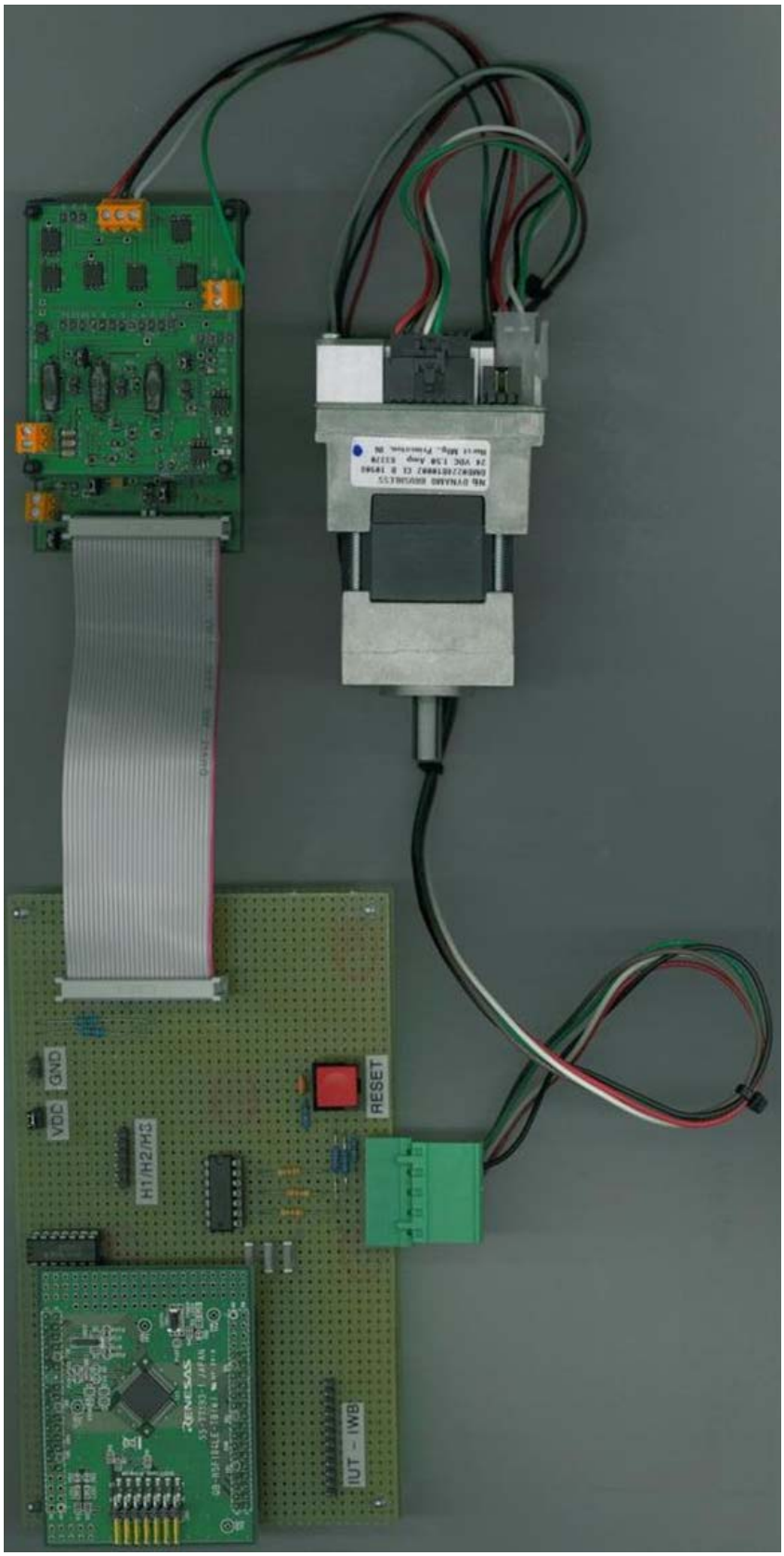


Figure 25 Schematic Inverter-bridge Board

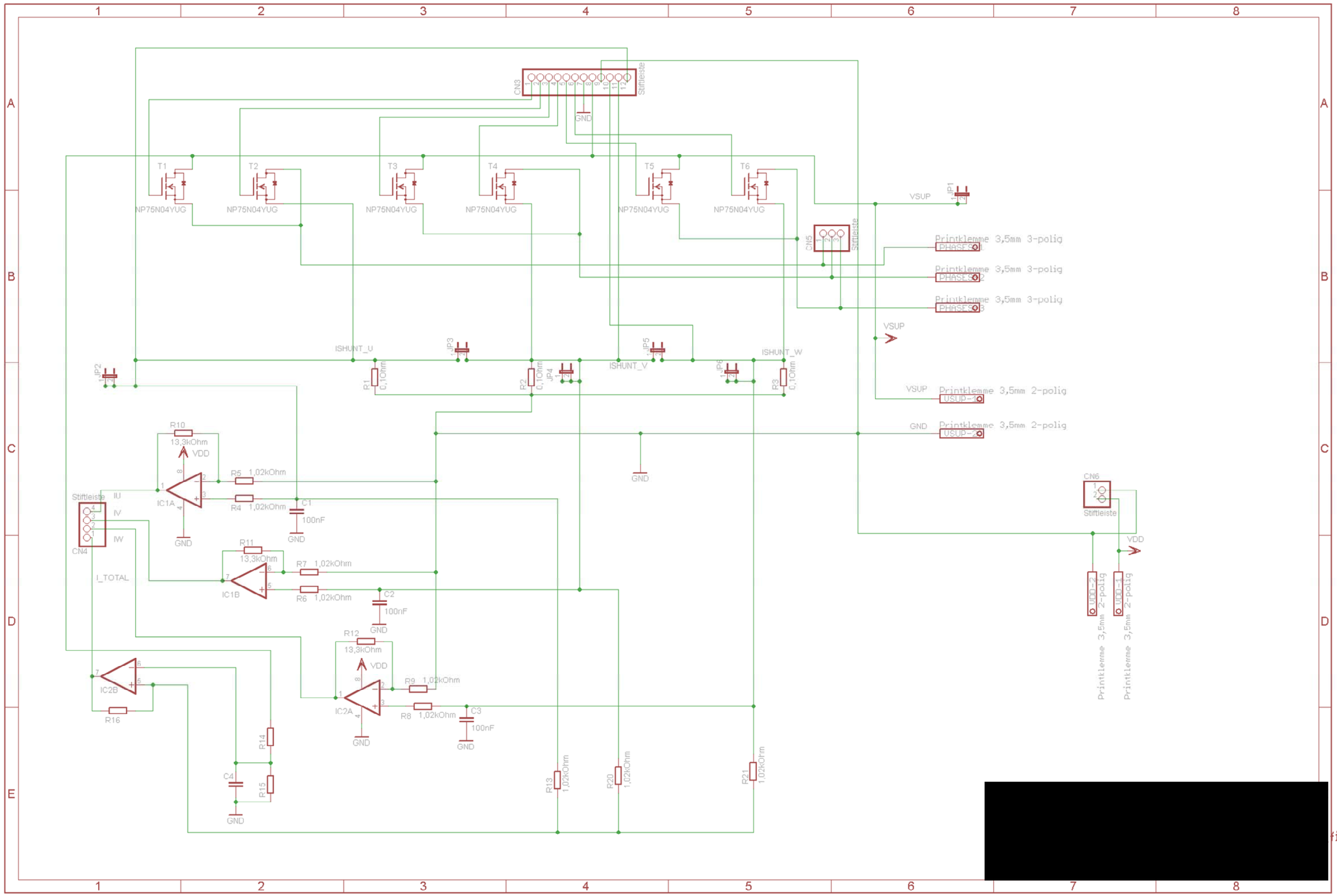


Figure 26 Schematic Target Power Board

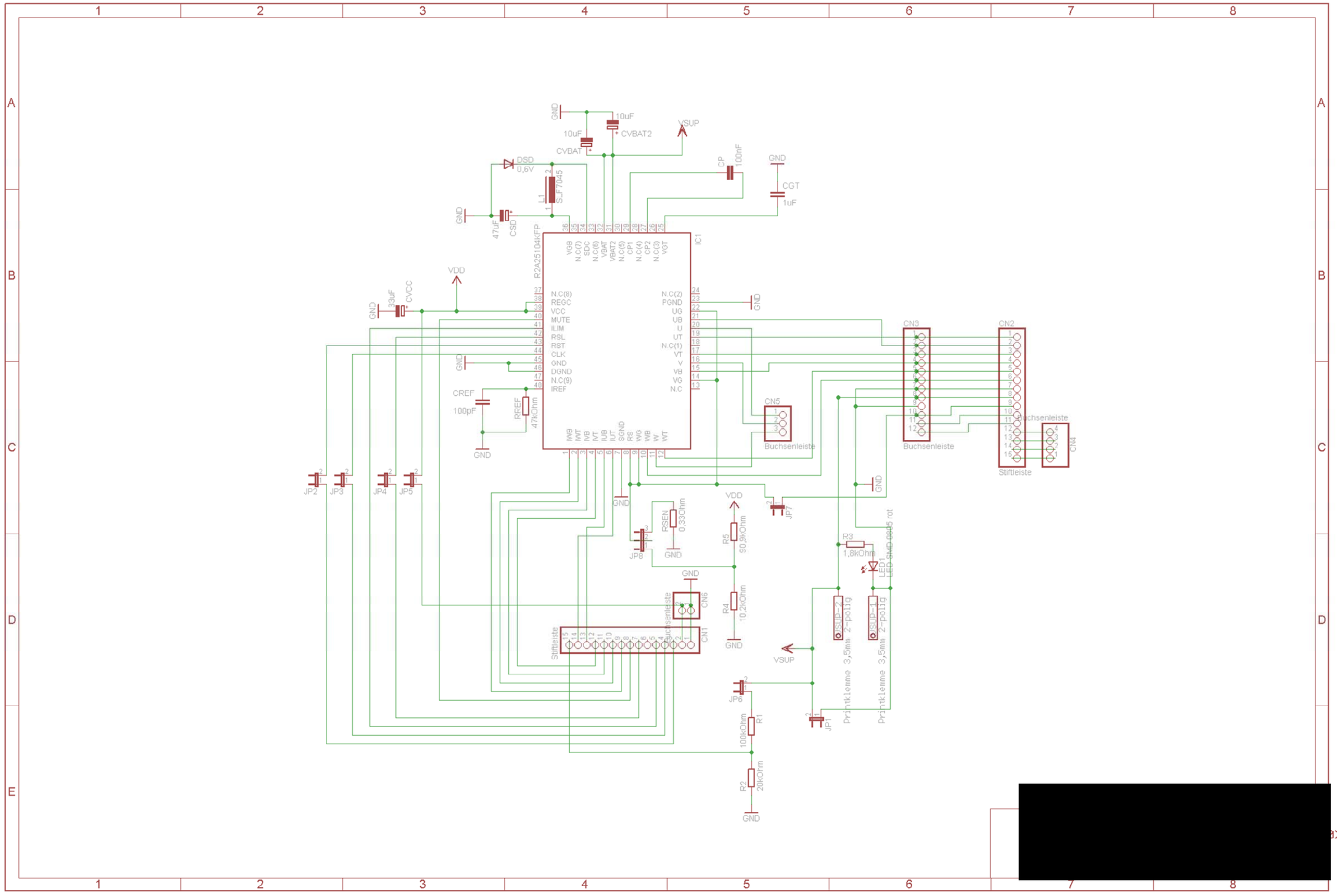
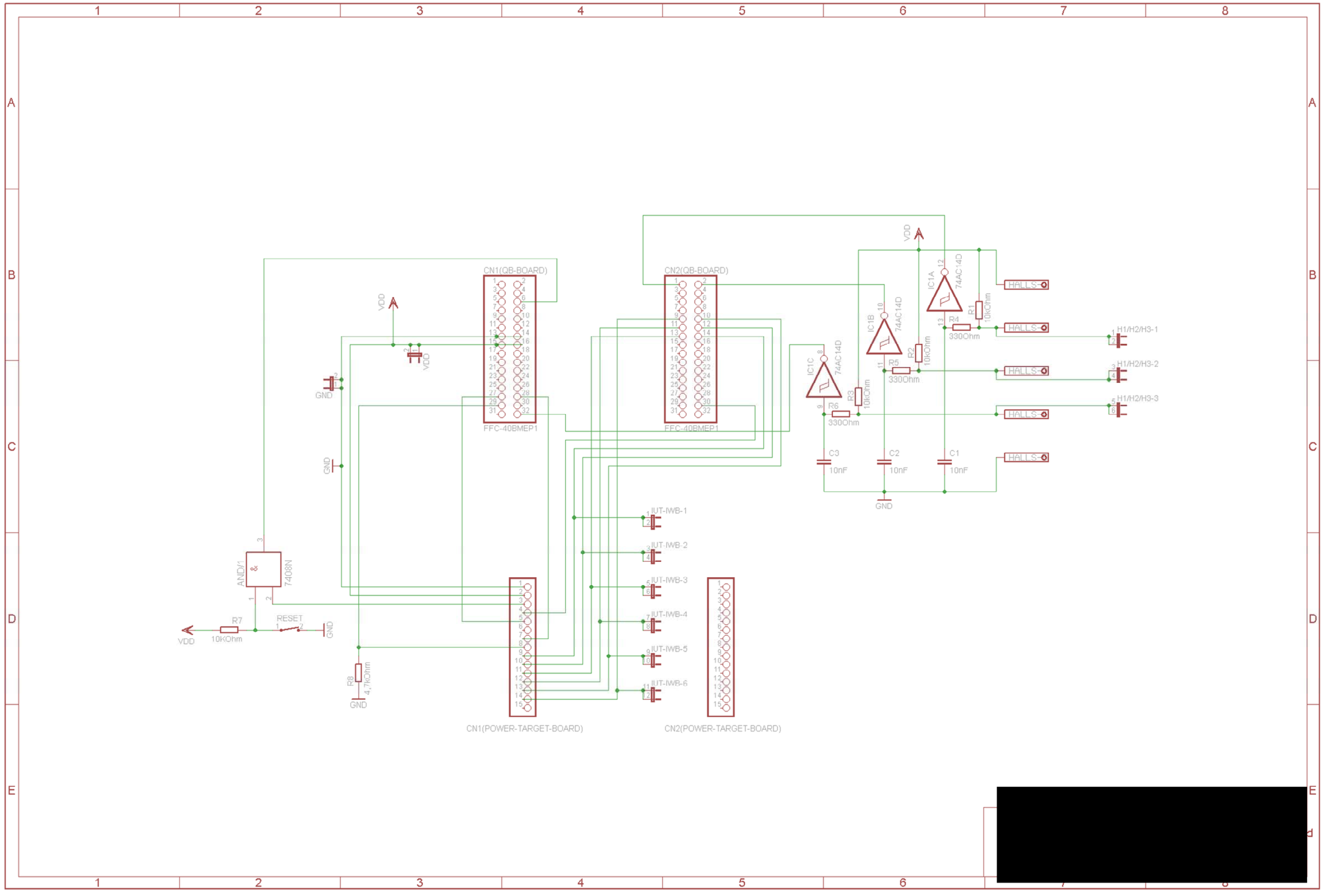


Figure 27 Schematic Microcontrollerboard



Chapter 11 Revision History

Table 2 Revision History

Version	Date	Change Description
0100	3. November 2011	This is the initial version of the document.

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