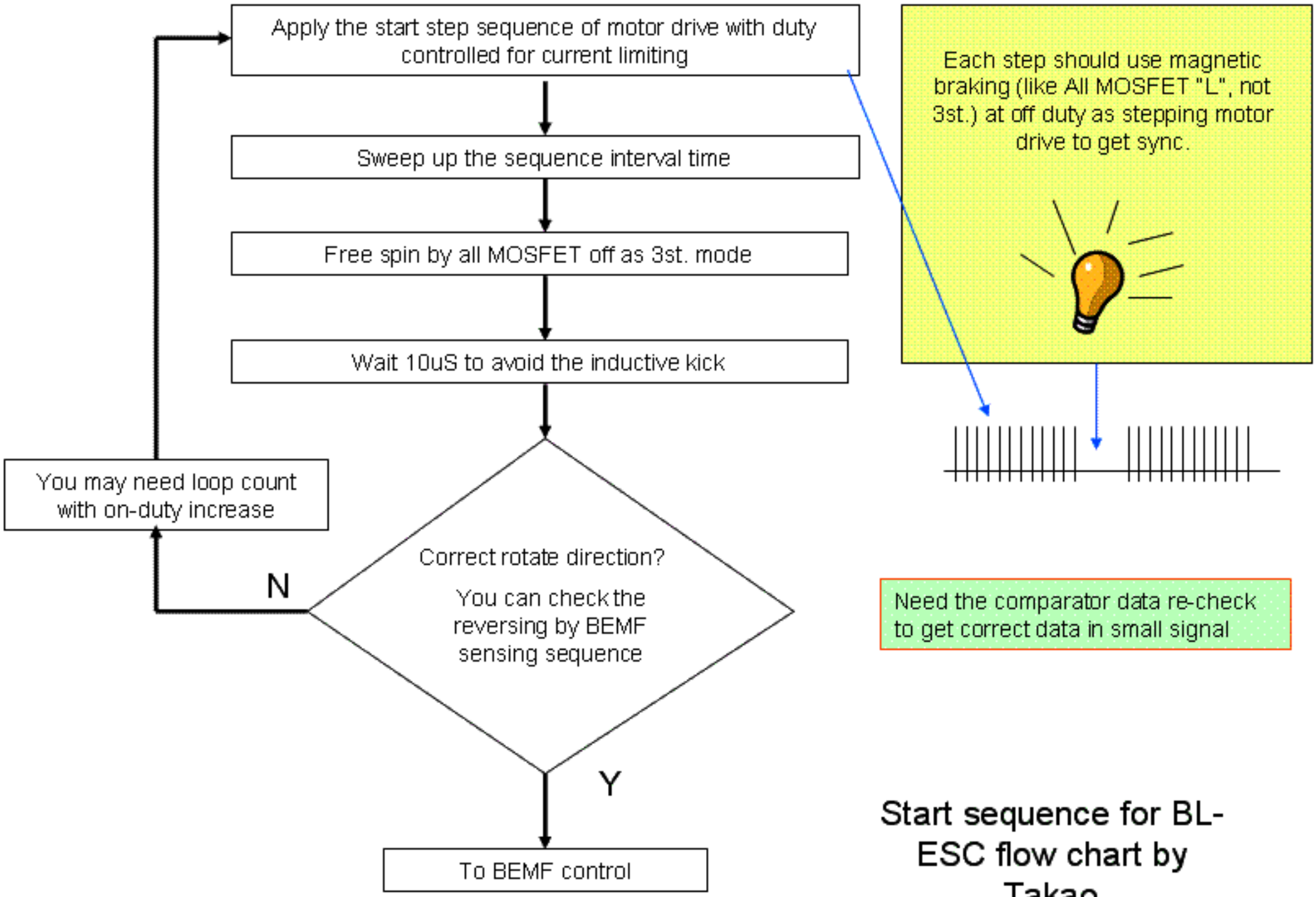
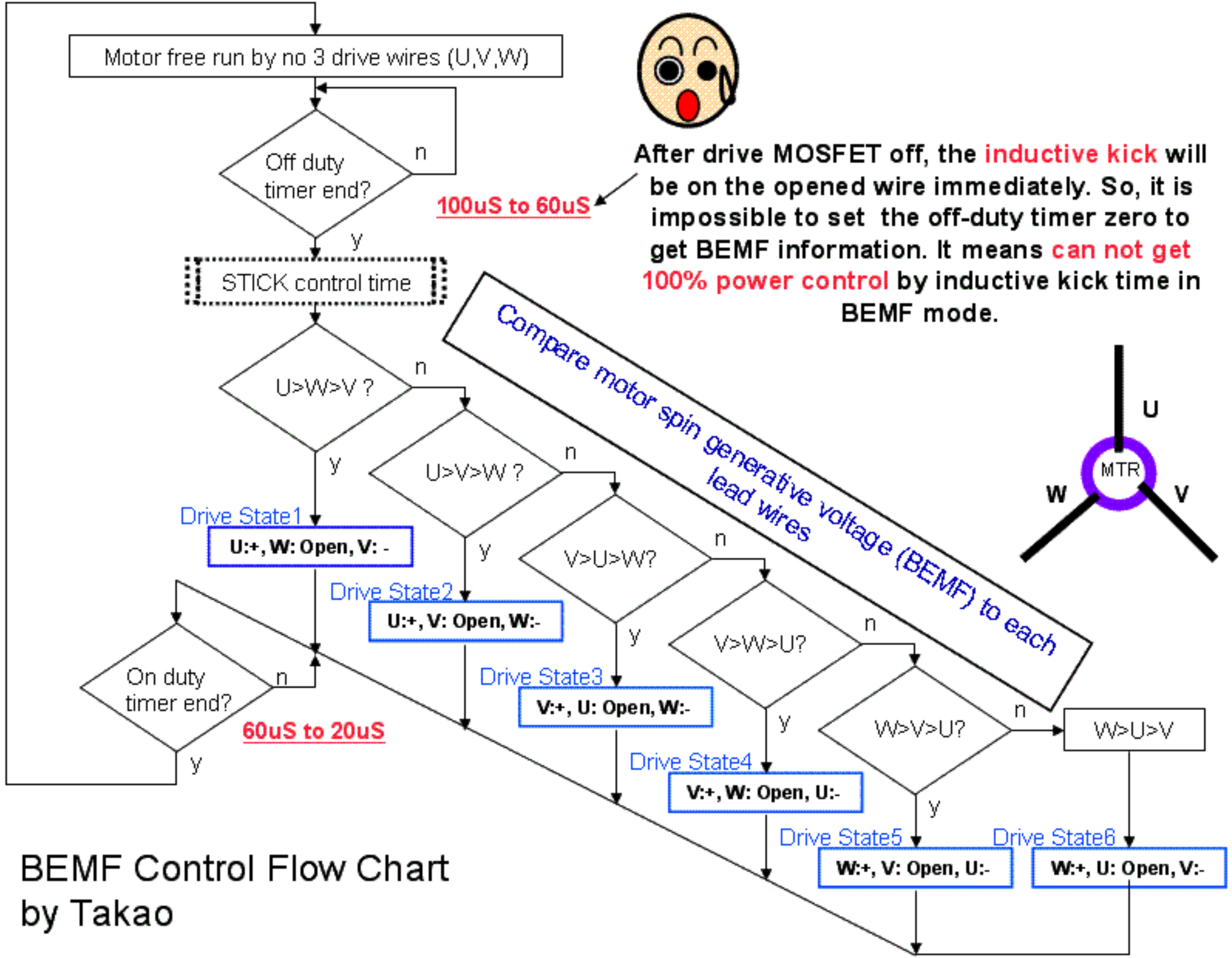
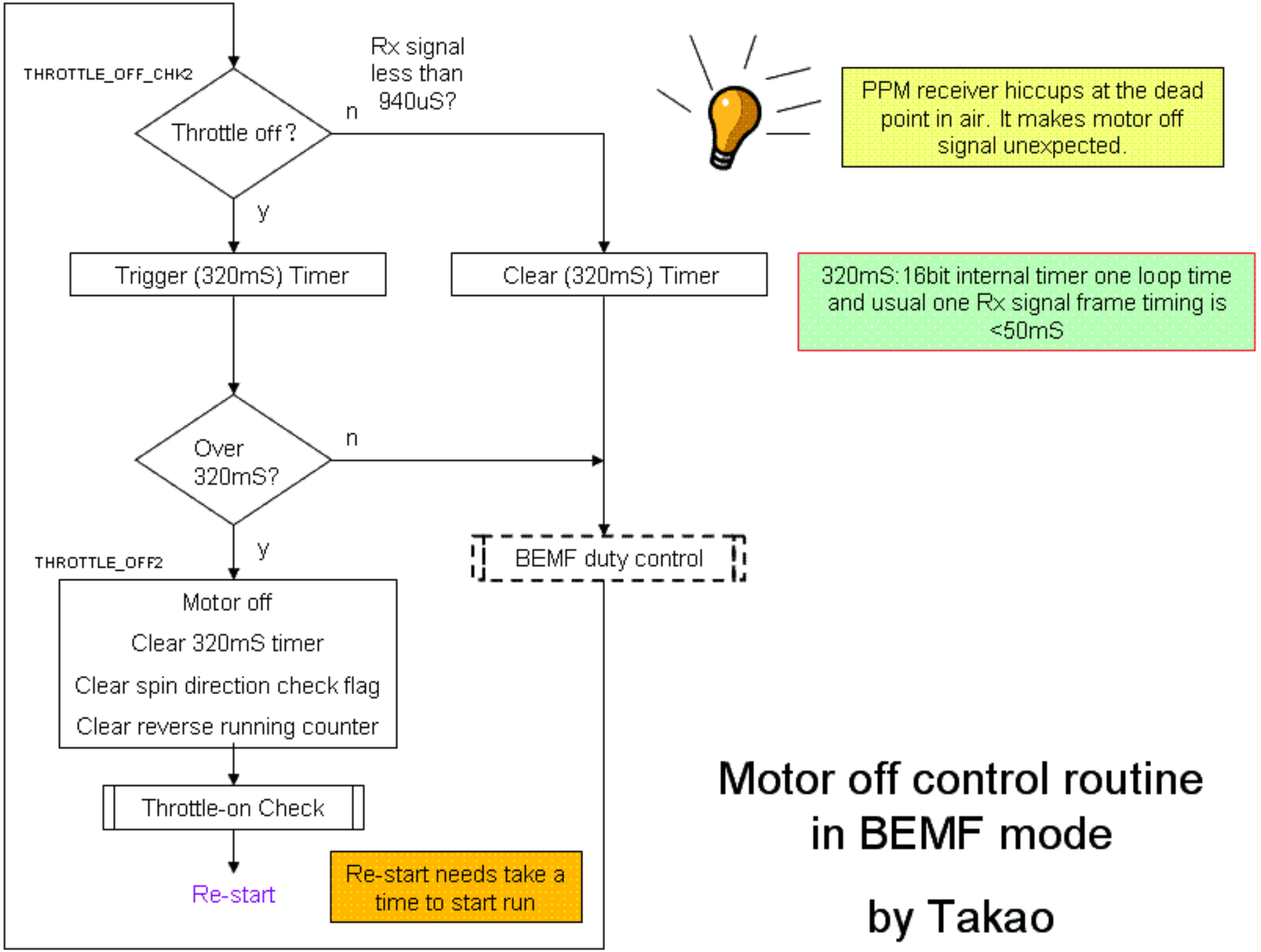
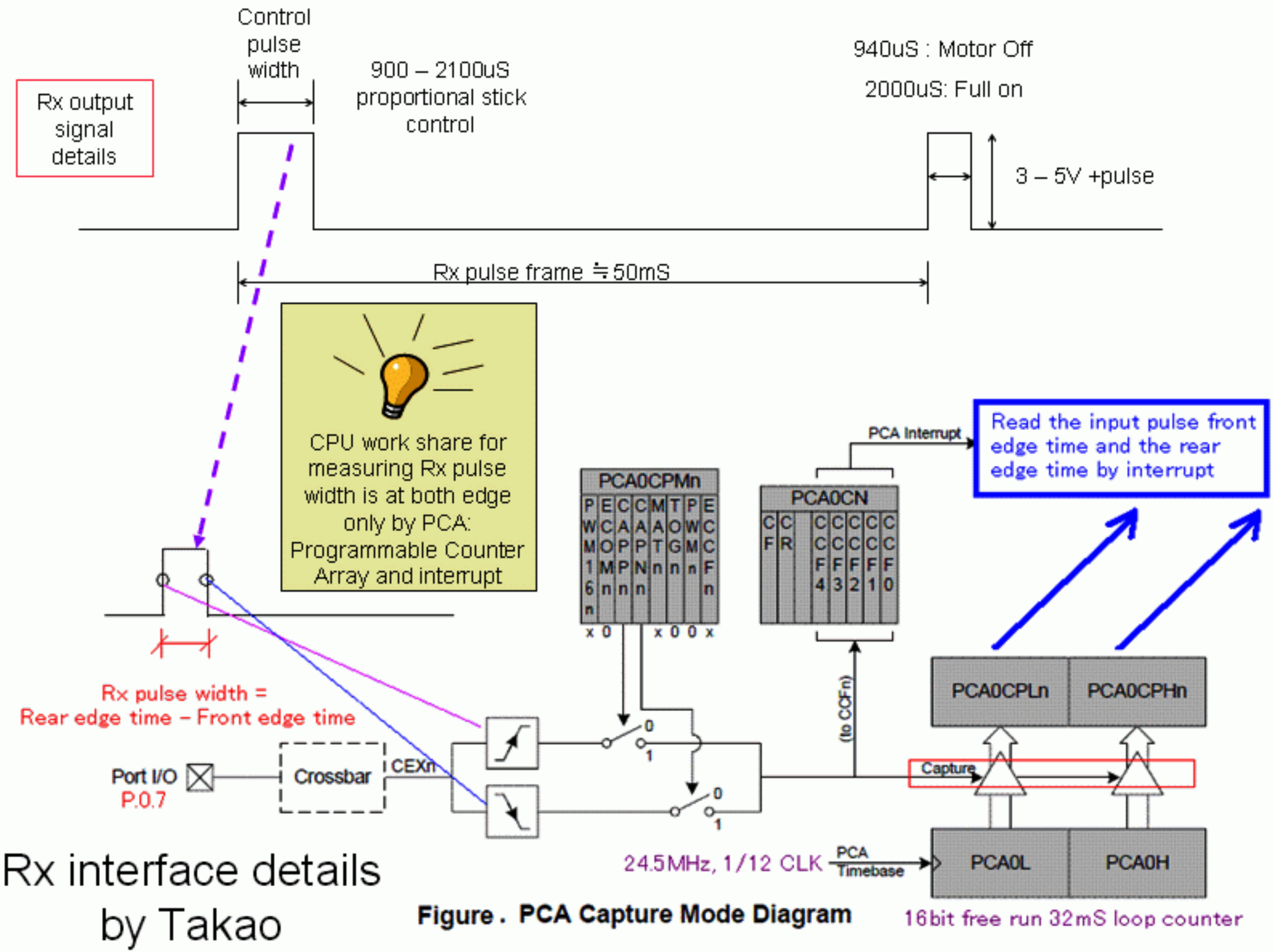


Start sequence for BL-ESC flow chart by Takao


Motor free run by no 3 drive wires (U,V,W)
Off duty timer end?
n
y
100uS to 60uS
STICK control time
U>W>V ?
n
y
U>V>W ?
n
y
V>U>W?
n
y
V>W>U?
n
y
W>V>U?
n
y
W>U>V
Drive State1
U:+, W: Open, V: -
Drive State2
U:+, V: Open, W:-
Drive State3
V:+, U: Open, W:-
Drive State4
V:+, W: Open, U:-
Drive State5
W:+, V: Open, U:-
Drive State6
W:+, U: Open, V:-
On duty timer end?
n
y
60uS to 20uS
Compare motor spin generative voltage (BEMF) to each lead wires
After drive MOSFET off, the inductive kick will be on the opened wire immediately. So, it is impossible to set the off-duty timer zero to get BEMF information. It means can not get 100% power control by inductive kick time in BEMF mode.
U
MTR
W
V
BEMF Control Flow Chart
by Takao


THROTTLE_OFF_CHK2
Throttle off ?
Rx signal less than 940uS?
n
y
Trigger (320mS) Timer
Clear (320mS) Timer
Over 320mS?
n
y
THROTTLE_OFF2
BEMF duty control
Motor off
Clear 320mS timer
Clear spin direction check flag
Clear reverse running counter
Throttle-on Check
Re-start
Re-start needs take a time to start run
PPM receiver hiccups at the dead point in air. It makes motor off signal unexpected.
320mS: 16bit internal timer one loop time and usual one Rx signal frame timing is <50mS
Motor off control routine in BEMF mode
by Takao



Rx interface details by Takao

Figure . PCA Capture Mode Diagram

Stick Control

Control Data = Rx pulse width x k
(24.5/12MHz clock resolution)

Control Data > On-Duty?

n

Slow down immediately for safe

Decrement motor On-Duty value

(Increment Off-duty value)

y

Time Over?

n

This timer setting may be called "Soft Start"

y

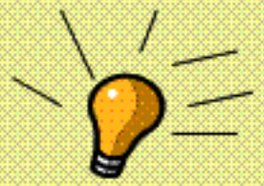
Clear Timer and Restart

Increment motor On-duty value

(Decrement Off-duty value)

Power On/Off duty setting routine

Can not drive big prop?

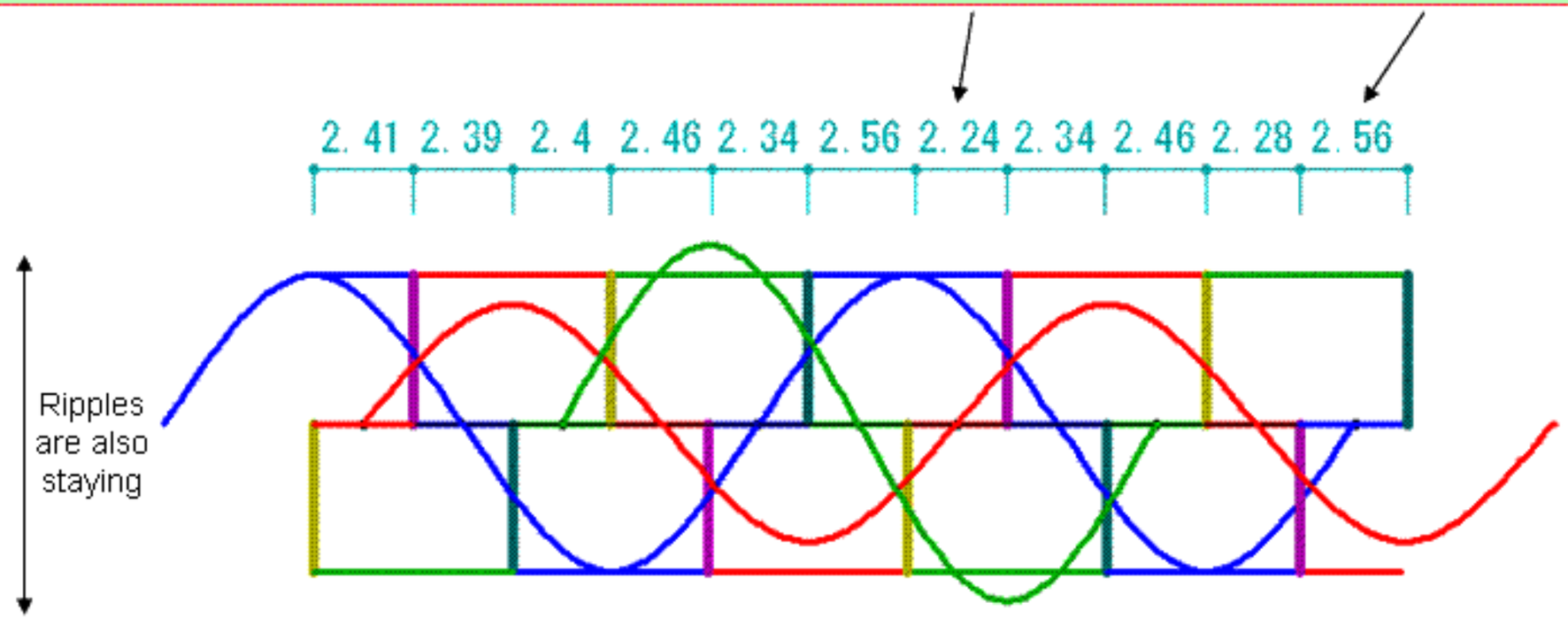


Acceleration should be slowly to avoid out of phase as motor stall

Motor Speed Setting Control

by Takao

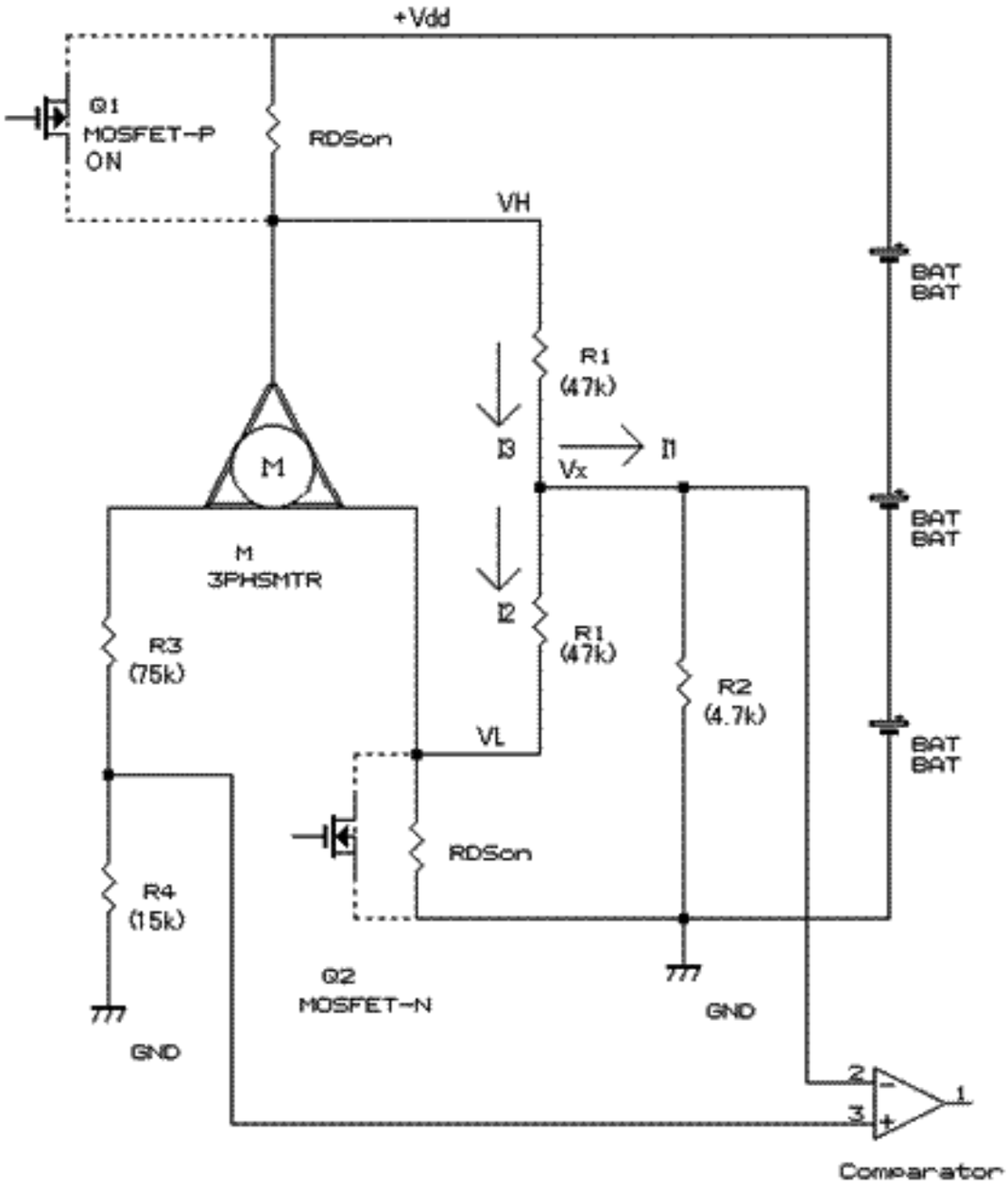
Consider the jitter of each state timing. It is never constant while spinning. Also, mechanical settings as coil turn tolerance, prop balance and magnet force are not precisely constant. Then, you may set ON_DUTY value constant roughly.



The BEMF Sampling time must be less than 1/6 one spin frame time to get drive sync.

I use min. 1/36 by sampling count routine in one frame (as min. 6 sample counts/state) and adjust sampling frequency automatically by software.

Some considerations for spin control by Takao



I3=(VH-Vx)/R1
I2=(Vx-VL)/R1
I1=Vx/R2

I3=I2+I1
(VH-Vx)/R1=((Vx-VL)/R1)+(Vx/R2)

(VH-Vx)=((Vx-VL))+(Vx・R1/R2)
VH+VL=2(Vx+Vx・R1/R2)

Zero Cross Poin: (VH+VL)/2 = Vx(1+R1/2・R2)

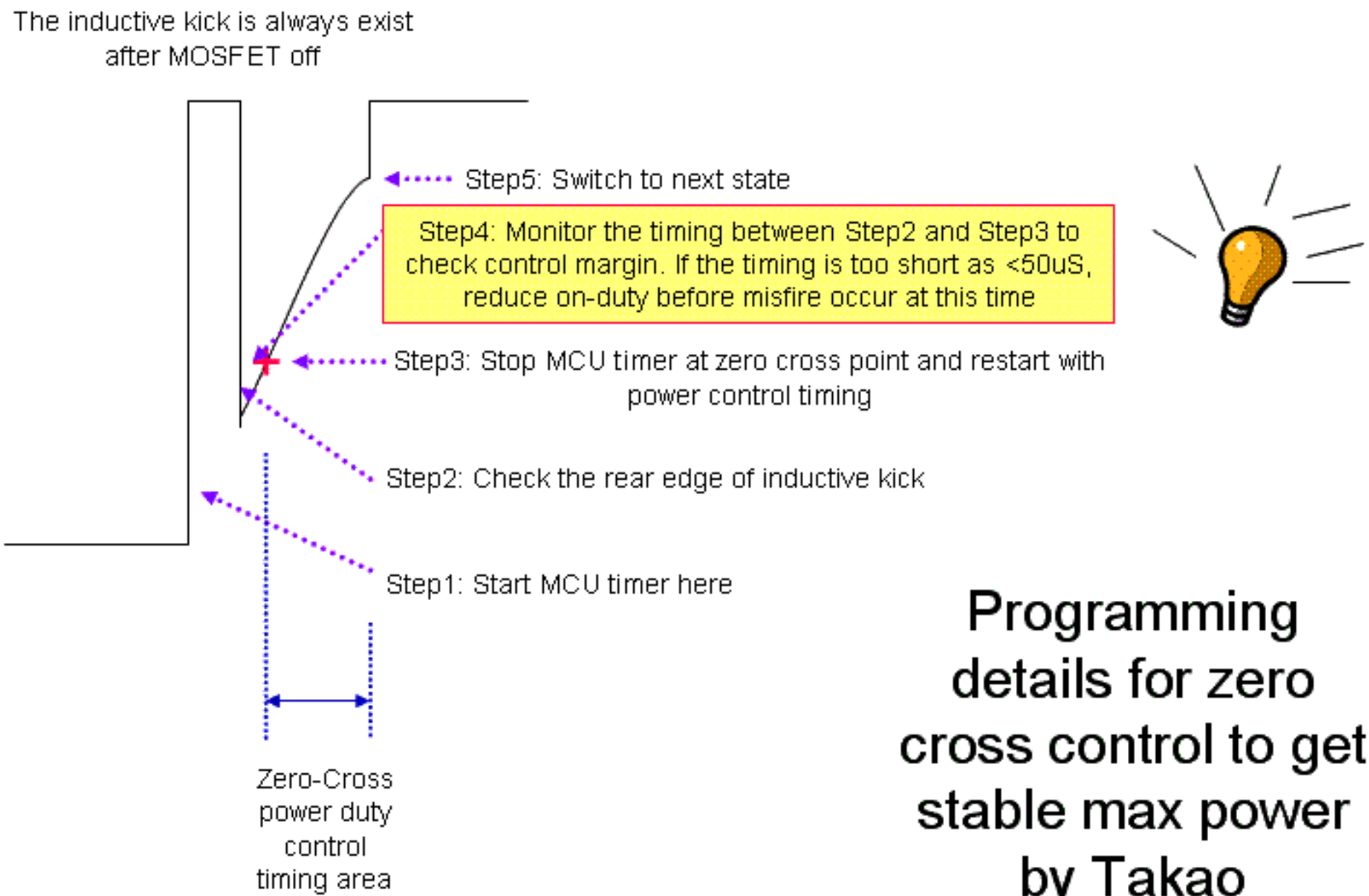
at R1/R2 : 47k/4.7k
Zero Cross Point = Vx(1+10/0.2) = 6・Vx (≒Almost 1/2Vdd)
Hense R3:R4 = 5:1

N and P-channel MOSFET's Rds on(ON Resistance drain-source) should be considered to get precise zero cross point for maximum power control

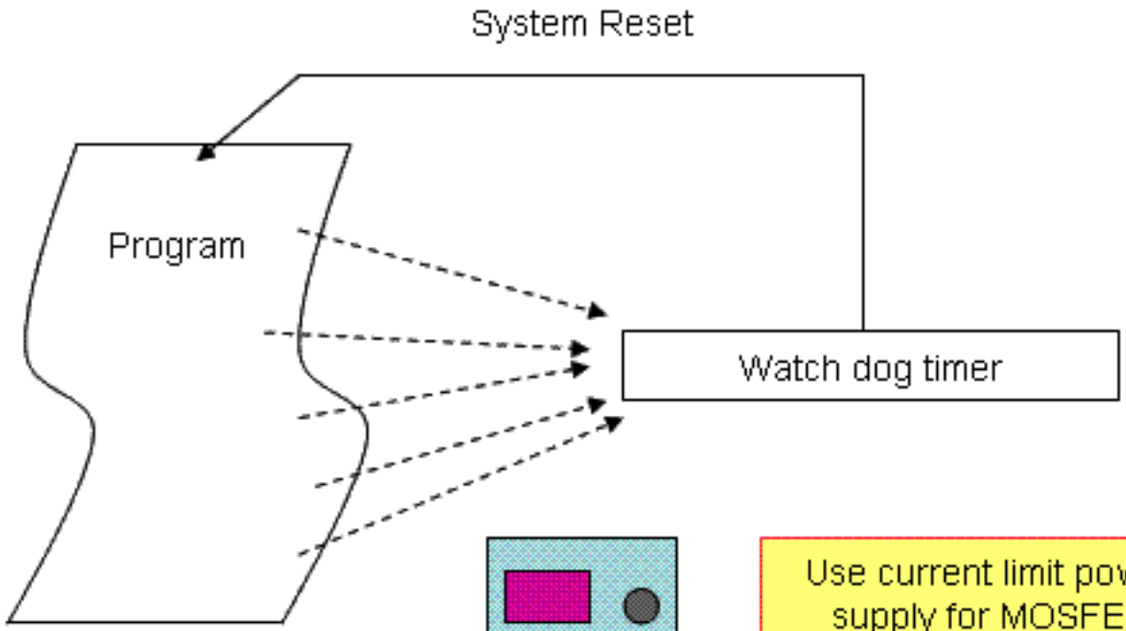
Precise Zero Cross Point Detection

by Takao

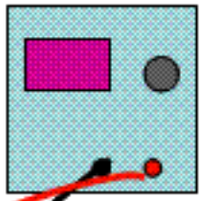
Misfire Check for Zero-Cross Power Control



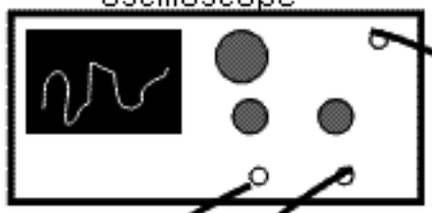
Programming details for zero cross control to get stable max power by Takao



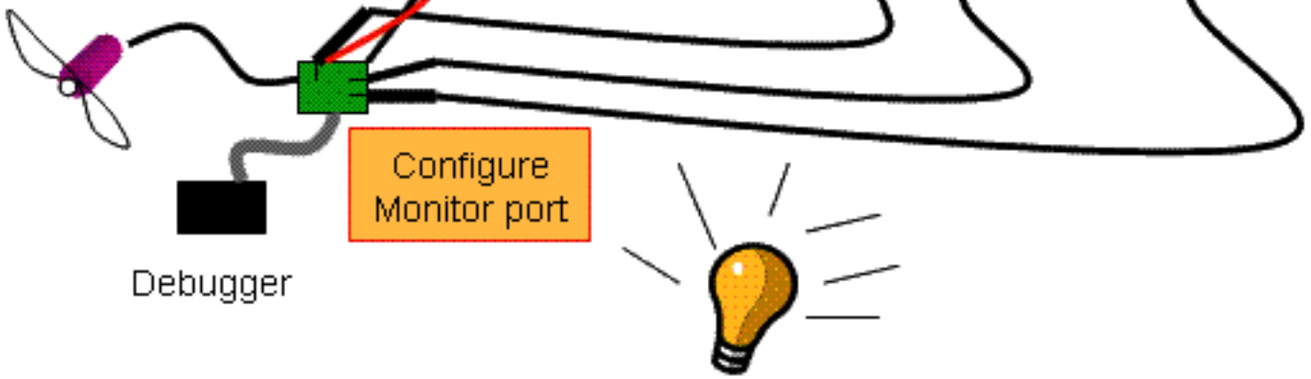
Watch dog timer can not protect devices, just for program over run happening system reset



Use current limit power supply for MOSFET protection in testing and debugging



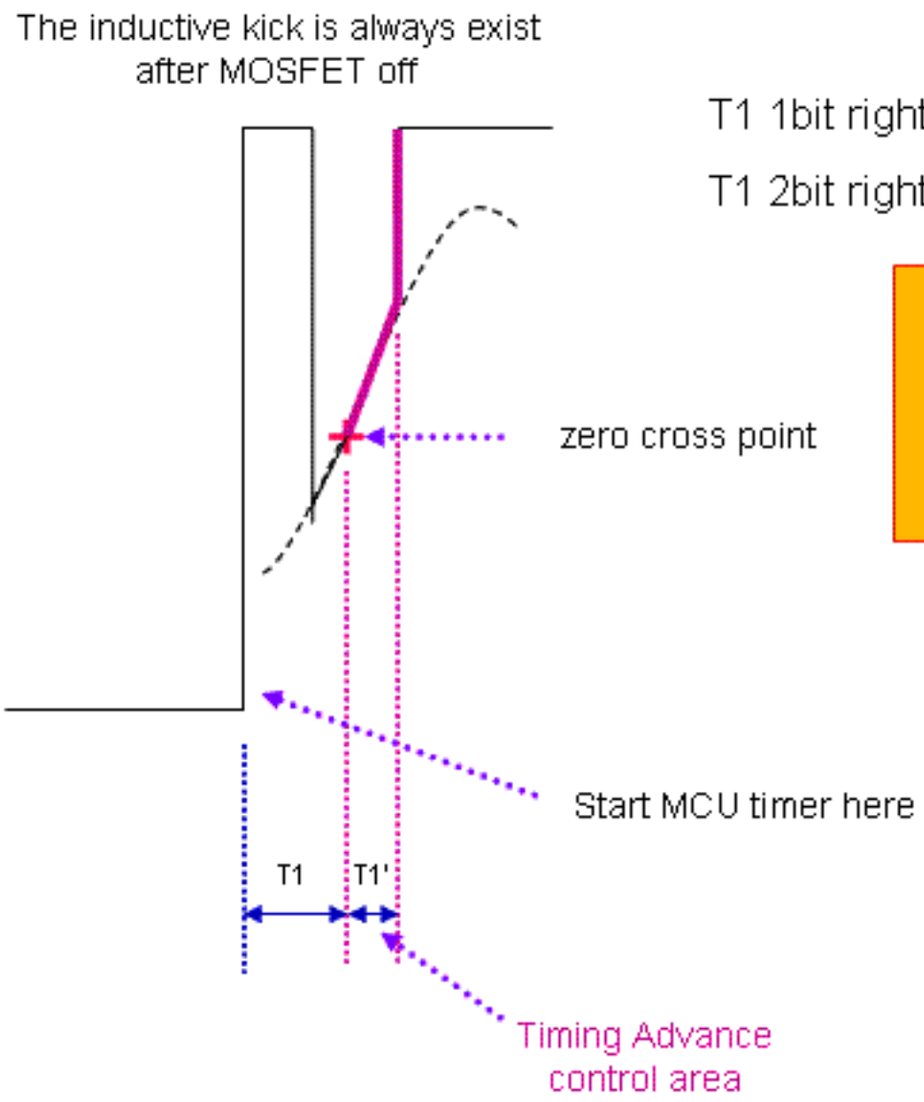
Watch and Monitor power voltage dip to find bug



Motor control software never halt and most of brake point info. is garbage for dynamic control. So, the monitor programming for scope trigger by output port is quite useful for debugging.

Basic programming tools for BL-ESC development by Takao

Timing Advance in Zero-Cross Power Control



T1 1bit right shift = T1': 25% advance

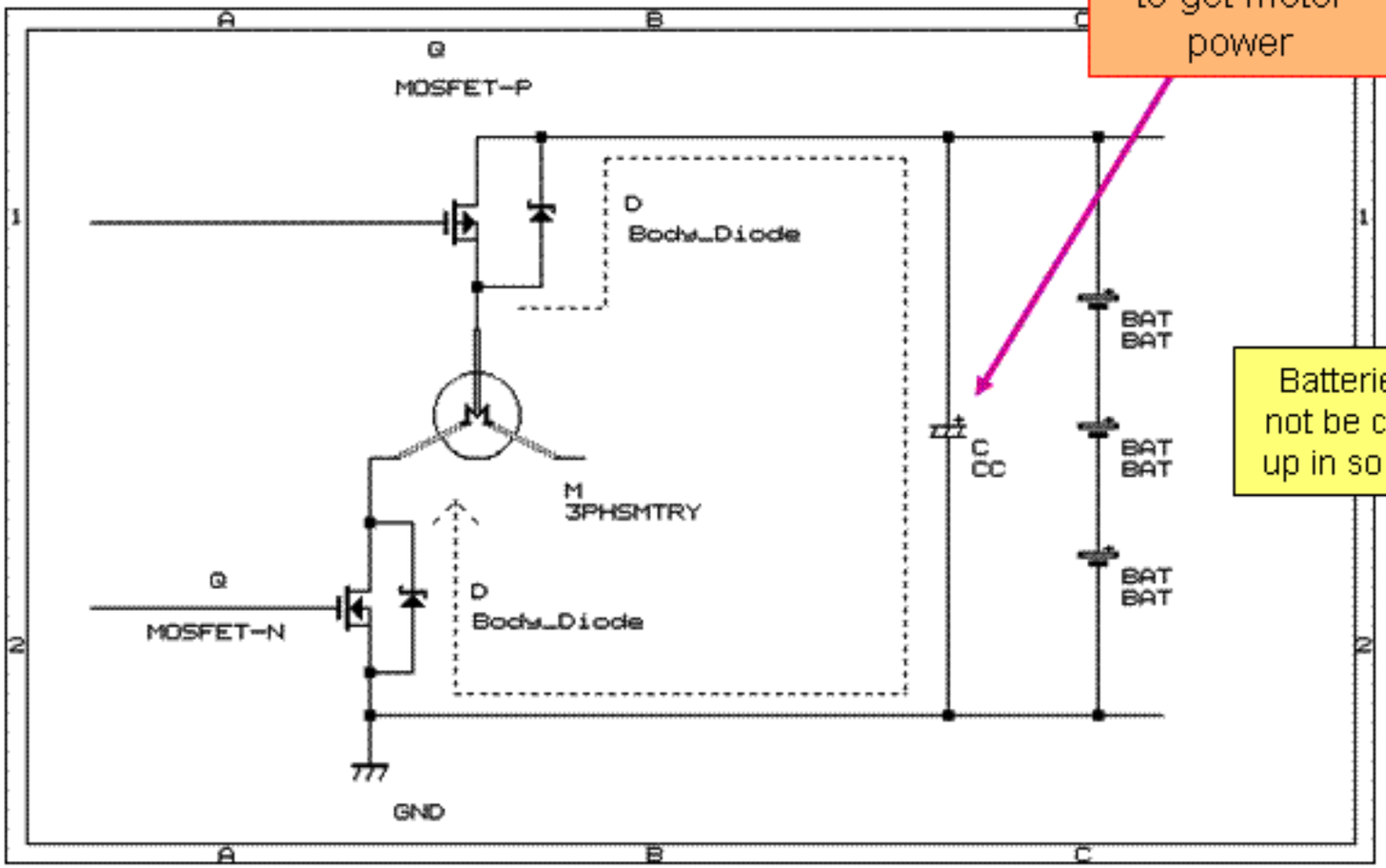
T1 2bit right shift = T1': 12.5% advance

Timing Advance helps unsymmetrical motor generate sine wave form e.g. magnet field /coil winding tolerance for stable control.

Programming details for Timing Advance control to get stable max power

The battery's internal resistance is very low enough, but the bypass cap on the power line works so great. Why?

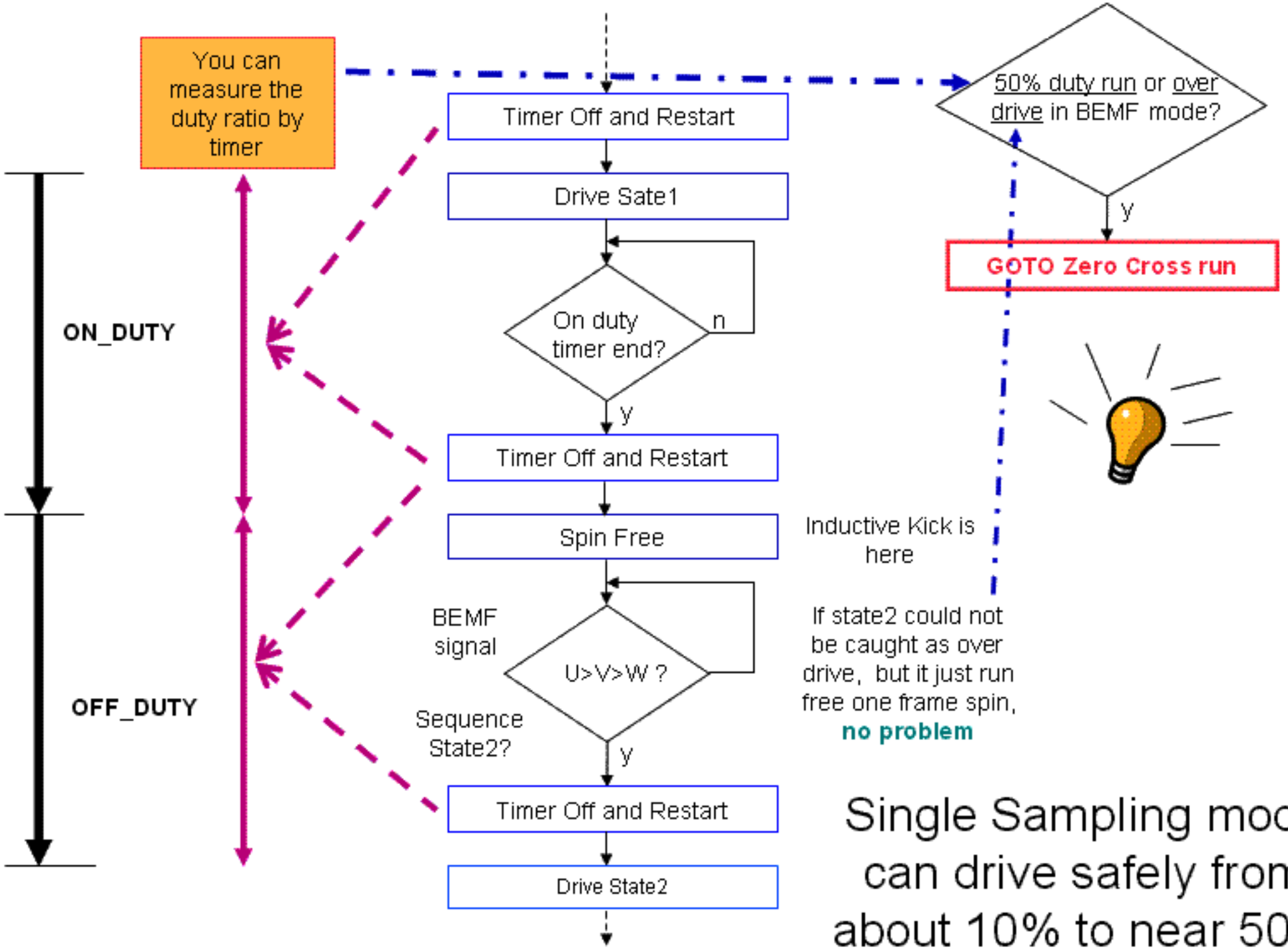
The body avalanche diode as integral reverse p-n diode in MOSFET not only protects MOS device, but also charge-up the capacitor on the power line by inductive power from motor coil.

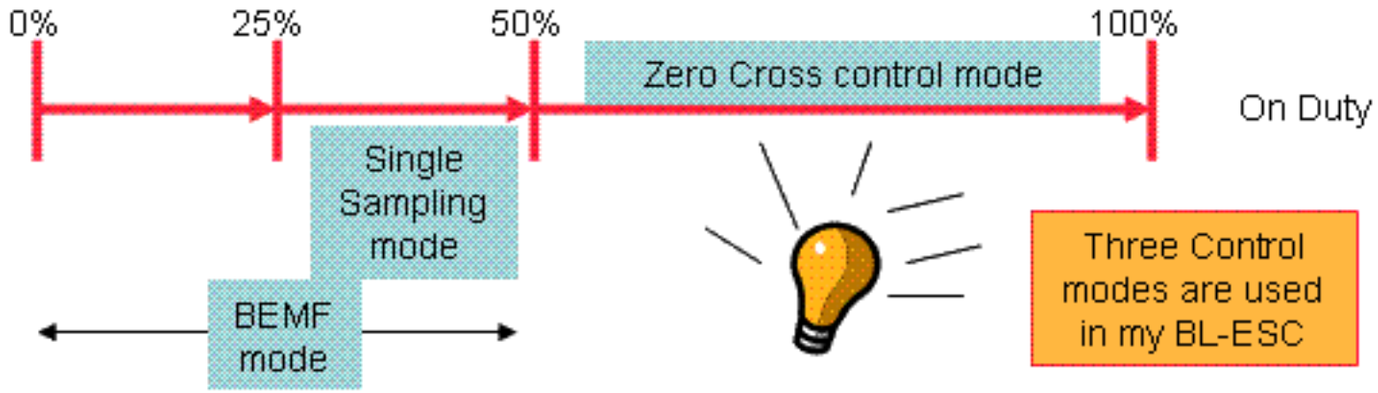


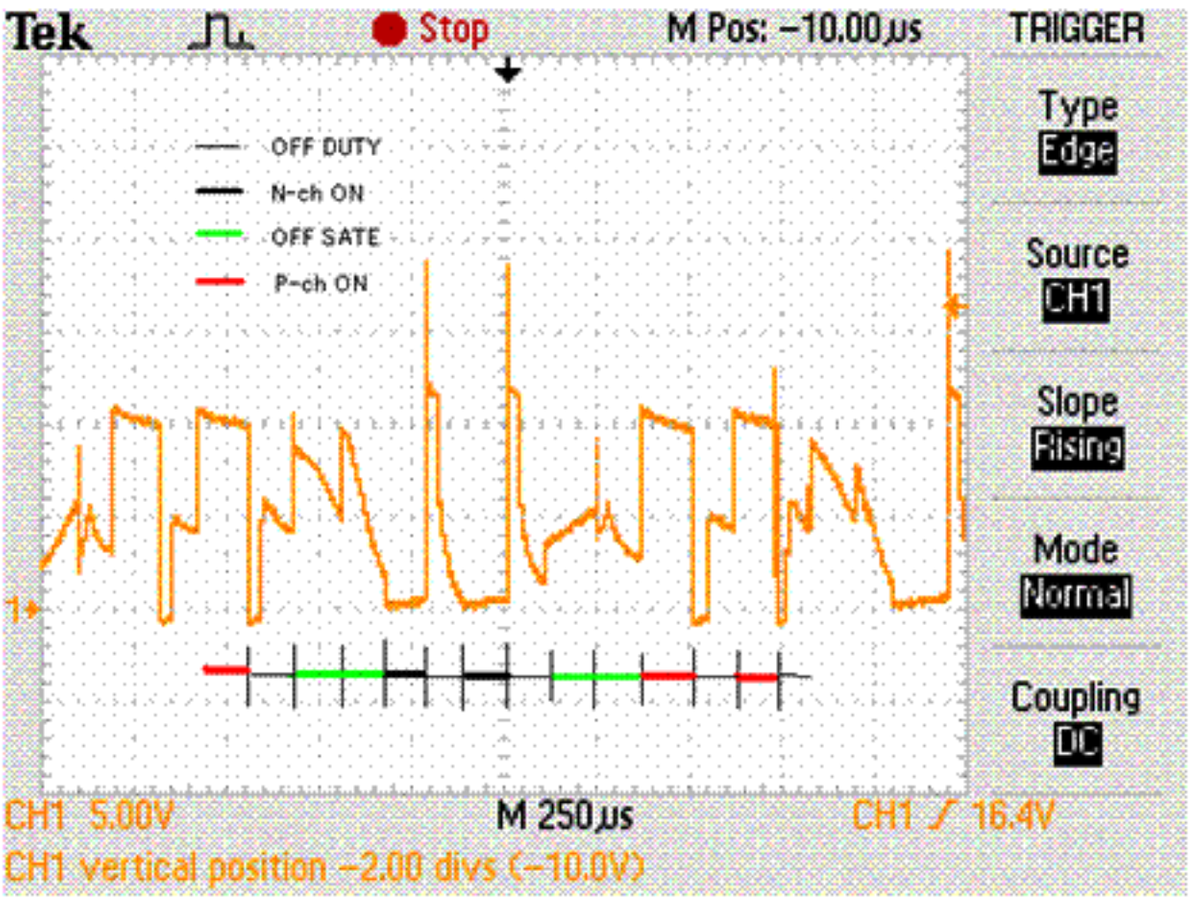
Need big cap to get motor power

Batteries can not be charged up in so quickly

Flywheel diode in MOSFET

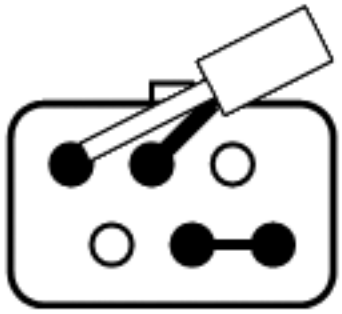

You can measure the duty ratio by timer
ON_DUTY
OFF_DUTY
Timer Off and Restart
Drive Sate1
On duty timer end?
n
y
Timer Off and Restart
Spin Free
BEMF signal
U>V>W ?
Sequence State2?
y
Timer Off and Restart
Drive State2
50% duty run or over drive in BEMF mode?
y
GOTO Zero Cross run
Inductive Kick is here
If state2 could not be caught as over drive, but it just run free one frame spin, no problem
Single Sampling mode can drive safely from about 10% to near 50% on-duty





Wave form of Single Sampling mode
by Takao

FMS-FF9



Futaba
FF9 Tx

1n4148
Diode or
similar

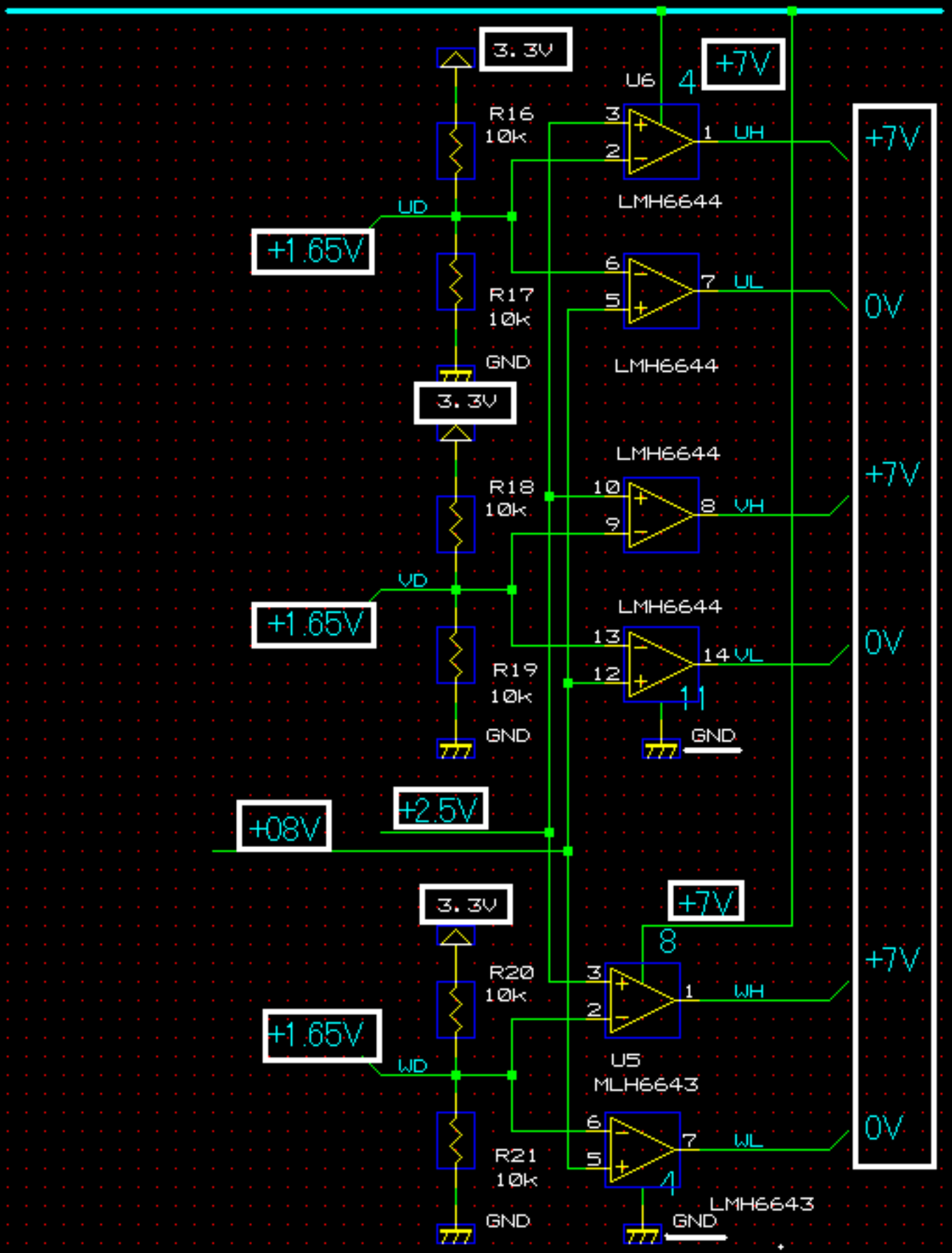
1k8

4v7
Zener
Diode

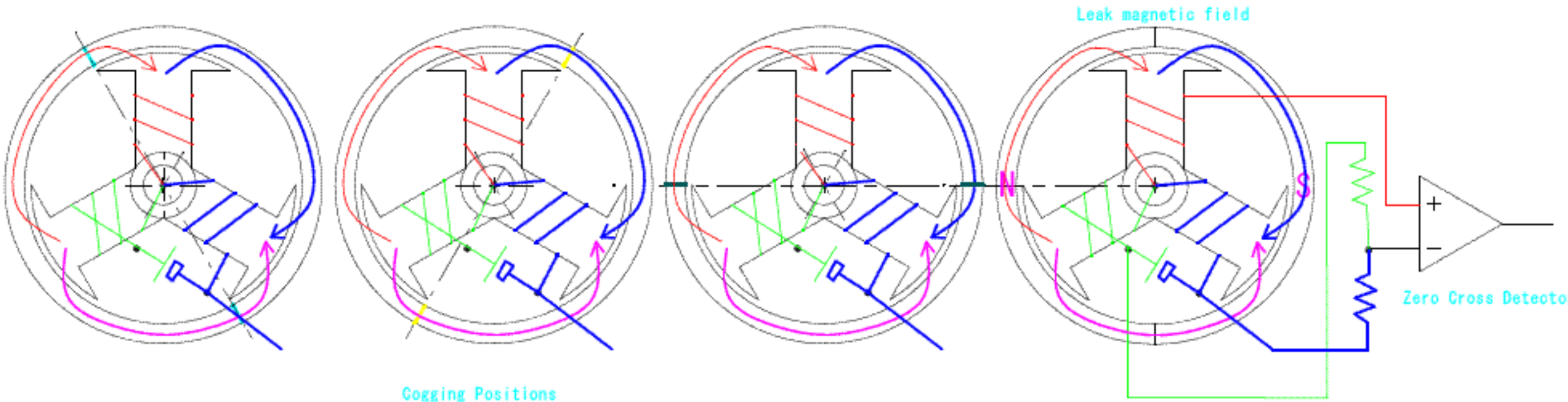
BC327 or
Any small
signal PNP
device

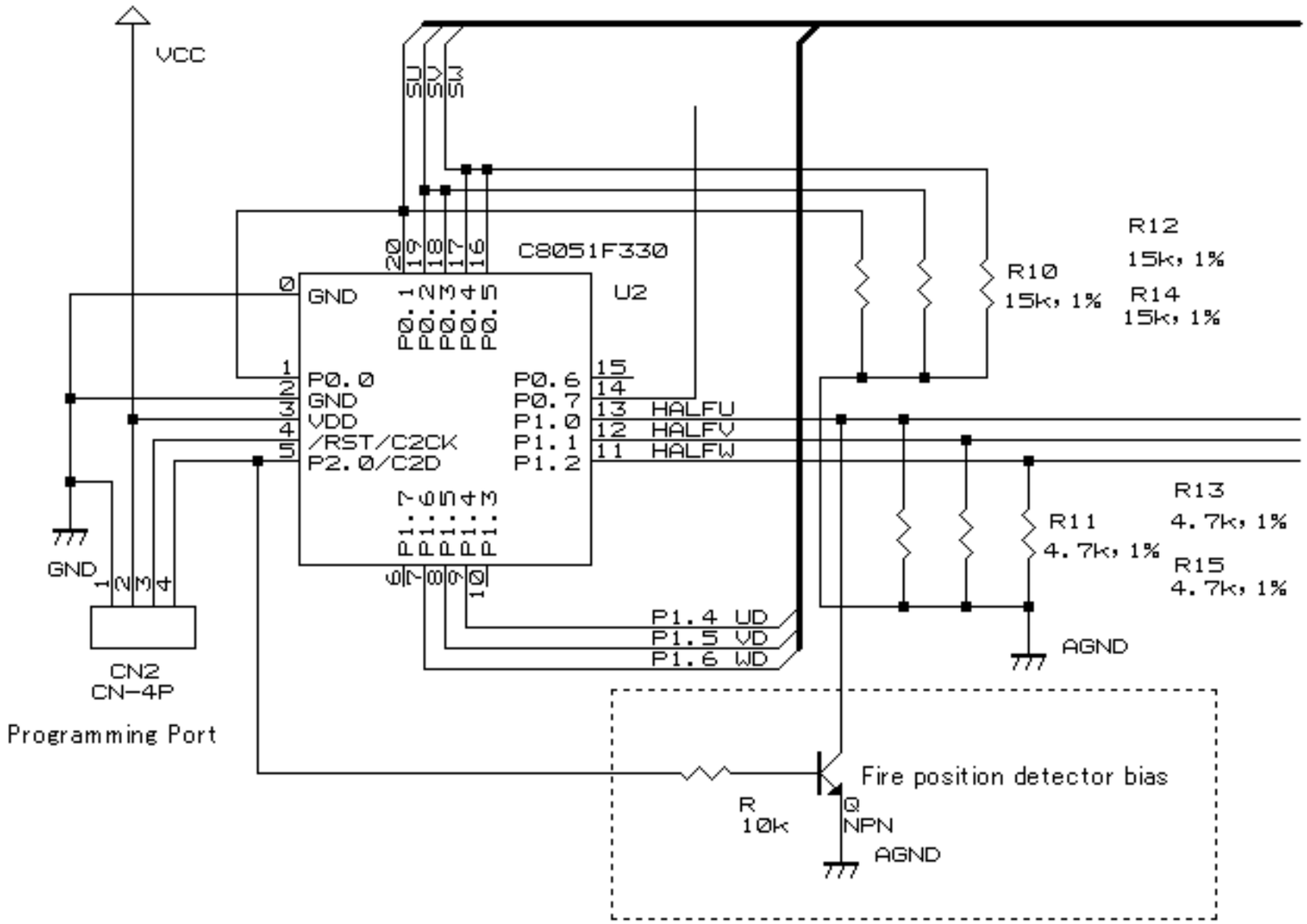
Pin 10

Pin 18


3.3V
R16
10k
UD
+1.65V
R17
10k
GND
3.3V
R18
10k
VD
+1.65V
R19
10k
GND
+08V
+2.5V
3.3V
R20
10k
+1.65V
WD
R21
10k
GND
U6
4
+7V
3
2
1
UH
LMH6644
6
5
7
UL
LMH6644
LMH6644
10
9
8
VH
LMH6644
13
12
14
VL
11
GND
GND
+7V
8
3
2
1
WH
U5
MLH6643
6
5
7
WL
4
LMH6643
GND
+7V
0V
+7V
0V
+7V
0V

Starting rotar position sensing (shown only one phase impulse drive sensing)




VCC
SU
SV
SW
C8051F330
U2
GND
P0.0
GND
VDD
/RST/C2CK
P2.0/C2D
P0.6
P0.7
P1.0
P1.1
P1.2
HALFU
HALFV
HALFW
P1.4 UD
P1.5 VD
P1.6 WD
R10
15k, 1%
R12
15k, 1%
R14
15k, 1%
R11
4.7k, 1%
R13
4.7k, 1%
R15
4.7k, 1%
AGND
GND
CN2
CN-4P
Programming Port
Fire position detector bias
R
10k
Q
NPN
AGND

or FDS8679 Fairchild P-MOSFET

+12.8V max

D1
1SS319

U1
NJU0072L33
3.3V, 1%

C1
47uF/16V

C2
10uF/6.3V

R1
820

R2
1.8k

R3
820

2.5V

0.8V

GND

(NEC)
U3
LM2905AT

C3
33uF/6.3V

U4
LM2905AT

High Ripple type.

CN2
CN-3P

3.3V

U6
LMH6644

R11
10k

R12
10k

R13
10k

R14
10k

UH

UL

VH

VL

UD

LMH6644

LMH6644

LMH6644

R19
47k

IRF7425
U7

IRF7425
U9

IRF7425
U11

IRF7455
U8

IRF7455
U10

IRF7455
U12

R20
75k 1%

R21
75k 1%

R26
75k 1%

C4
47uF/25V

CN3
2HEADER

R17
2.2k

R18
10k

R24
47k 1%

R25
47k 1%

R27
47k 1%

R28
47k 1%

R22
47k 1%

R23
47k 1%

HALFU

HALFV

HALFW

U
V
W

BL Motor
M1

R15
10k

R16
10k

U5
MLH6643

LMH6643

Drive Wave Form

C8051F330
U2

R7
15k 1%

R5
15k 1%

R9
15k 1%

R8
4.7k 1%

R6
4.7k 1%

R10
4.7k 1%

P1.4 UD
P1.5 VD
P1.6 WD

AGND

CN1
CN-4P

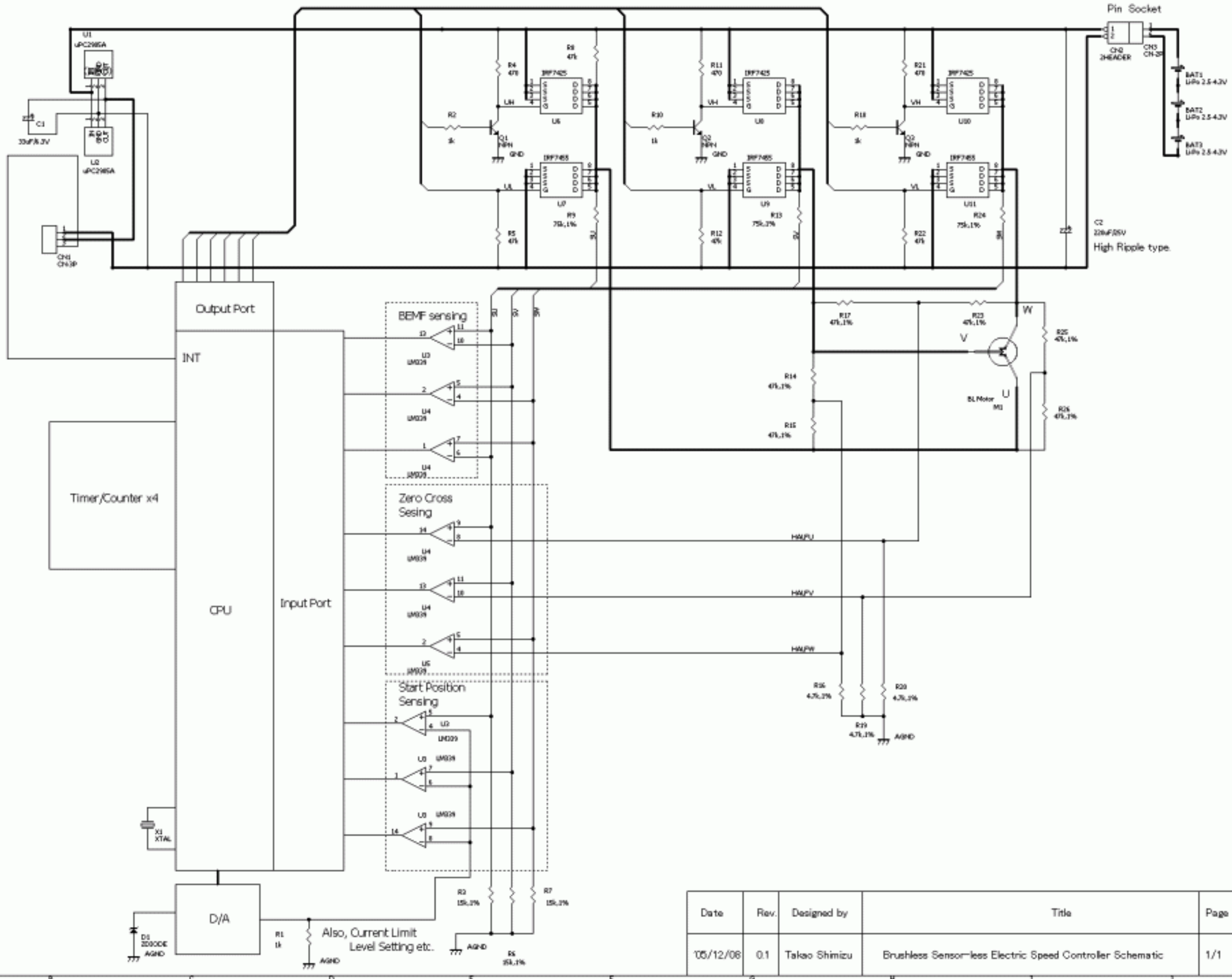
Programming Port

R4
10k

Q1
C1815

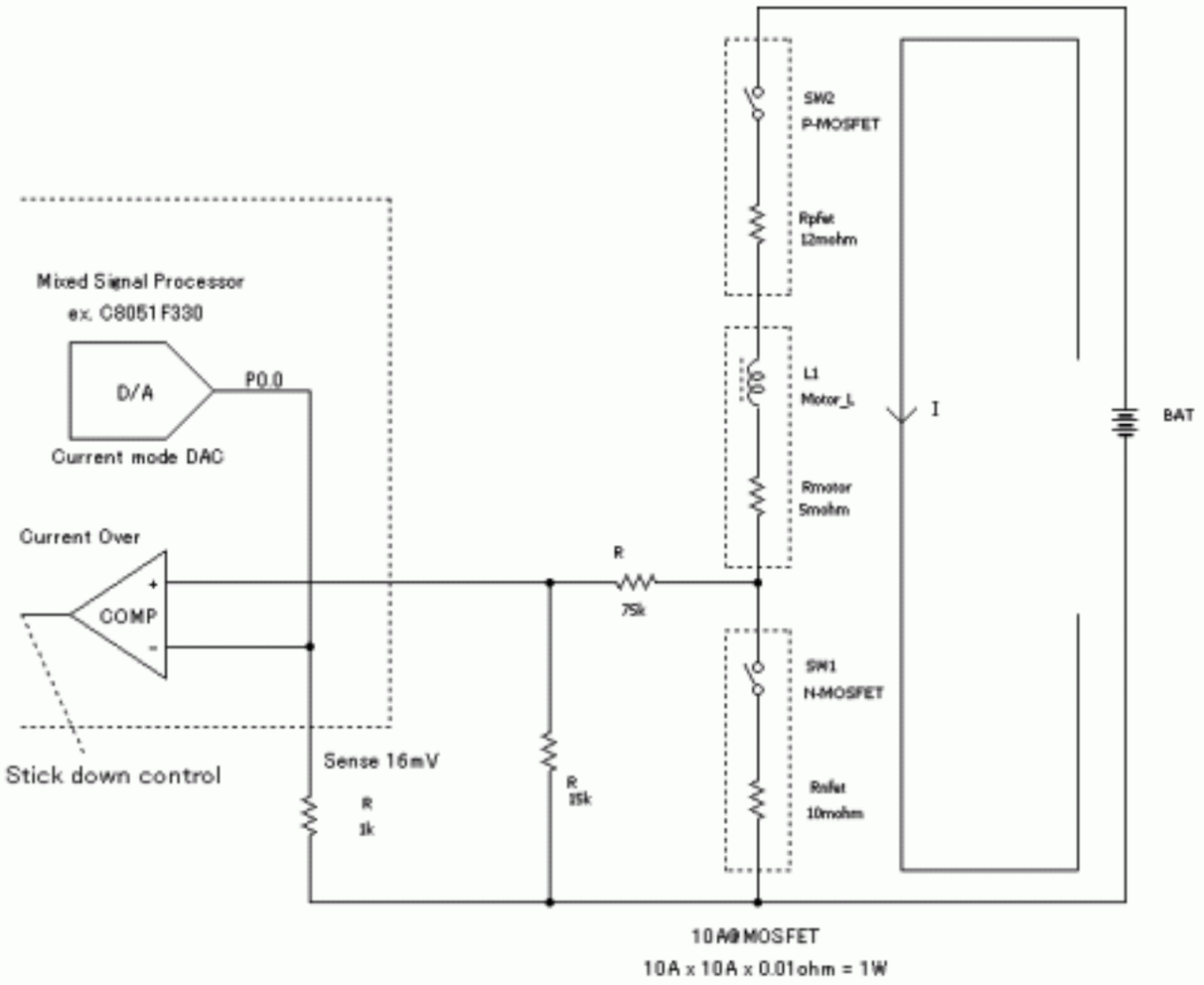
Fire position detector bias

Date	Rev.	Designed by	Title	Page
'05/08/15	0.5	Takao Shimizu	Brushless Sensor-less Electric Speed Controller Schematic	1/1



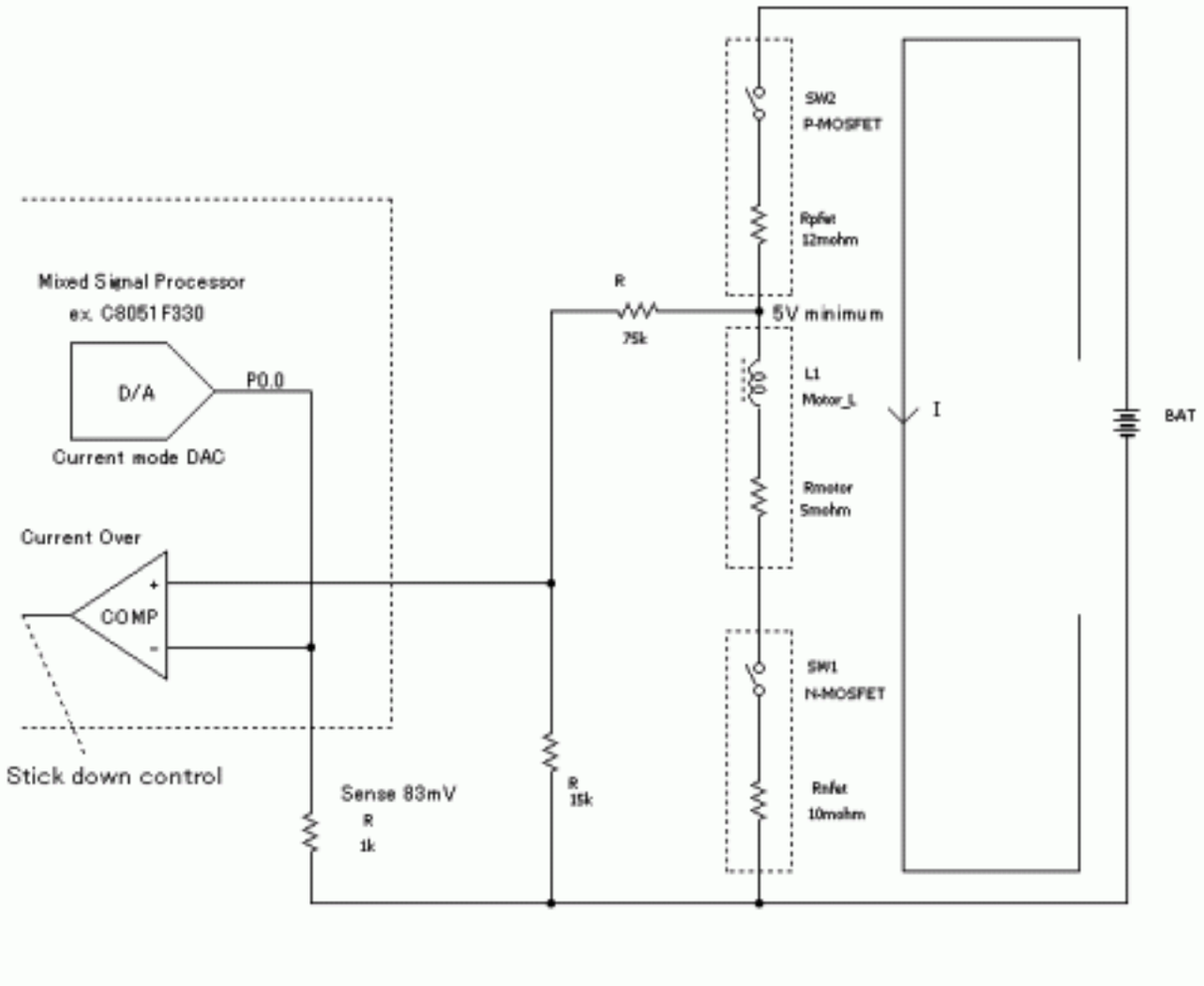
Date	Rev.	Designed by	Title	Page
'05/12/08	0.1	Takao Shimizu	Brushless Sensor-less Electric Speed Controller Schematic	1/1

Current Limiter function

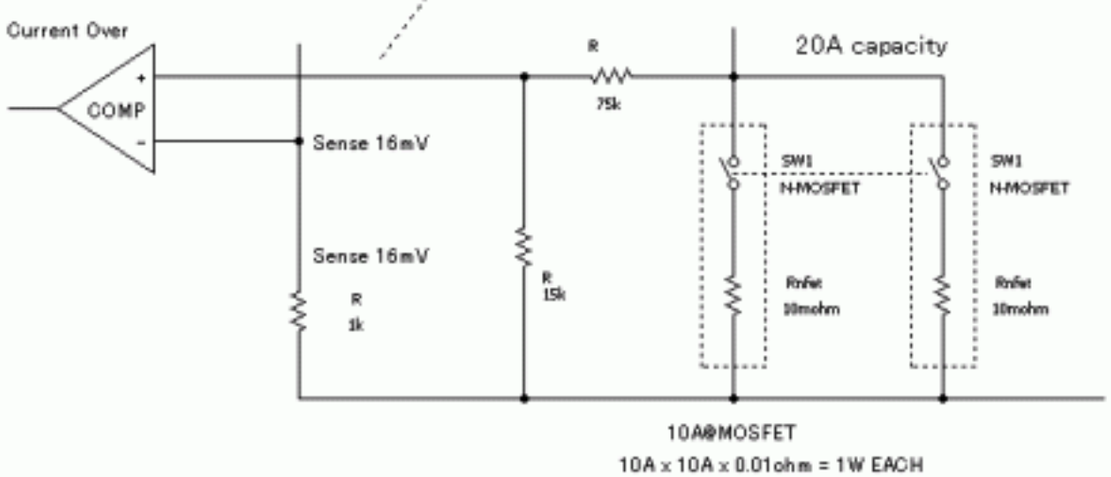


10A@MOSFET
10A x 10A x 0.01ohm = 1W

Keep the lowest operation voltage



The sensing voltage is same as single MOSFET drive!



10A@MOSFET
10A x 10A x 0.01ohm = 1W EACH

Date	Rev.	Designed by	Title	Page
'05/12/30	2	Takao Shimizu	BL-ESC Protection diagram in MPU	1/1

Minus Spike is 3Vp-p

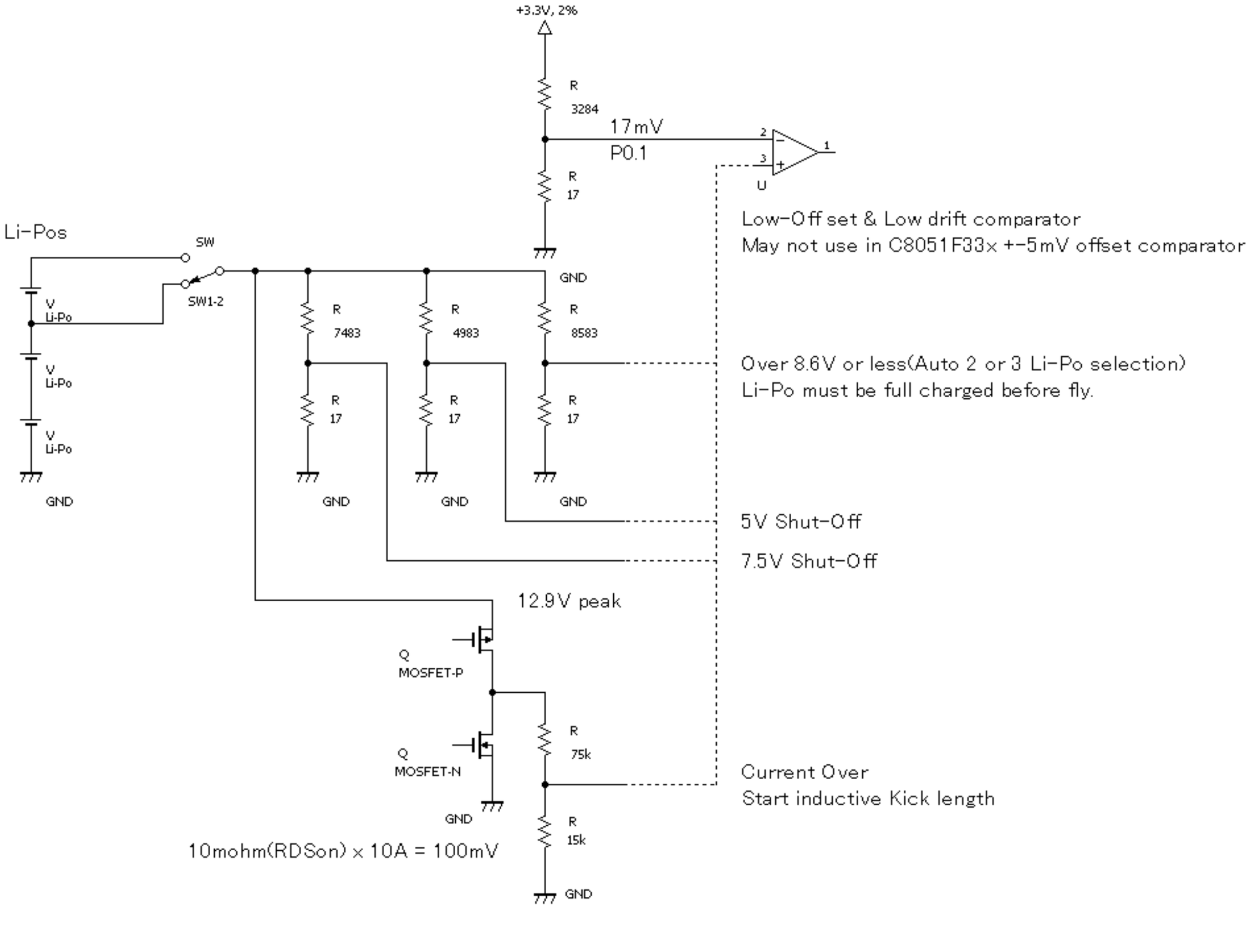
Programming Port

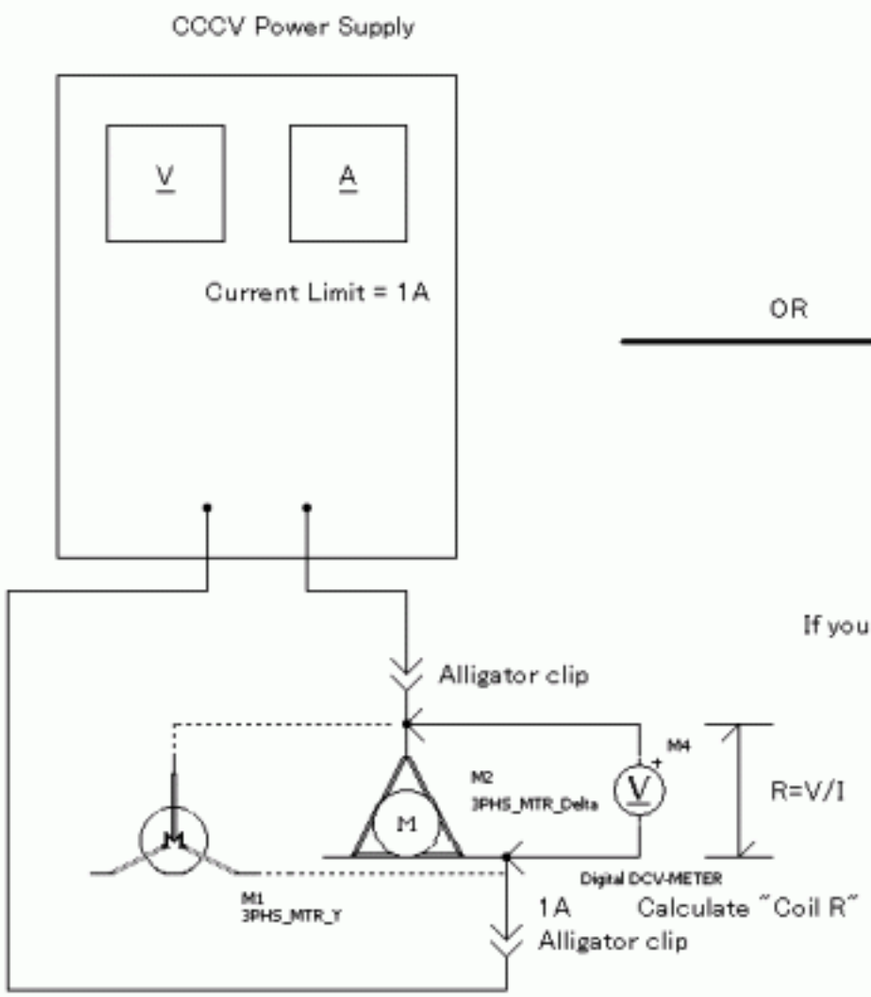
+18V max

+30V max

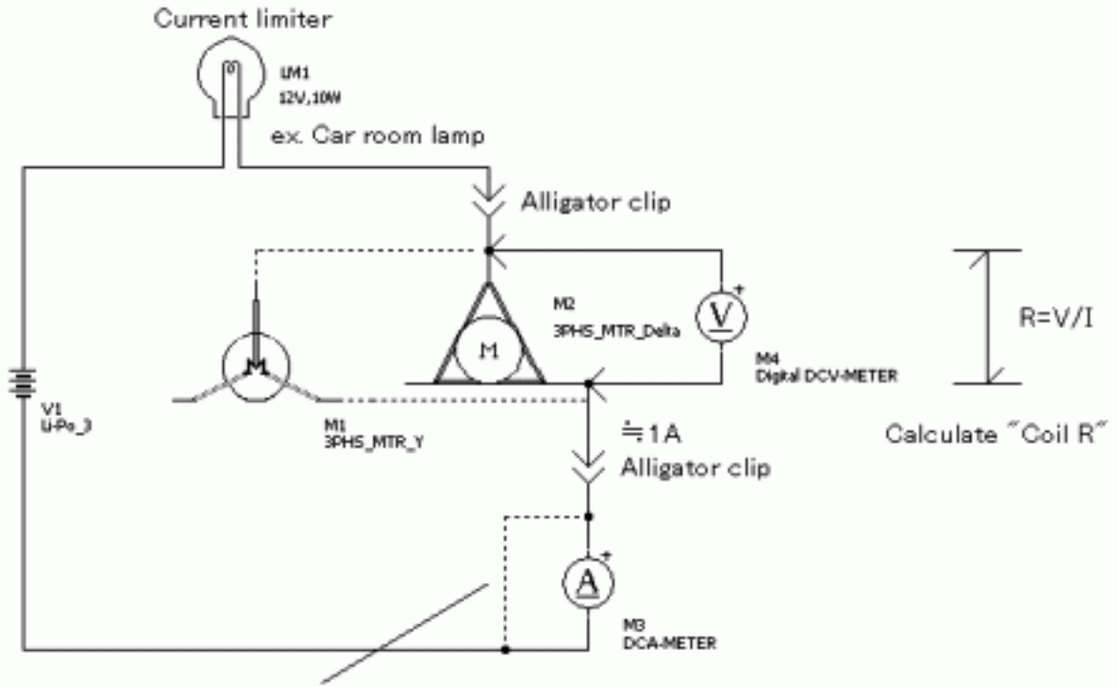
1.8mΩ Typ.

Date	Rev.	Designed by	Title	Page
'06/12/31	0.5b	Takao Shimizu	100A, 30V BL-ESC Schematic	1/1


+3.3V, 2%
R
3284
17mV
P0.1
R
17
2
3
1
U
Low-Off set & Low drift comparator
May not use in C8051F33x +-5mV offset comparator
Li-Pos
SW
SW1-2
V
Li-Po
V
Li-Po
V
Li-Po
GND
GND
R
7483
R
4983
R
8583
R
17
R
17
R
17
GND
GND
GND
Over 8.6V or less(Auto 2 or 3 Li-Po selection)
Li-Po must be full charged before fly.
5V Shut-Off
7.5V Shut-Off
12.9V peak
Q
MOSFET-P
Q
MOSFET-N
R
75k
R
15k
GND
GND
Current Over
Start inductive Kick length
10mohm(RDSon) x 10A = 100mV

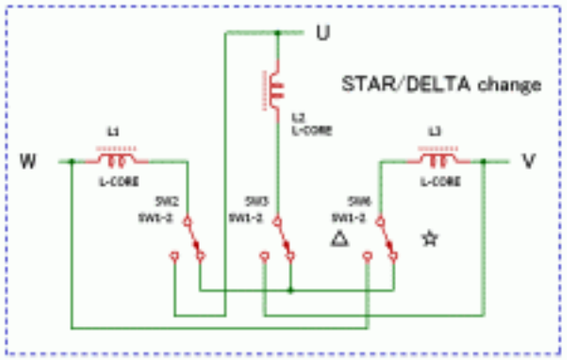


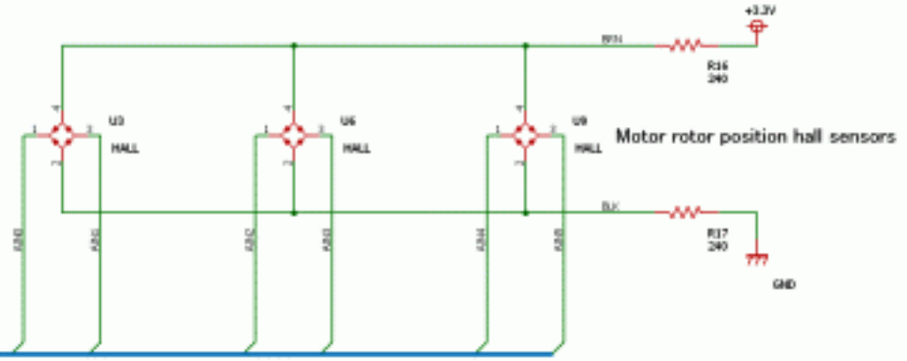
OR

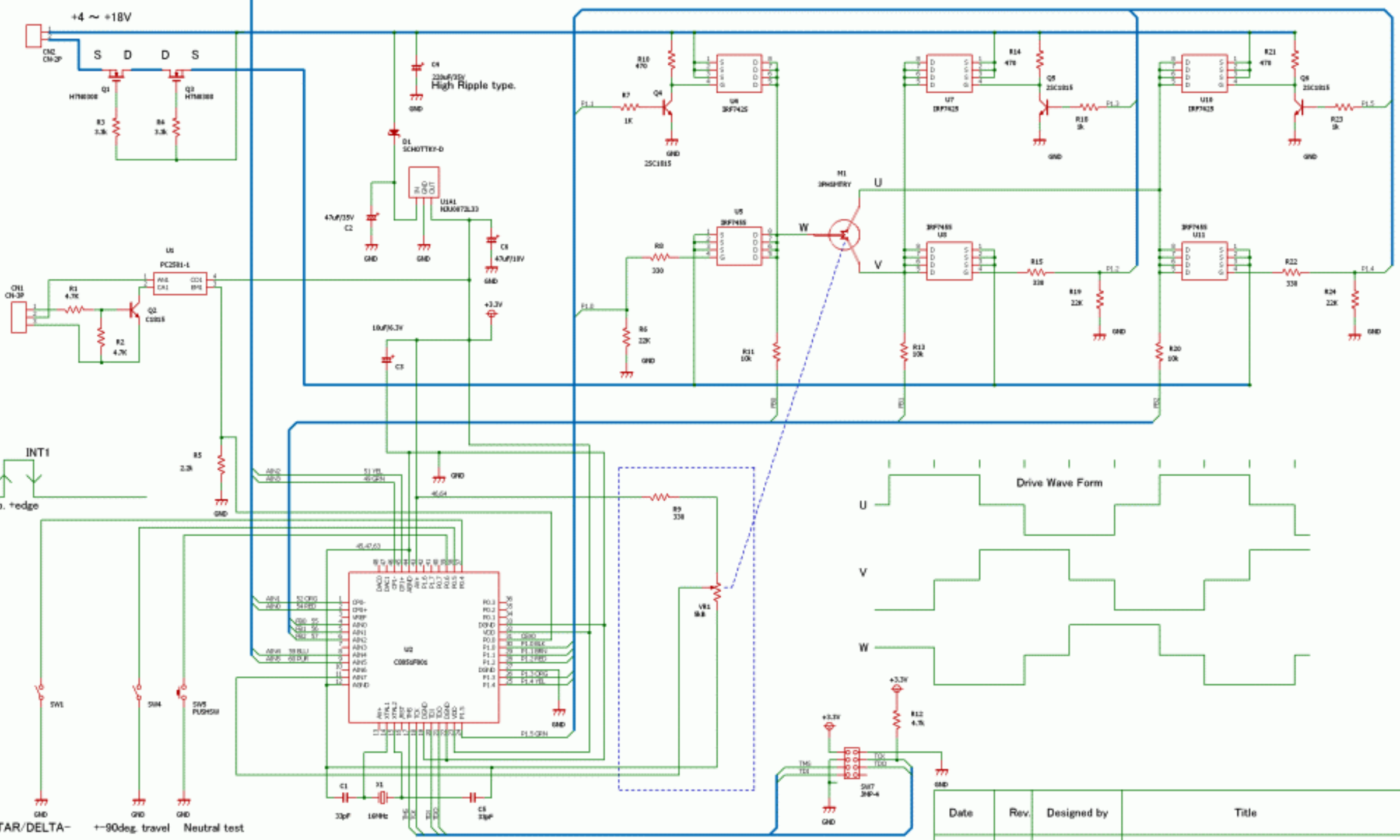


If you have one multi meter, you could short here by the lamp I constant. characteristic after "I" has been measured.

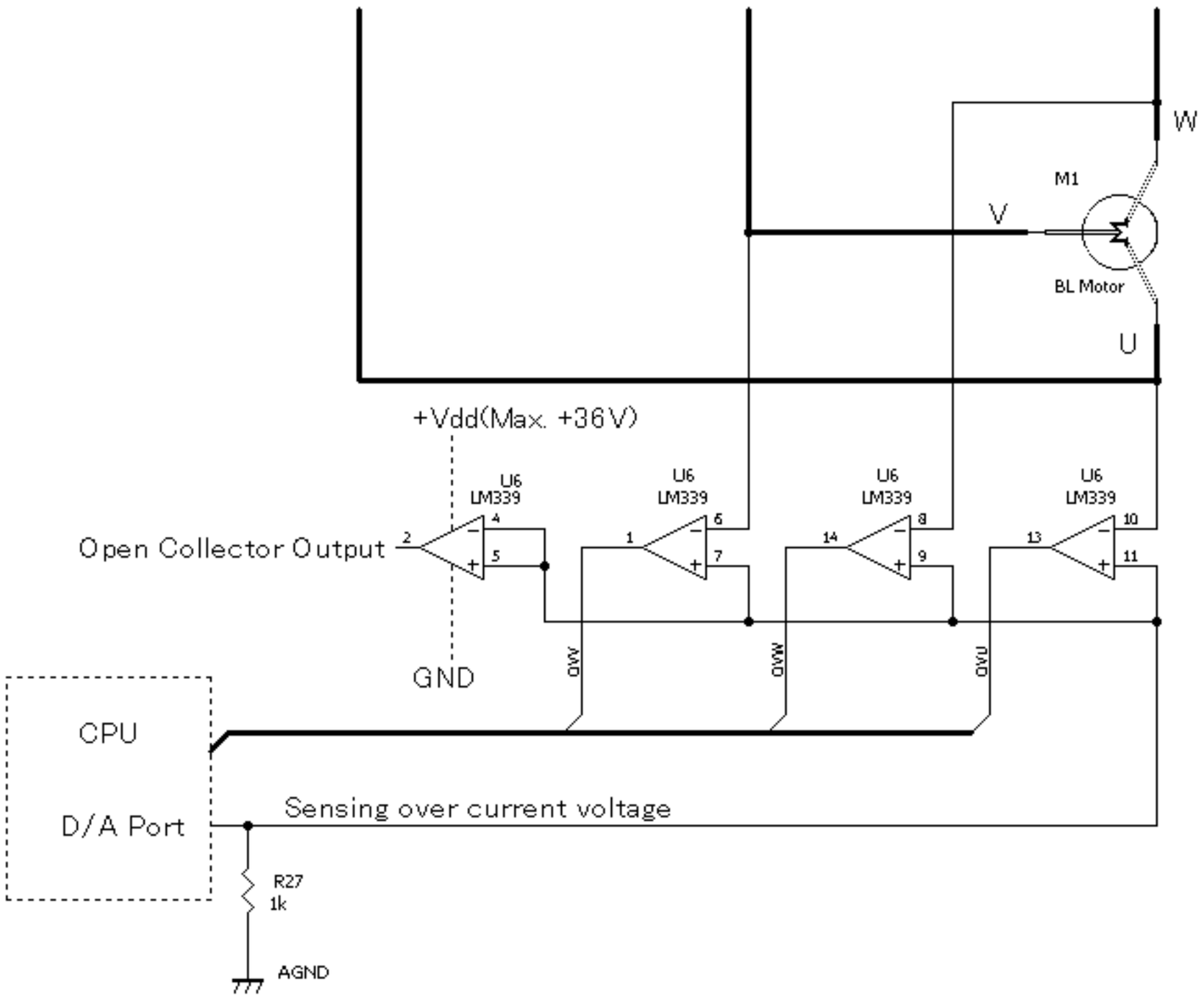
Date	Rev.	Designed by	Title	Page
'06/01/10	0.1	Takao Shimizu	Measuring method of motor coil resistance	1/1



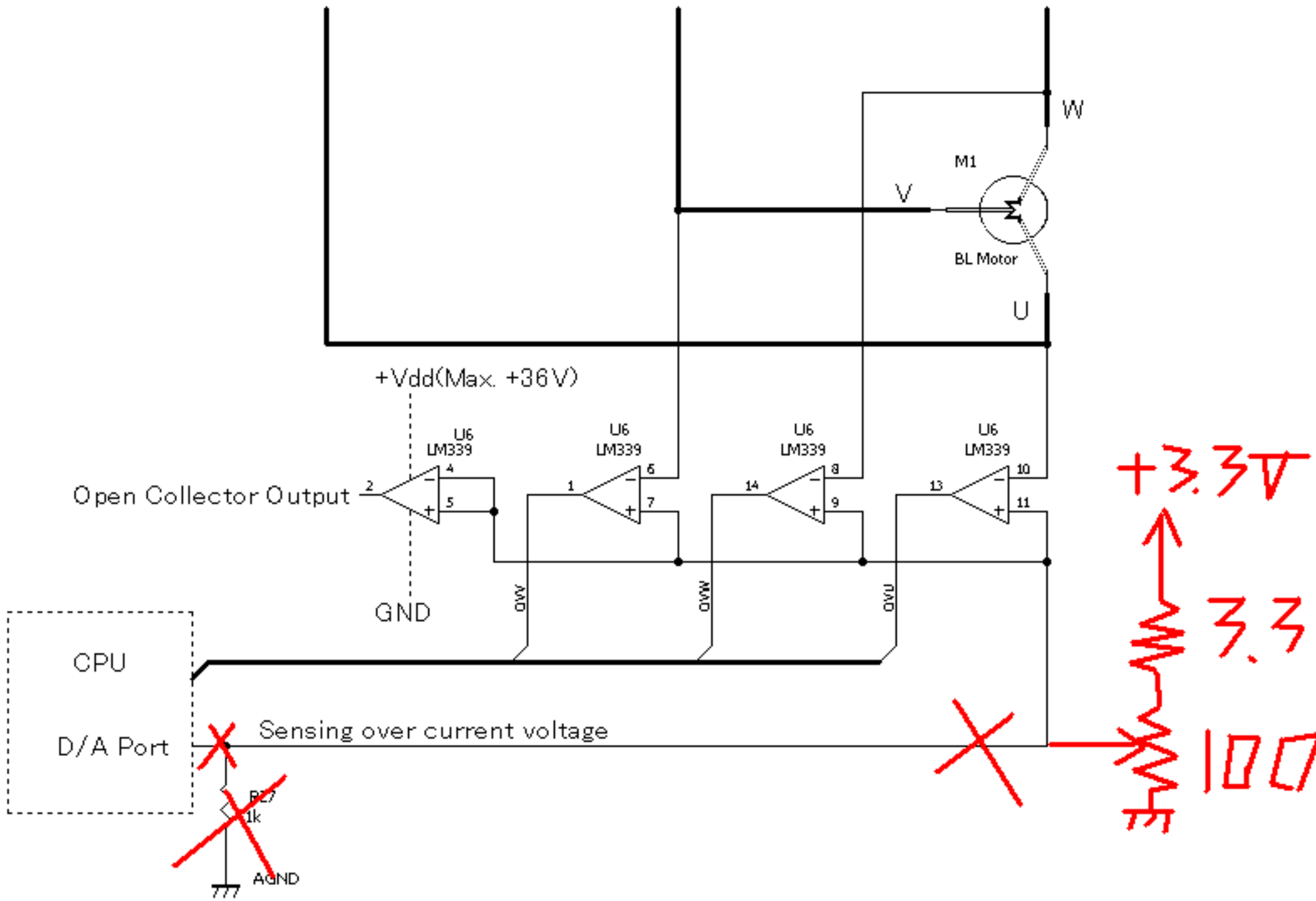




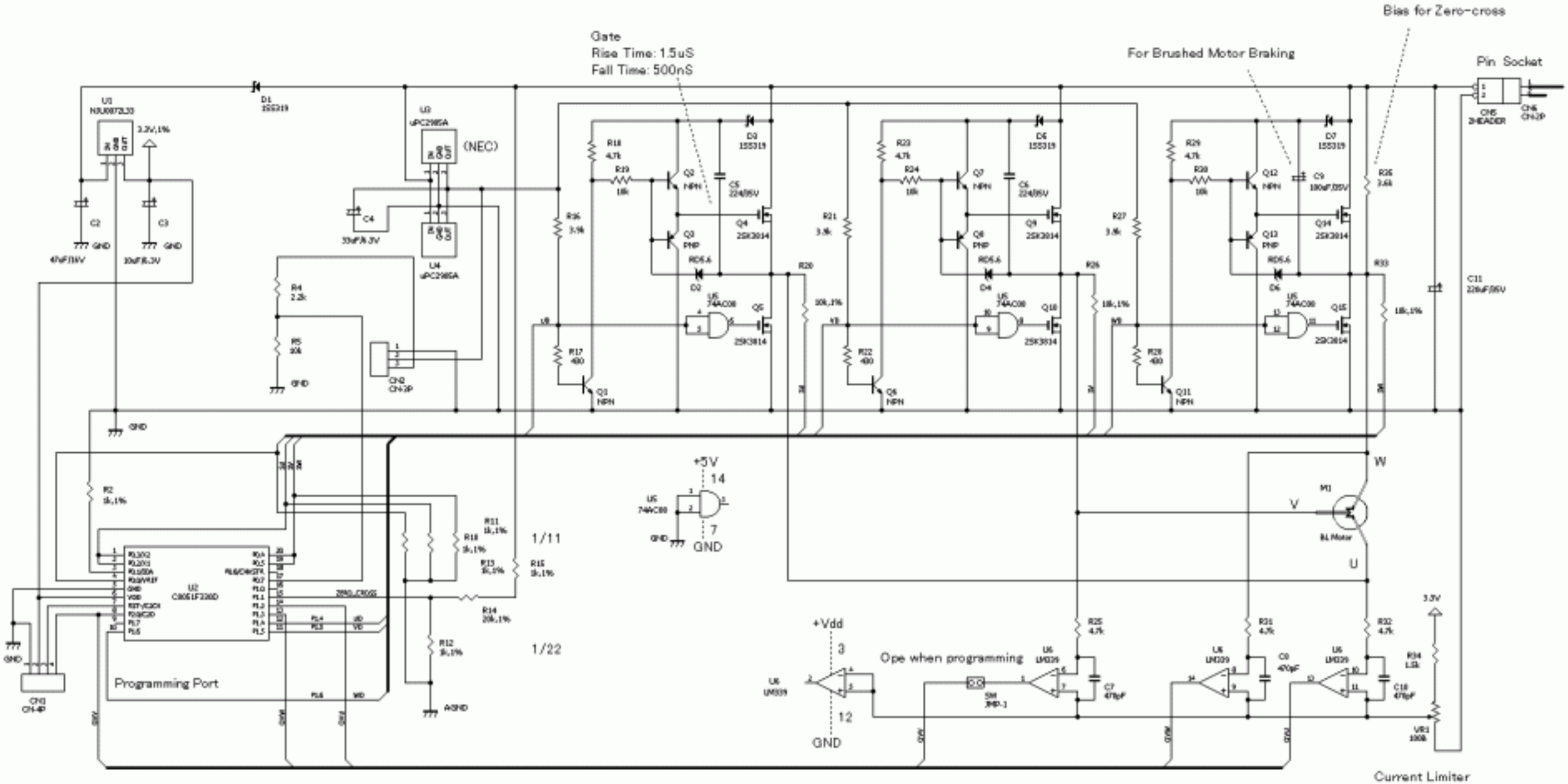
Date	Rev.	Designed by	Title	Page
'06/10/10	0.3b	Takao Shimizu	Brushless Digital Proportional Servo Schematic	1/1



Date	Rev.	Designed by	Title	Page
'05/01/25	0.1	Takao Shimizu	BL-Motor over current sensing schematic	1/1

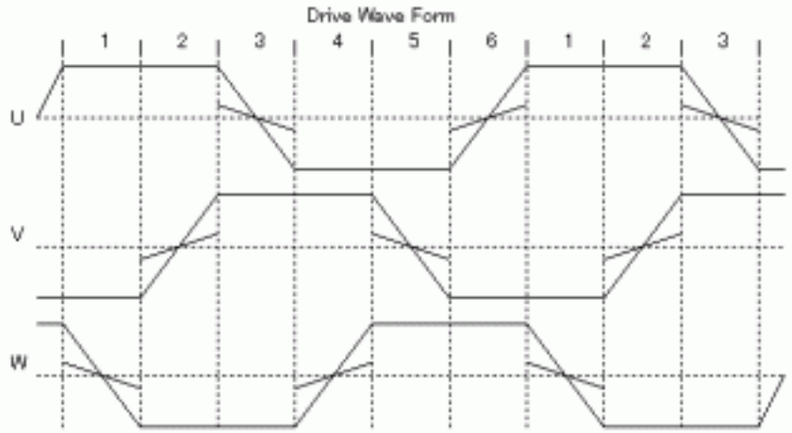


Date	Rev.	Designed by	Title	Page
'05/01/25	0.1	Takao Shimizu	BL-Motor over current sensing schematic	1/1

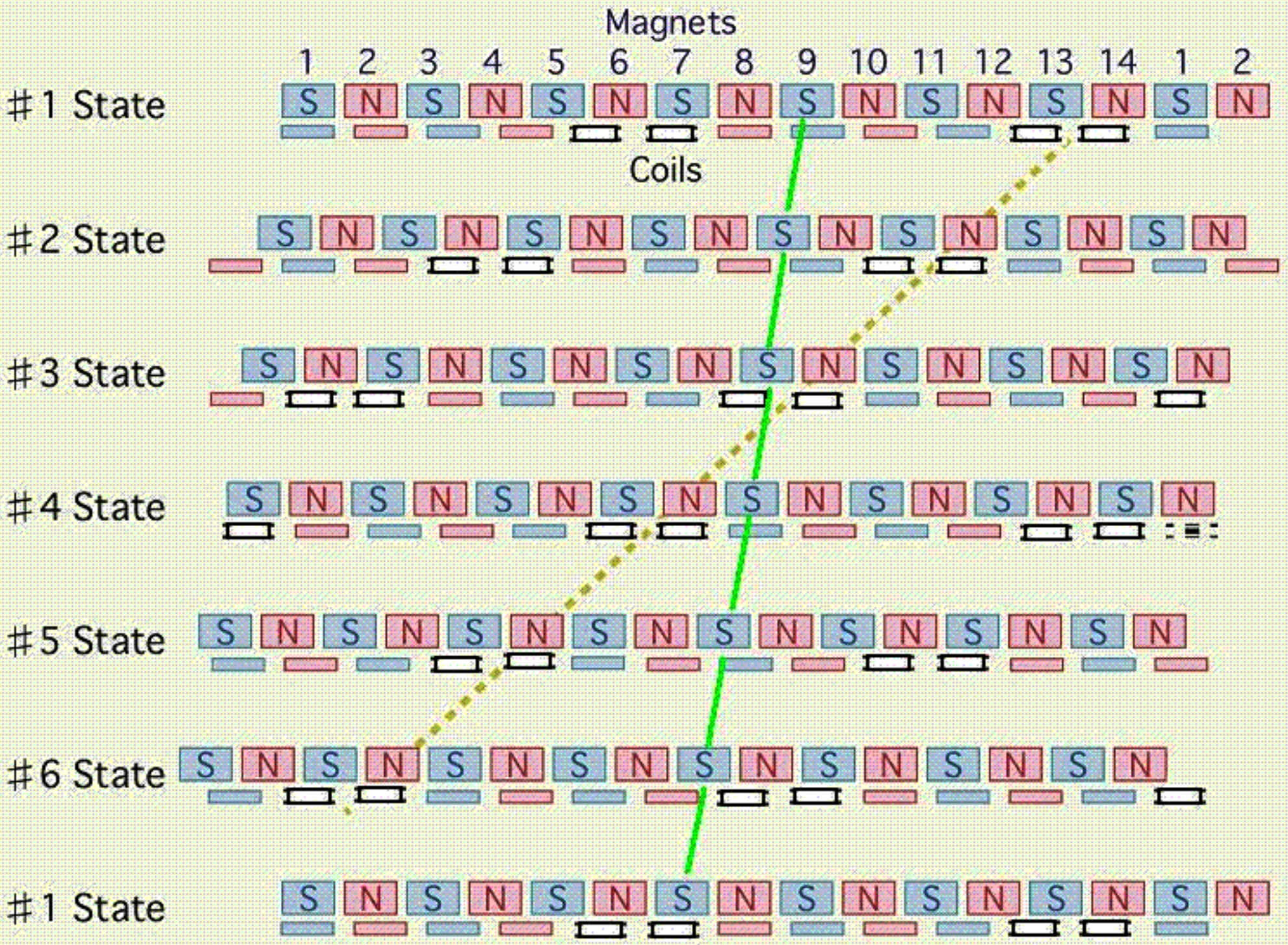


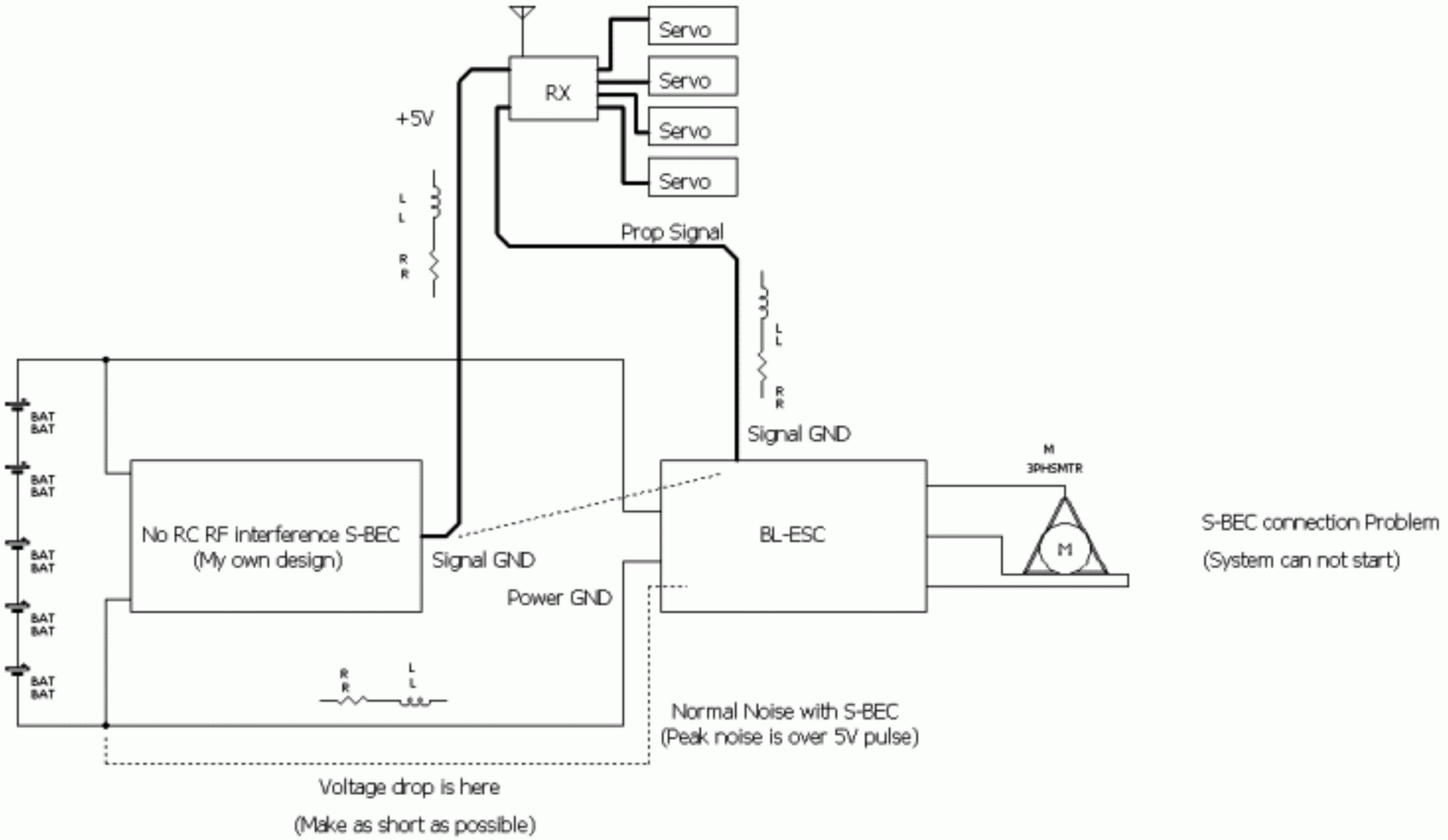
Each Cell Voltage Monitor

Drive Wave Form



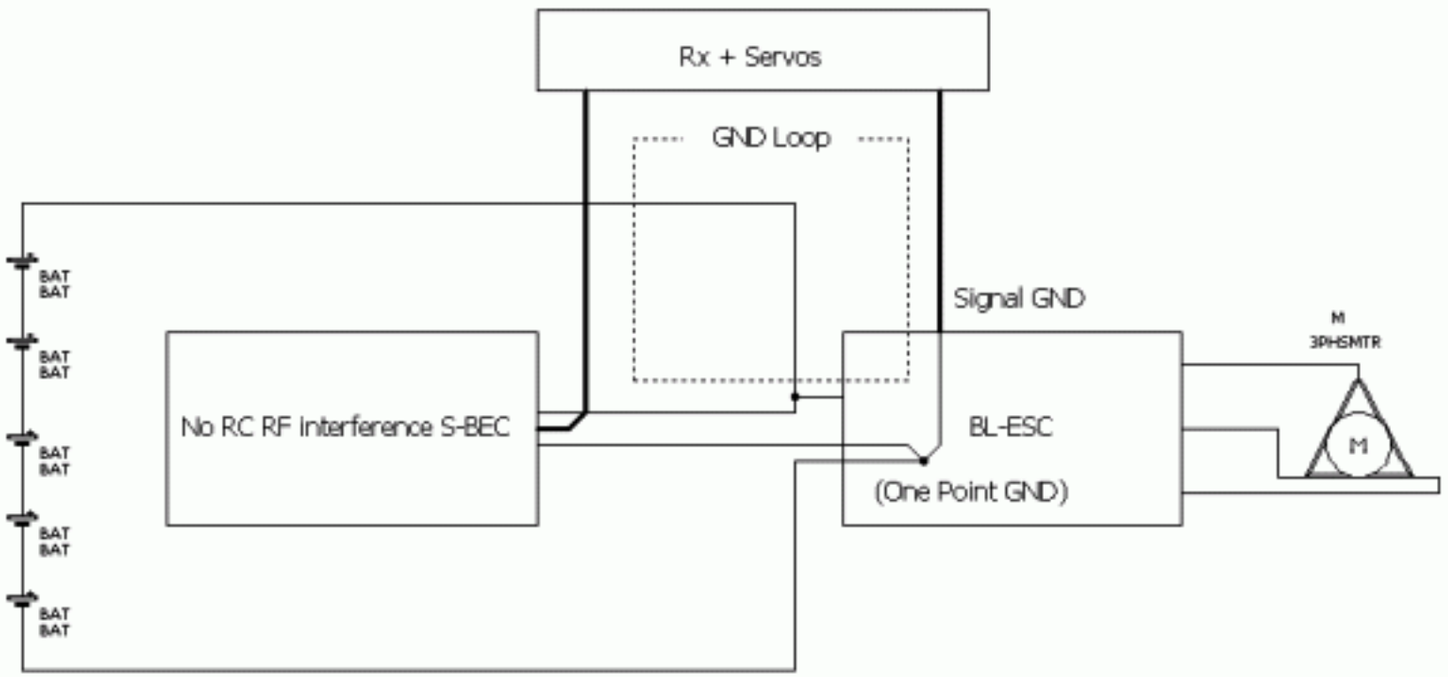
Date	Rev.	Designed by	Title	Page
'05/01/14	0.1	Takao Shimizu	Brushless Sensorless Electric Speed Controller Schematic	1/1


Magnets
1 2 3 4 5 6 7 8 9 10 11 12 13 14 1 2
#1 State
Coils
#2 State
#3 State
#4 State
#5 State
#6 State
#1 State



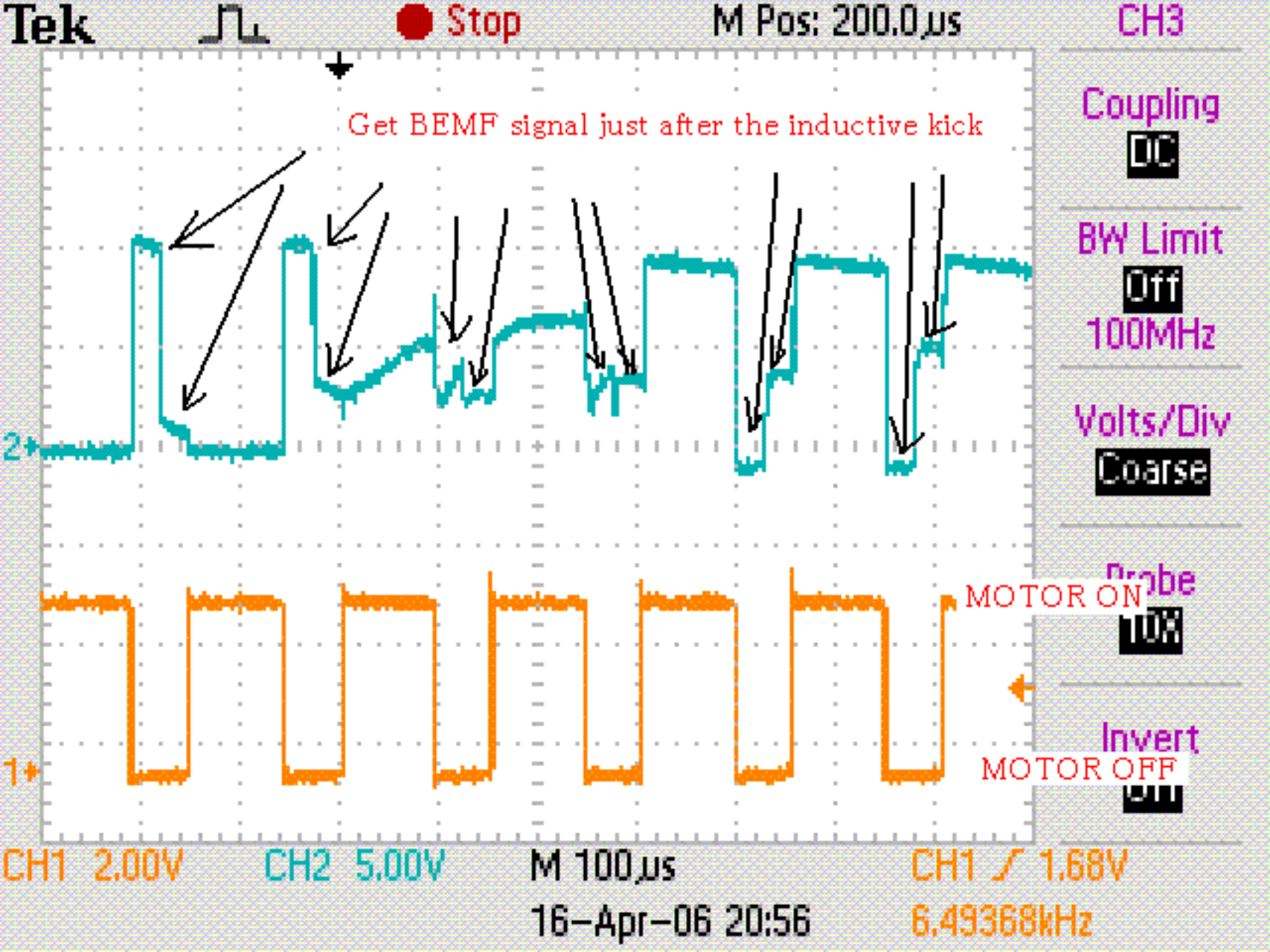
S-BEC connection Problem

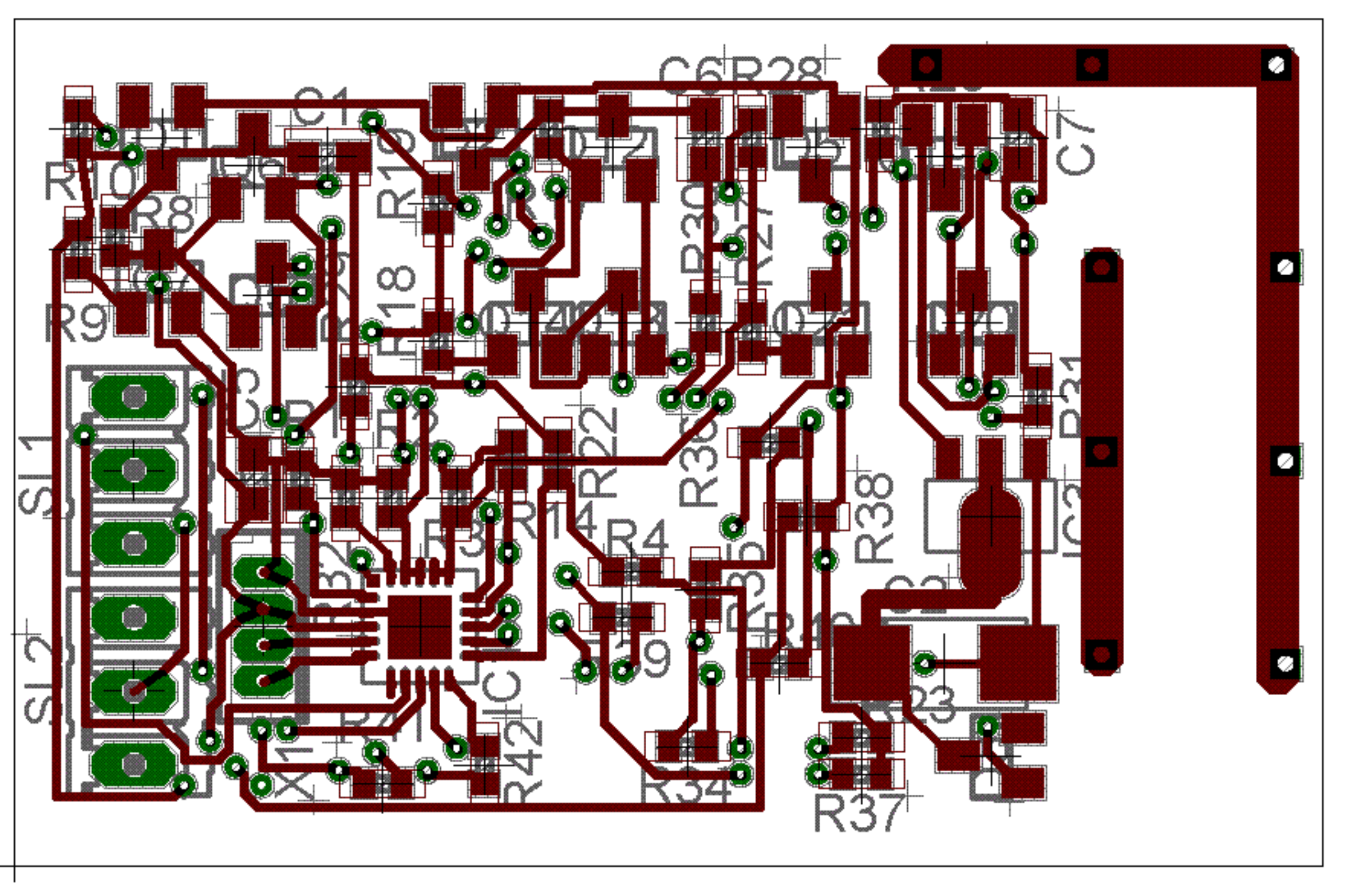
(System can not start)

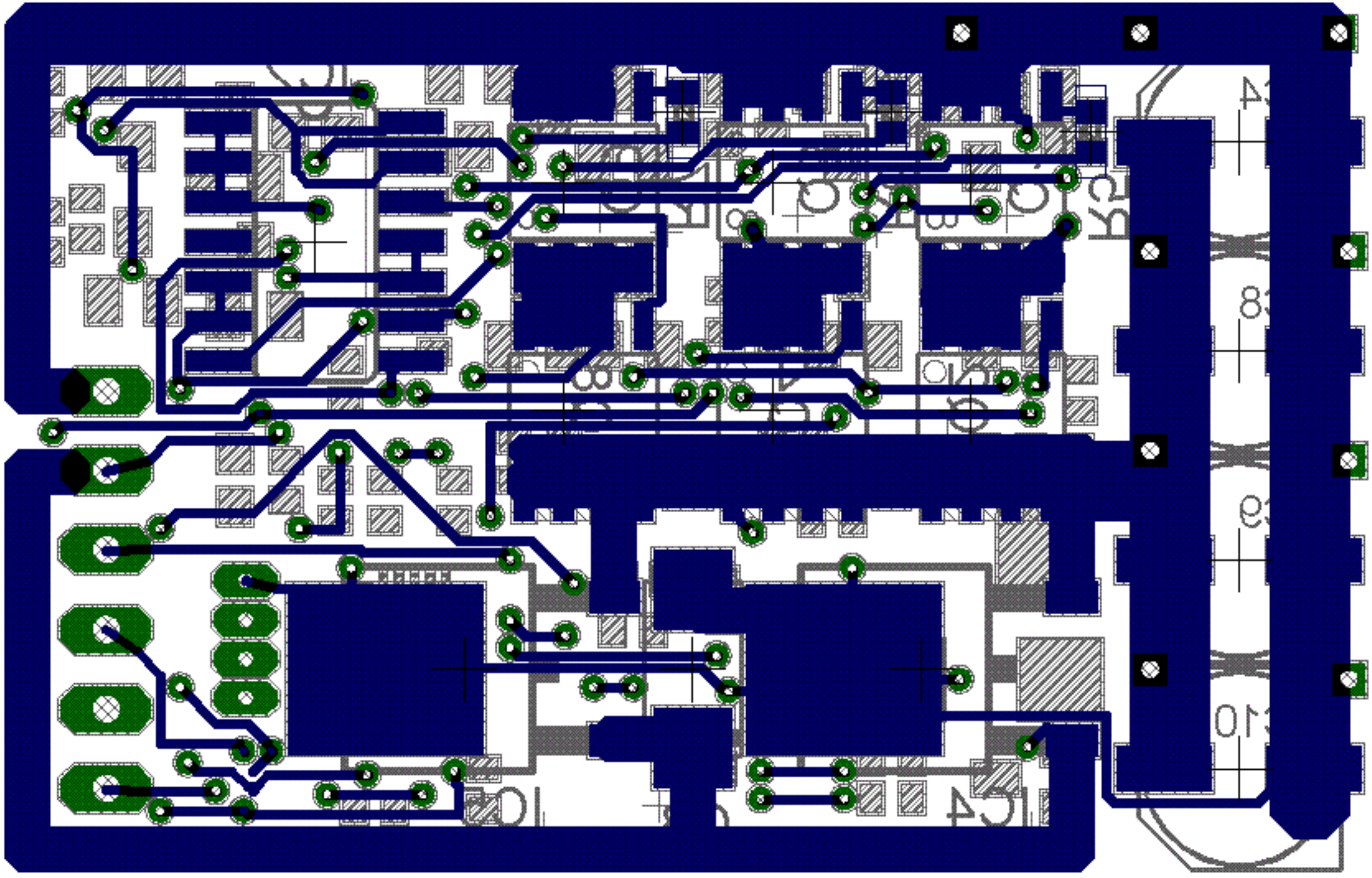


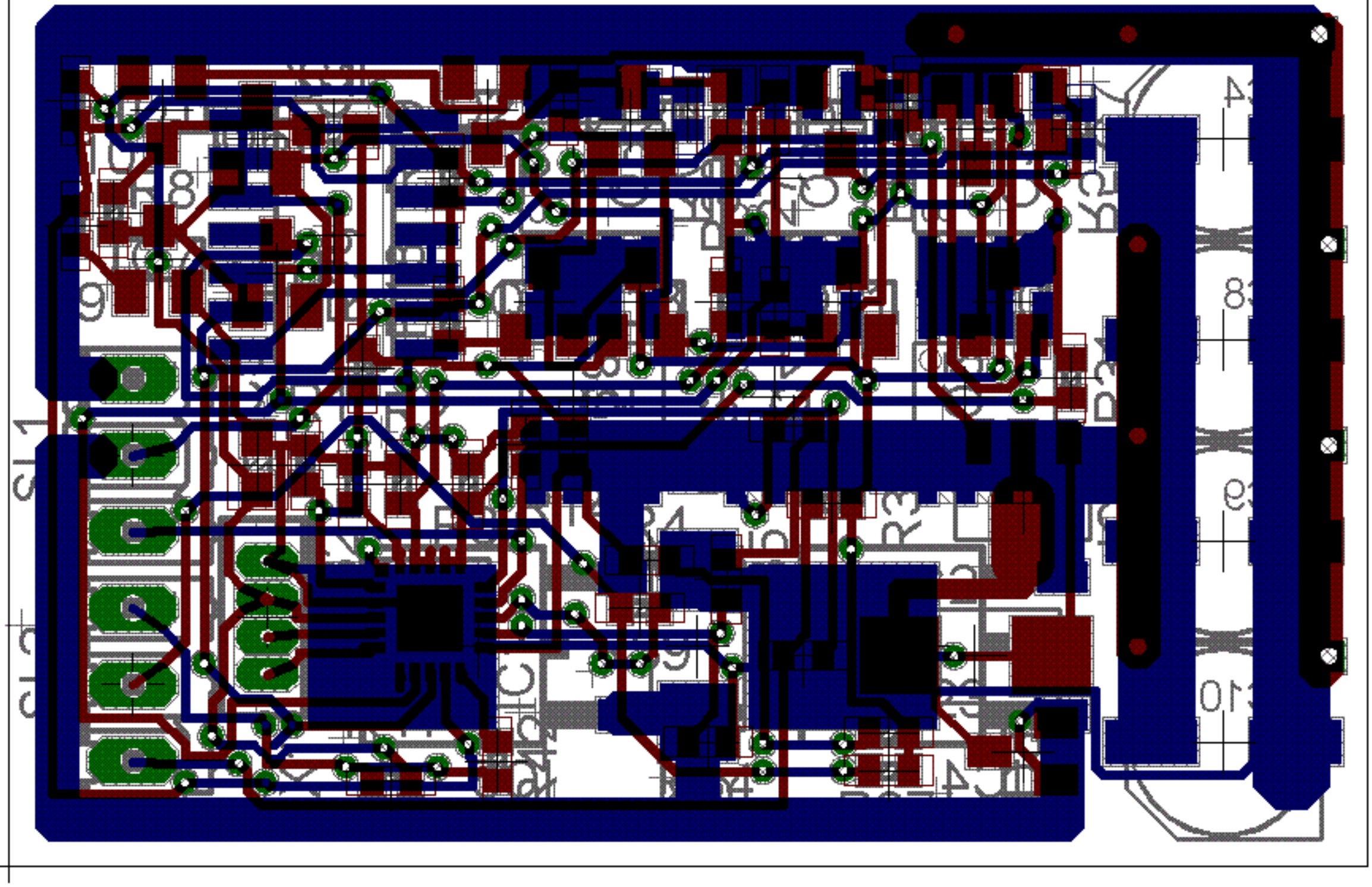
The S-BEC power line GND loop problem

Date	Rev.	Designed by	Title	Page
Feb. 20, '06	0.1	Takao Shimizu	S-BEC Connection Problem	1/1

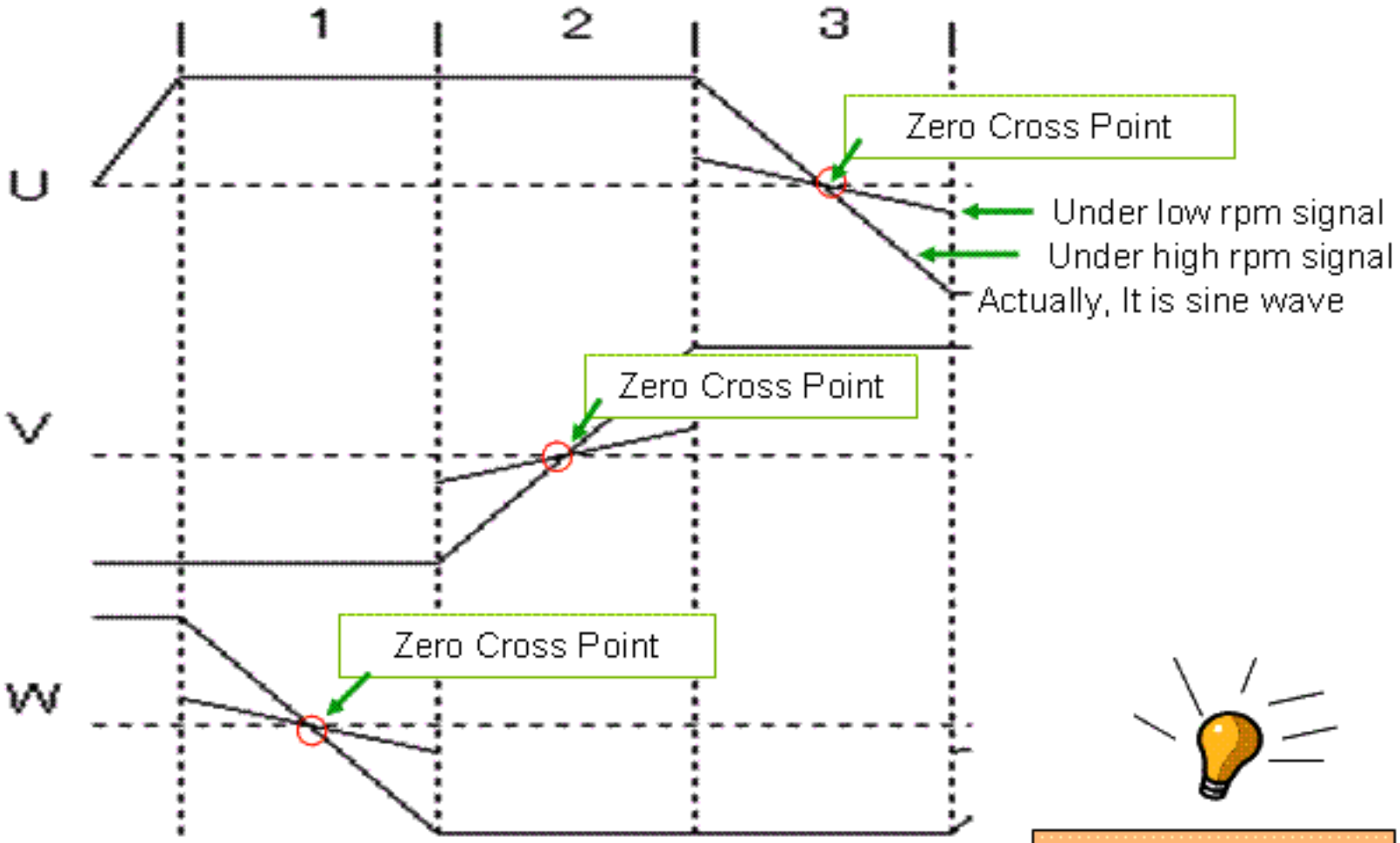

Tek
Stop
M Pos: 200.0µs
CH3
Coupling
DC
BW Limit
Off
100MHz
Volts/Div
Coarse
Probe
10X
Invert
Get BEMF signal just after the inductive kick
MOTOR ON
MOTOR OFF
2+
1+
CH1 2.00V
CH2 5.00V
M 100µs
CH1 ƒ 1.68V
16-Apr-06 20:56
6.49368kHz


C6
R28
C1
C7
R10
R8
R18
R9
R22
R30
R38
R4
R14
SL1
SL2
R42
R34
R37
R3
R31





Zero Cross Control

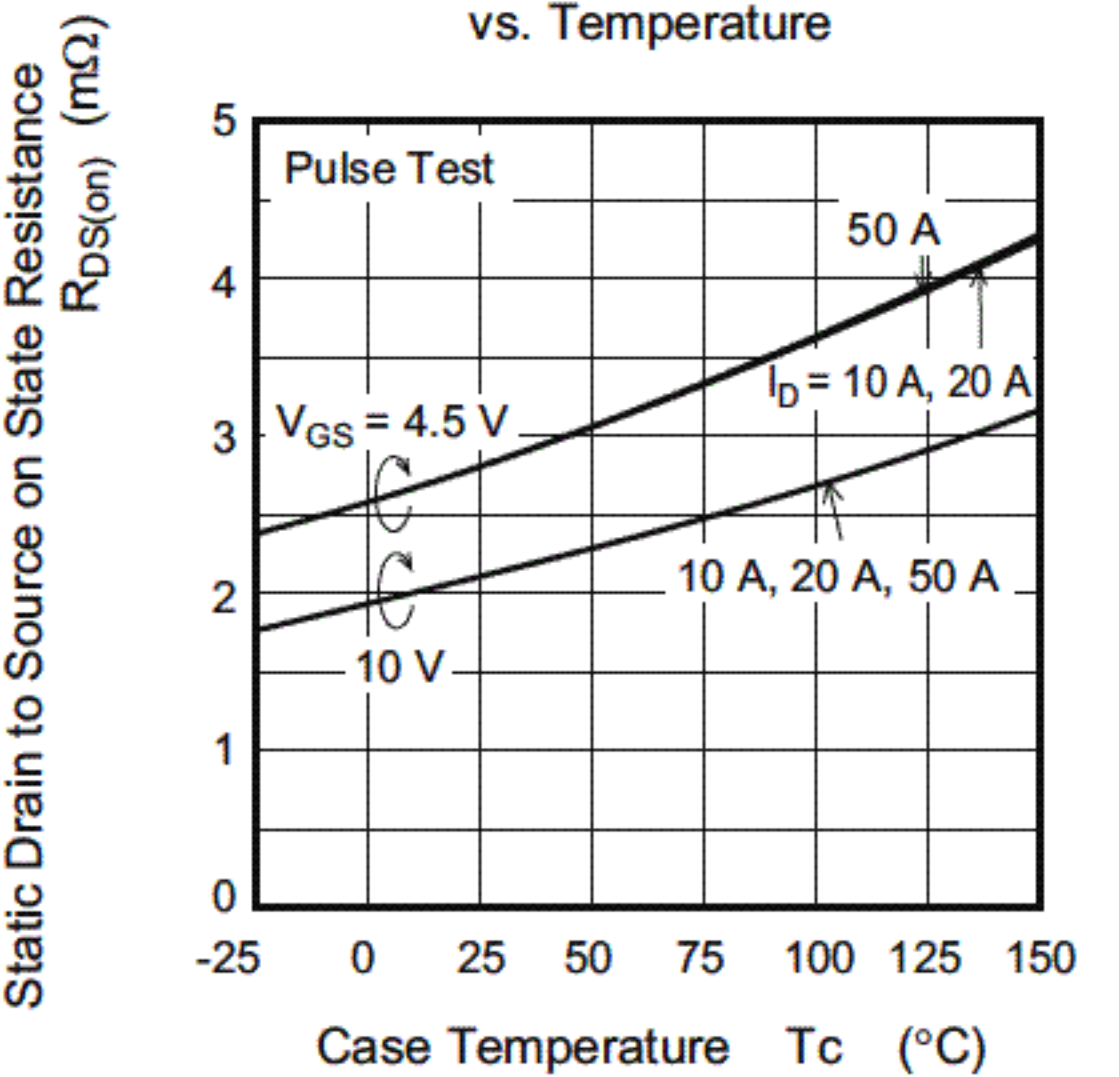


Measure the time to the ZC point by timer…

Then you can get the state switch timing

You can off-duty time power control in T1', T2', T3' (It is as timing advance)

Static Drain to Source on State Resistance vs. Temperature



Get the shaft position by measuring the each state inductive kick length.
The minimum length of inductive kick is driving state. And next drive state is the start drive state.

Current limiter

Ton: Toff = 1:10~5

Drive duty control

Tframe

(450uS)

Power limiter

50~7 Pulse/State

Did you get one state spin?

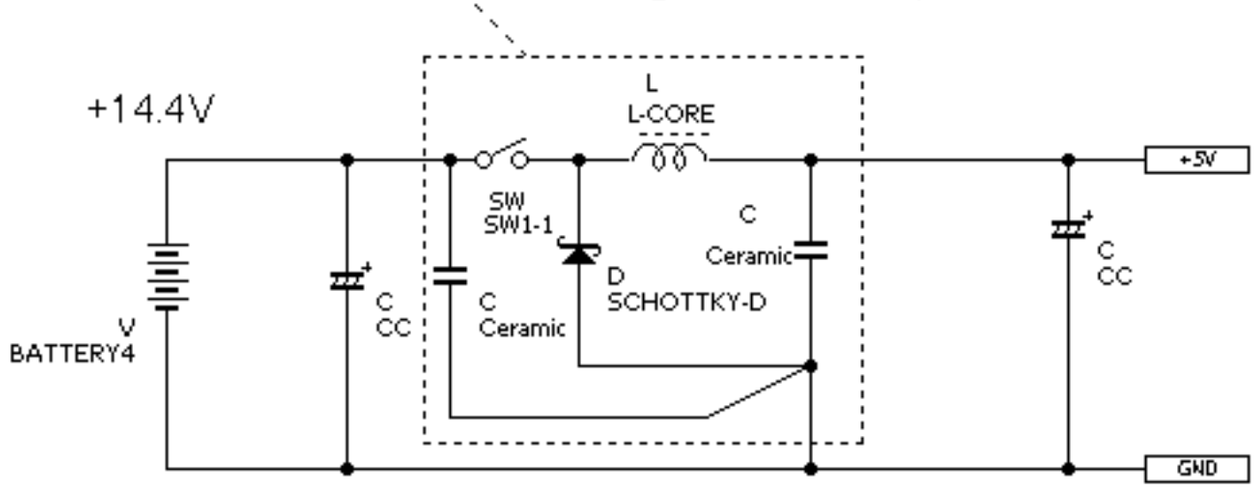
Vibrates a few times to get out the cogging sticky area

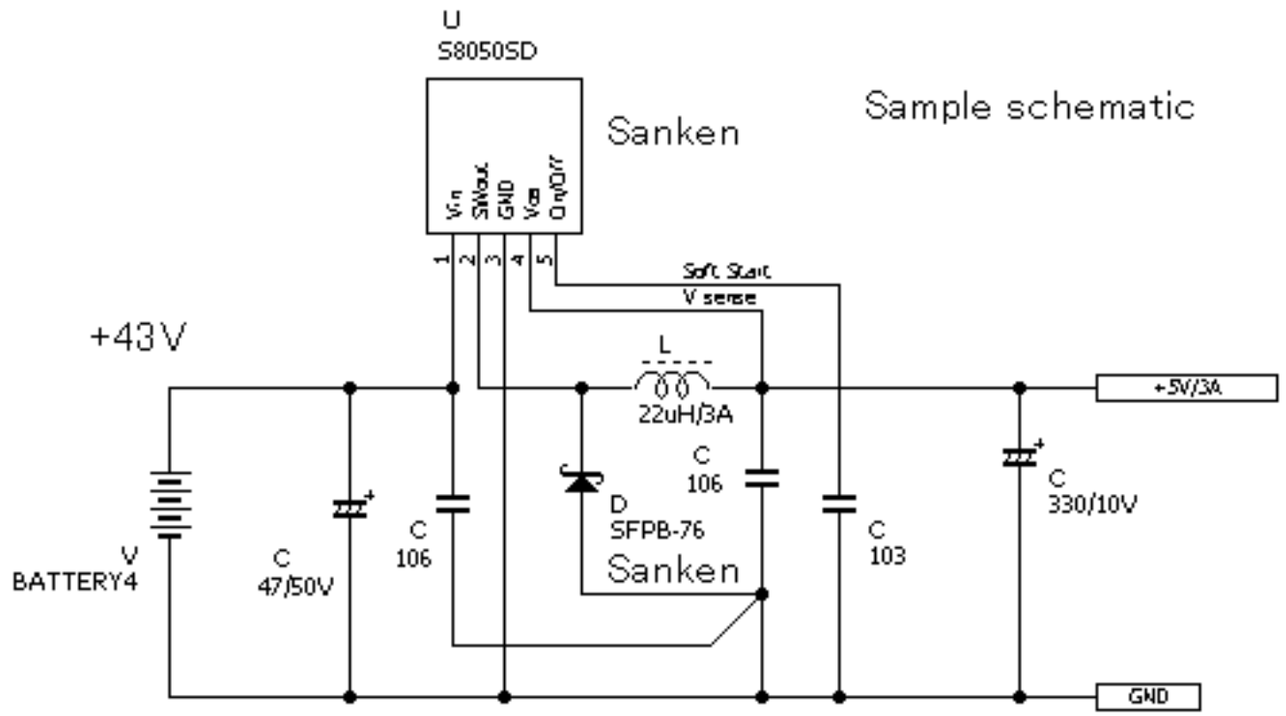
If not, Increase the On-Duty first. Change to decease the drive state timing for resonance of spin, second.

Once the spin starts, then check the next one more state spin as well.
And you can decrease the number of state driving pulse to get spin speed up acceleration to shift to BEMF mode.

Auto adjust for starting parameters

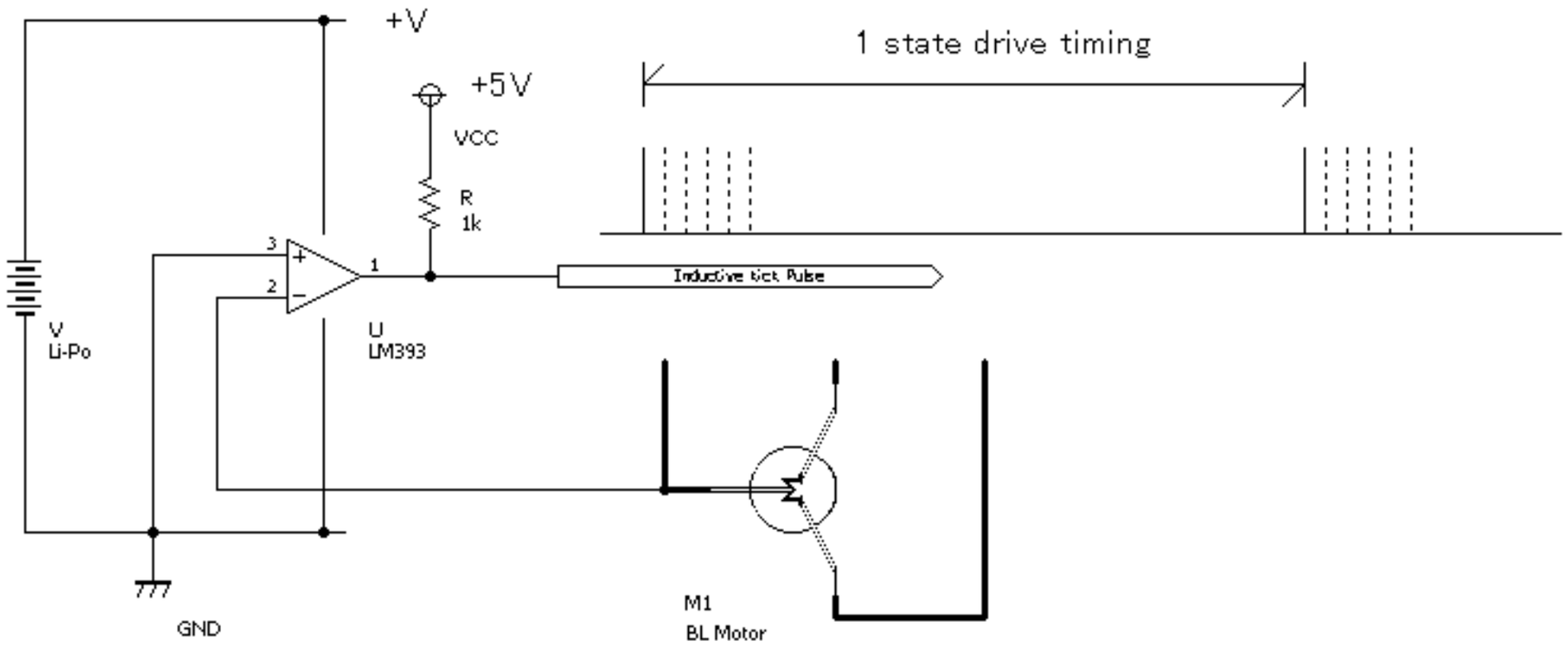
There is a possibility of RF interference from Sw. BEC.
The wiring point is making small as possible at switching area.
as the smallest antenna in high current loop.





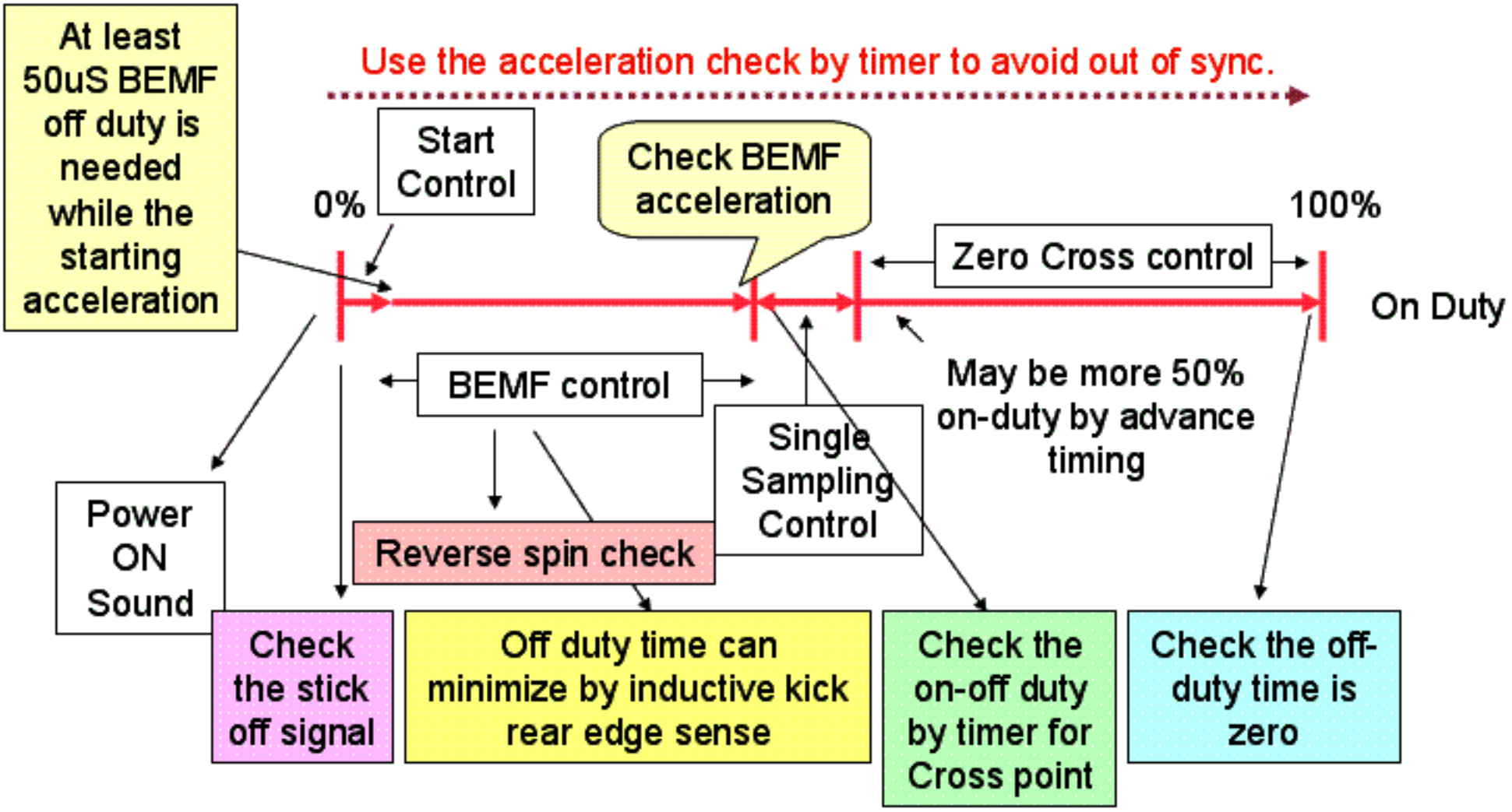
Sample schematic

Two pole as Hacker motor : 1 spin timing
LRK motor: 1/7 spin timing



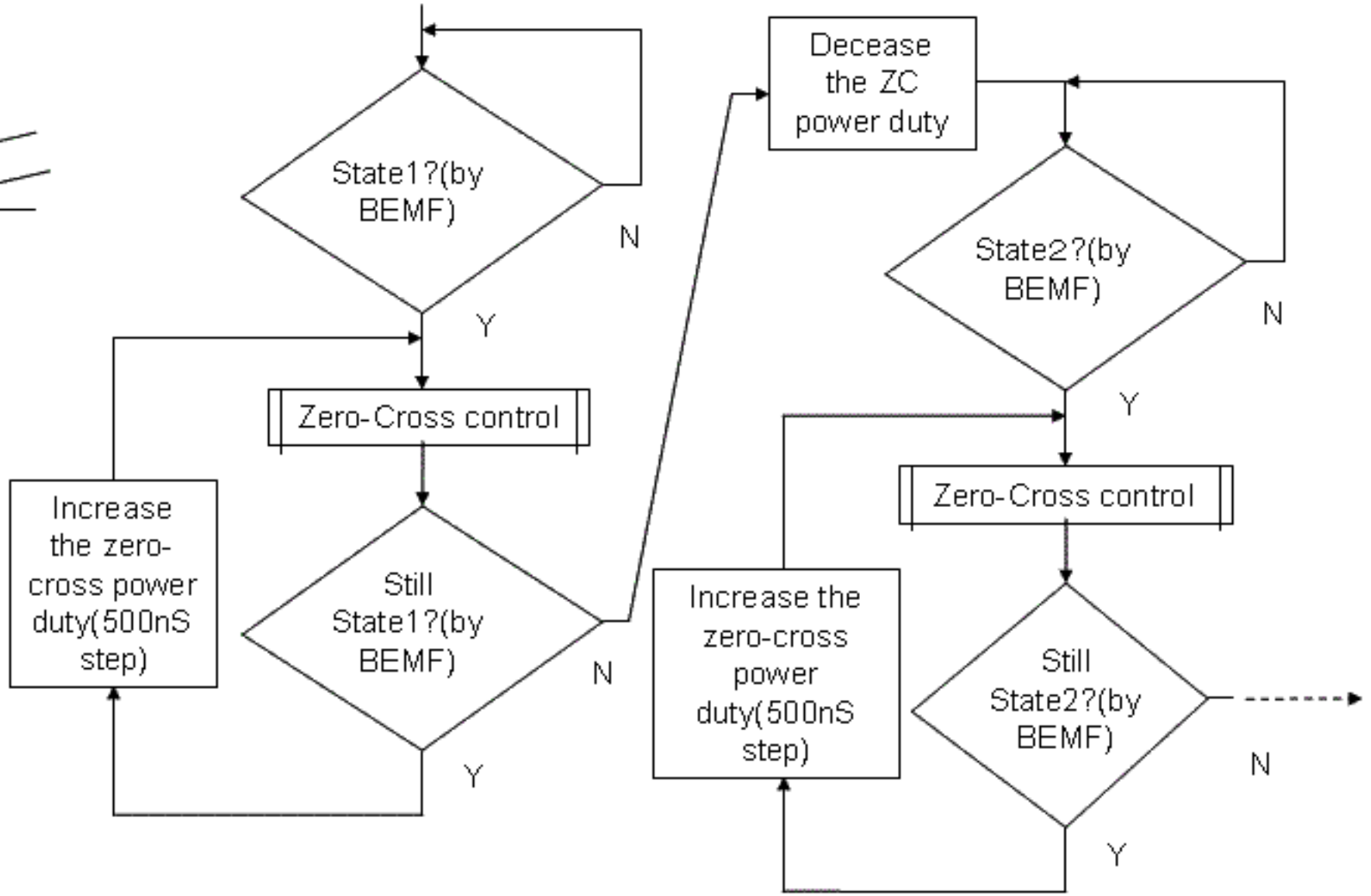
Date	Rev.	Designed by	Title	Page
'06/08/15	0.2	Takao Shimizu	RPM sensing tap	1/1

Points for Acceleration Control



The Single Sampling control for AUTO 50% power spin to start zero-cross control

The level sense of zero cross pint is already over in this loop. Therefore, the loop timing is very short. And the 50% power can preciously set



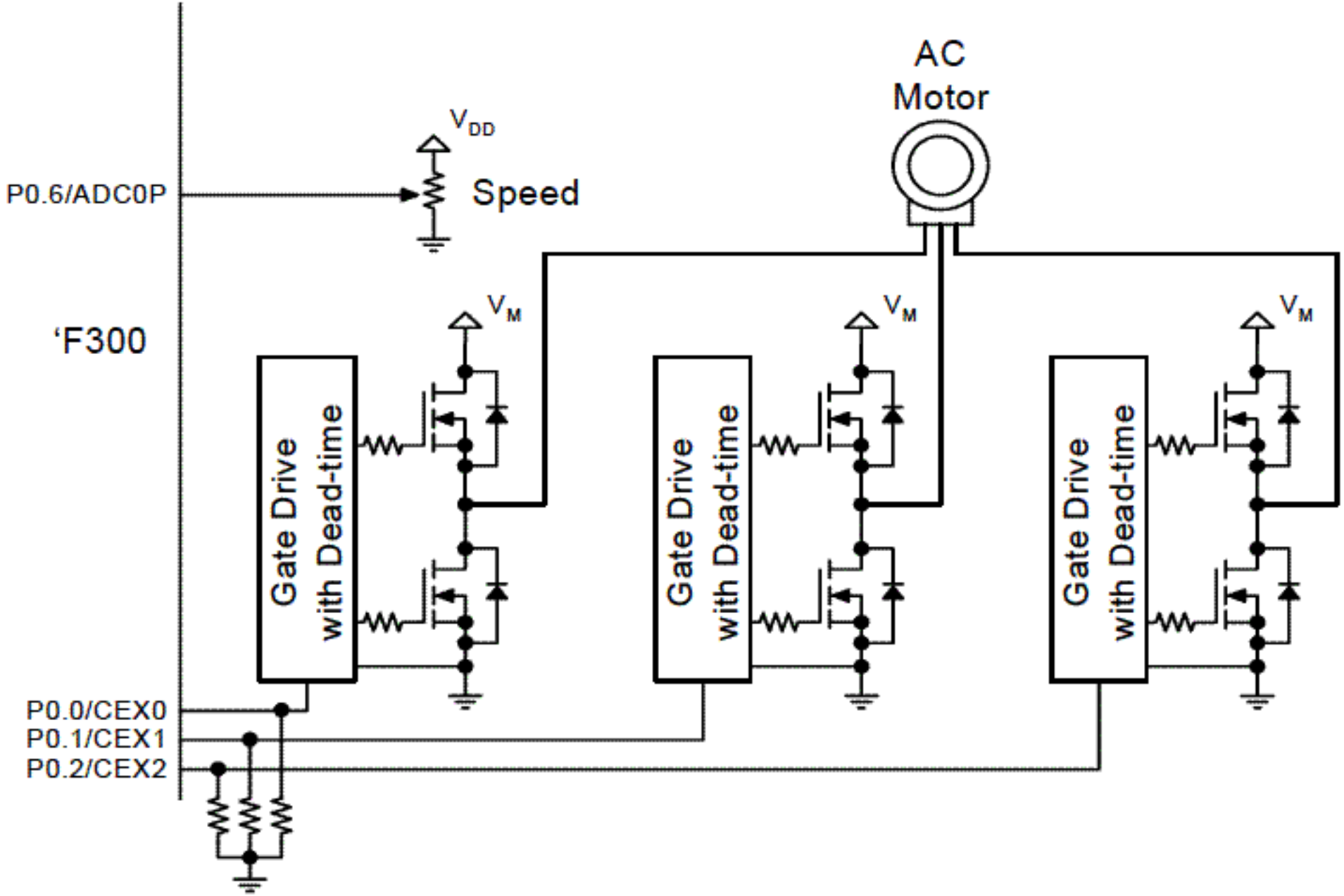
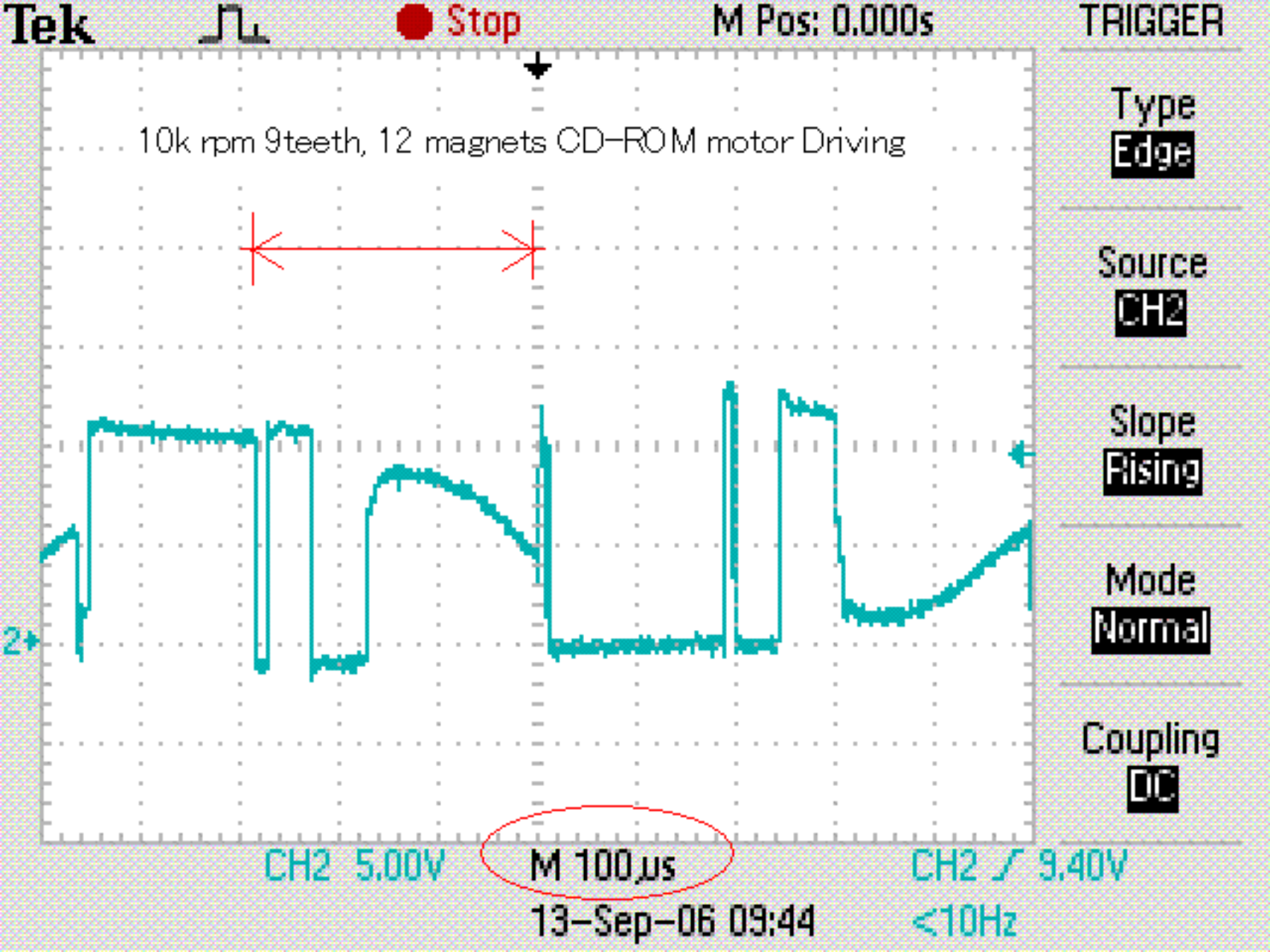
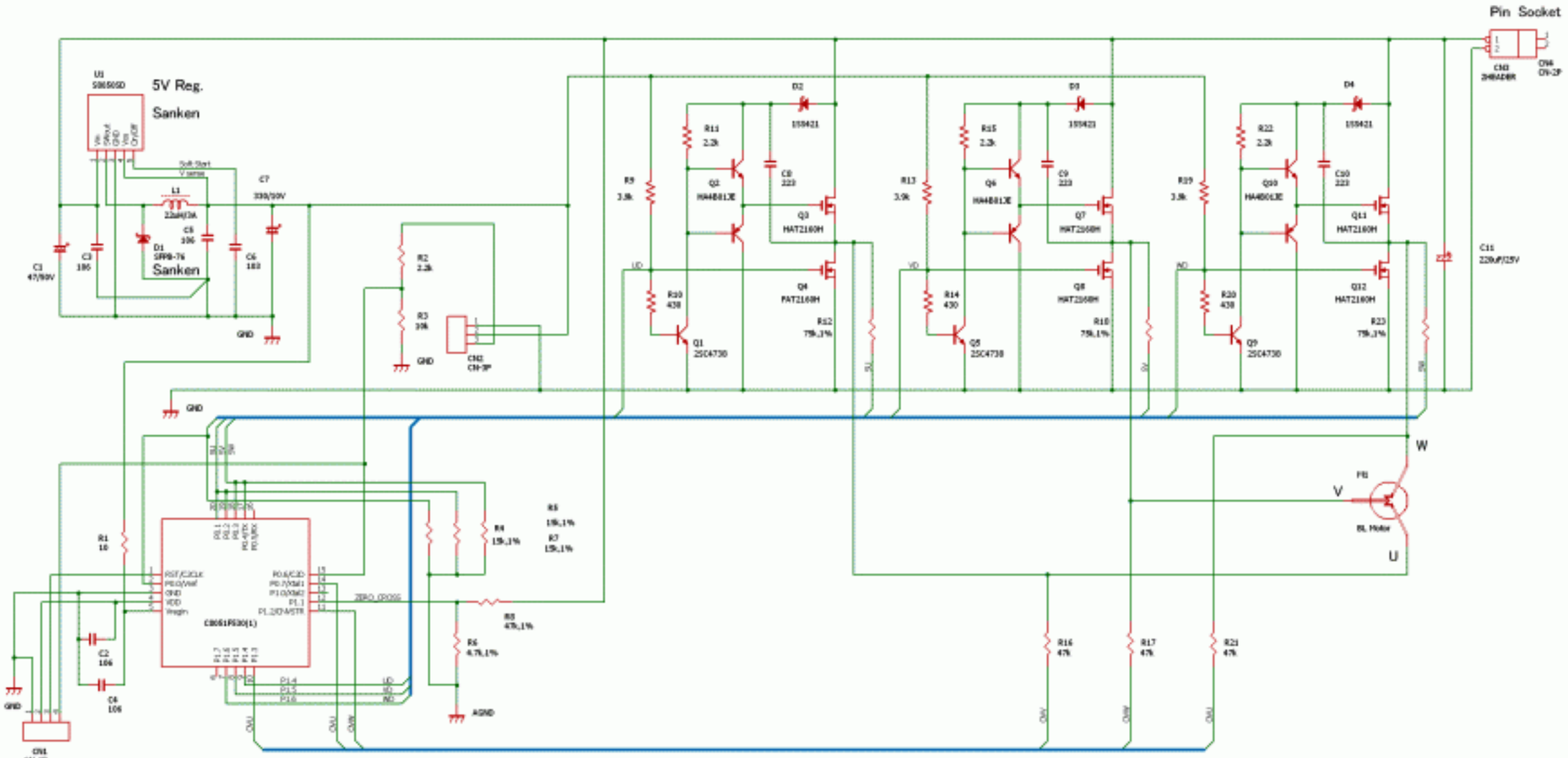
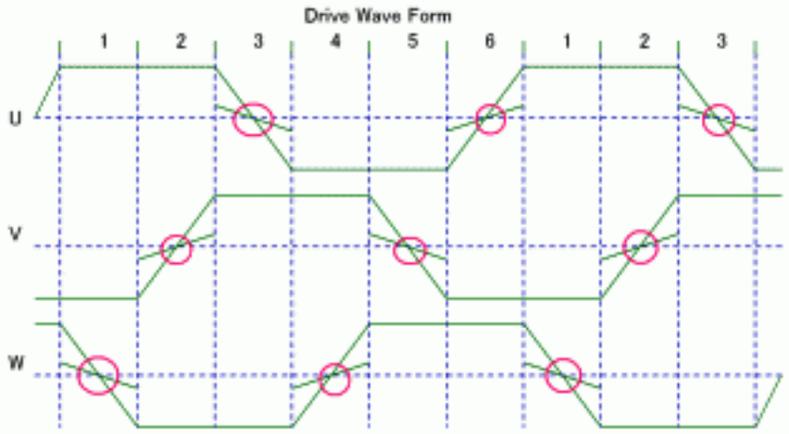


Figure 7. AC Induction Motor Drive


Tek
Stop
M Pos: 0.000s
TRIGGER
10k rpm 9teeth, 12 magnets CD-ROM motor Driving
Type
Edge
Source
CH2
Slope
Rising
Mode
Normal
Coupling
DC
2+
CH2 5.00V
M 100µs
CH2 ƒ 9.40V
13-Sep-06 09:44
<10Hz



Drive Wave Form



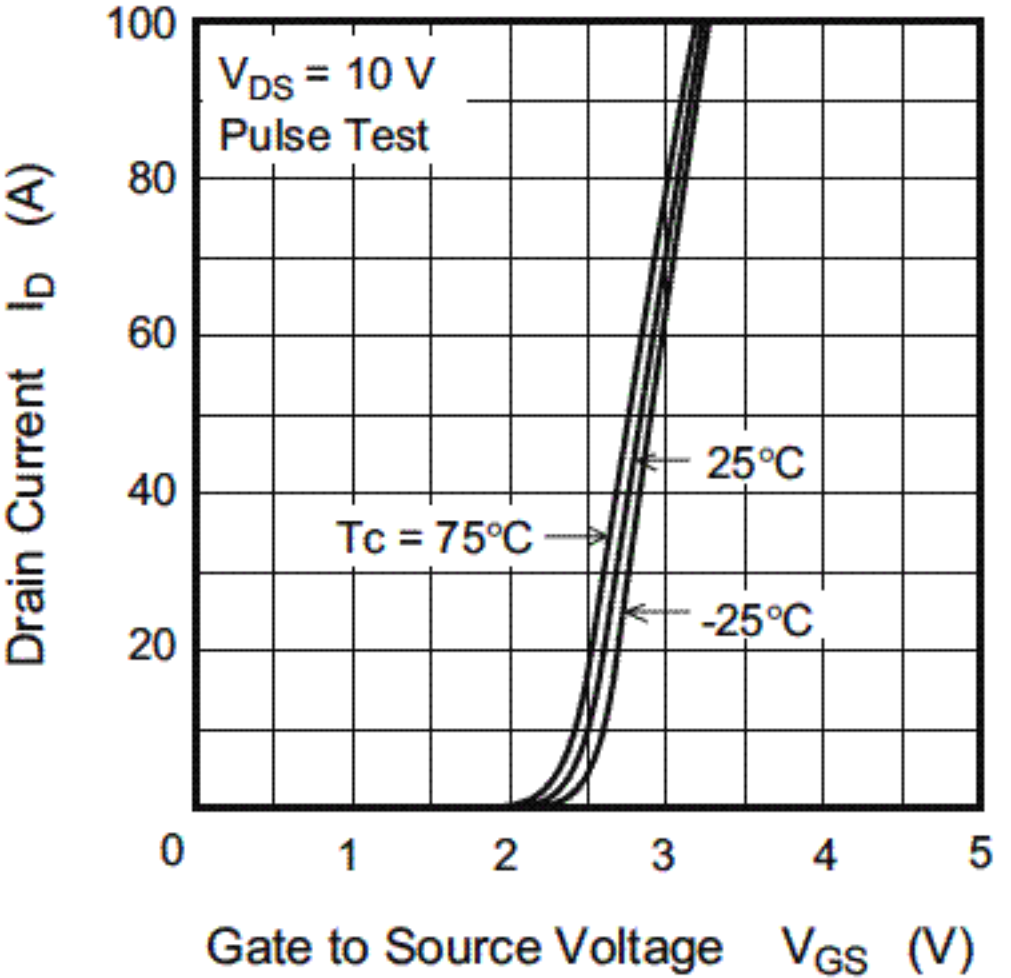
Date	Rev.	Designed by	Title	Page
'06/12/06	0.1a	Takao Shimizu	Brushless Sensor-less Electric Speed Controller Schematic	1/1

Table 14.1. Port I/O DC Electrical Characteristics

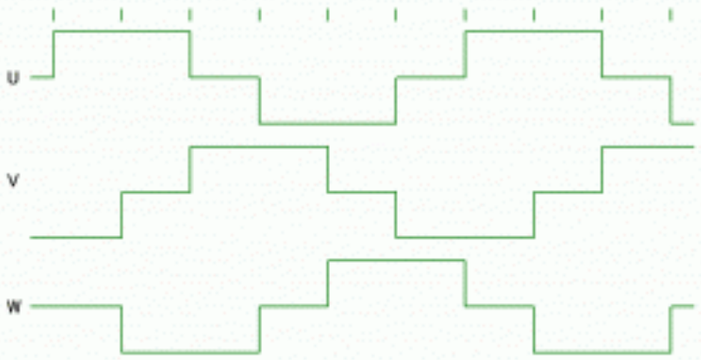
V_{IO} = 2.7 to 5.25 V, –40 to +125 °C unless otherwise specified

Parameters	Conditions	Min	Typ	Max	Units
Output High Voltage	I_{OH} = –3 mA, Port I/O push-pull	TBD	—	—	V
	I_{OH} = –10 µA, Port I/O push-pull	TBD	—	—	
	I_{OH} = –10 mA, Port I/O push-pull	—	TBD	—	
Output Low Voltage	**V = 2.7 V:**				V
	I_{OL} = 10 µA	—	—	TBD	
	I_{OL} = TBD	—	—	TBD	
	I_{OL} = TBD	—	TBD	—	
	V = 5.25 V:				
	I_{OL} = 10 µA	—	—	TBD	
	I_{OL} = 8.5 mA	—	—	TBD	
	I_{OL} = 25 mA	—	TBD	—	
Input High Voltage		TBD	—	—	V
Input Low Voltage		—	—	TBD	V
Input Leakage Current	Weak Pullup Off	—	—	±TBD	µA
	Weak Pullup On, V_{IN} = 0 V; V = 2.0 V	—	< 0.11	TBD	
	Weak Pullup On, V_{IN} = 0 V; V = 2.4 V	—	< 0.14	TBD	

Typical Transfer Characteristics

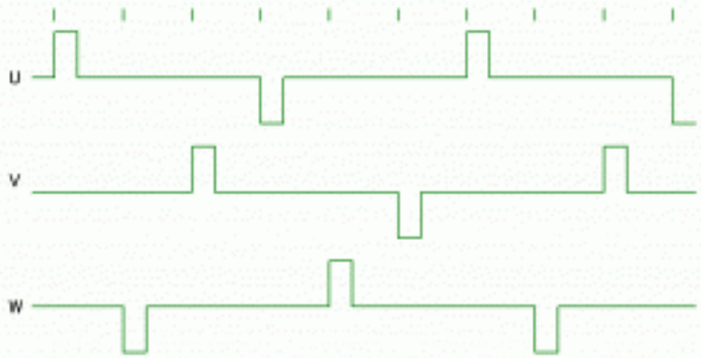


Drive Wave Form



Can not drive the coil too small resistance.

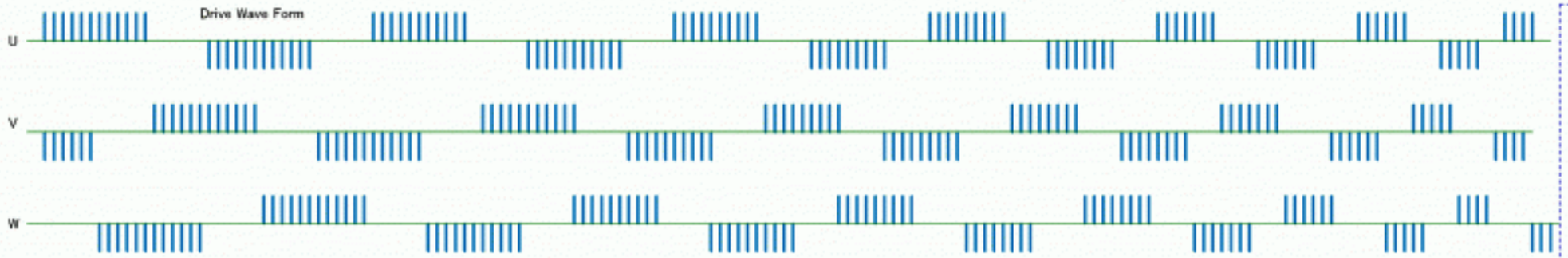
Drive Wave Form



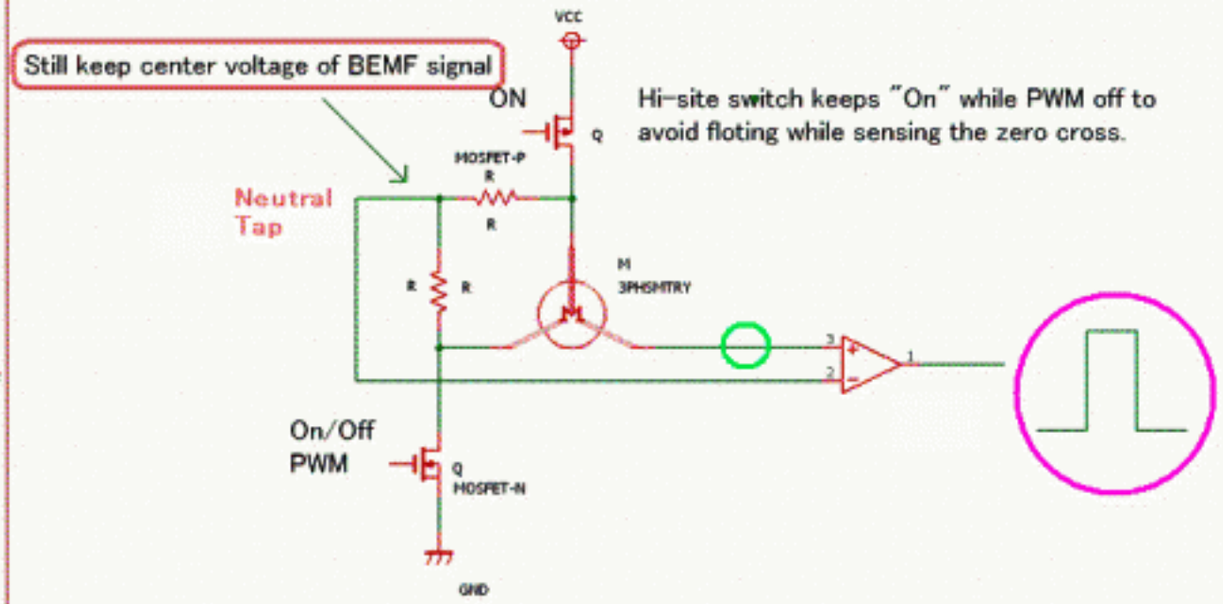
You can reduce the starting current. But, It only vibrate only. Never start.

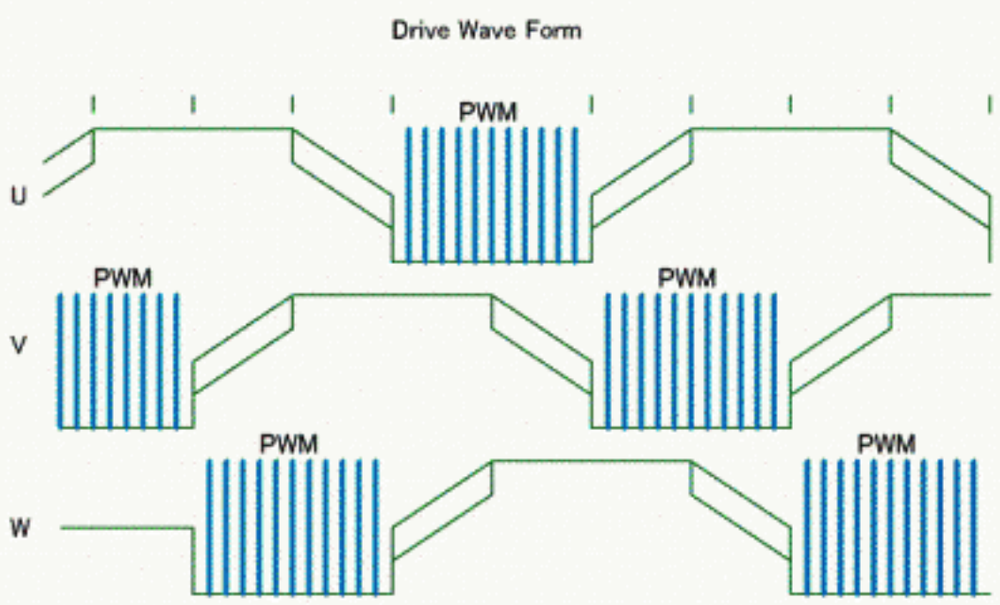
Use the magnetic-Electric brake for stepping drive. You need only a few amp. to sync. step. And do not forget the acceleration drive timing.

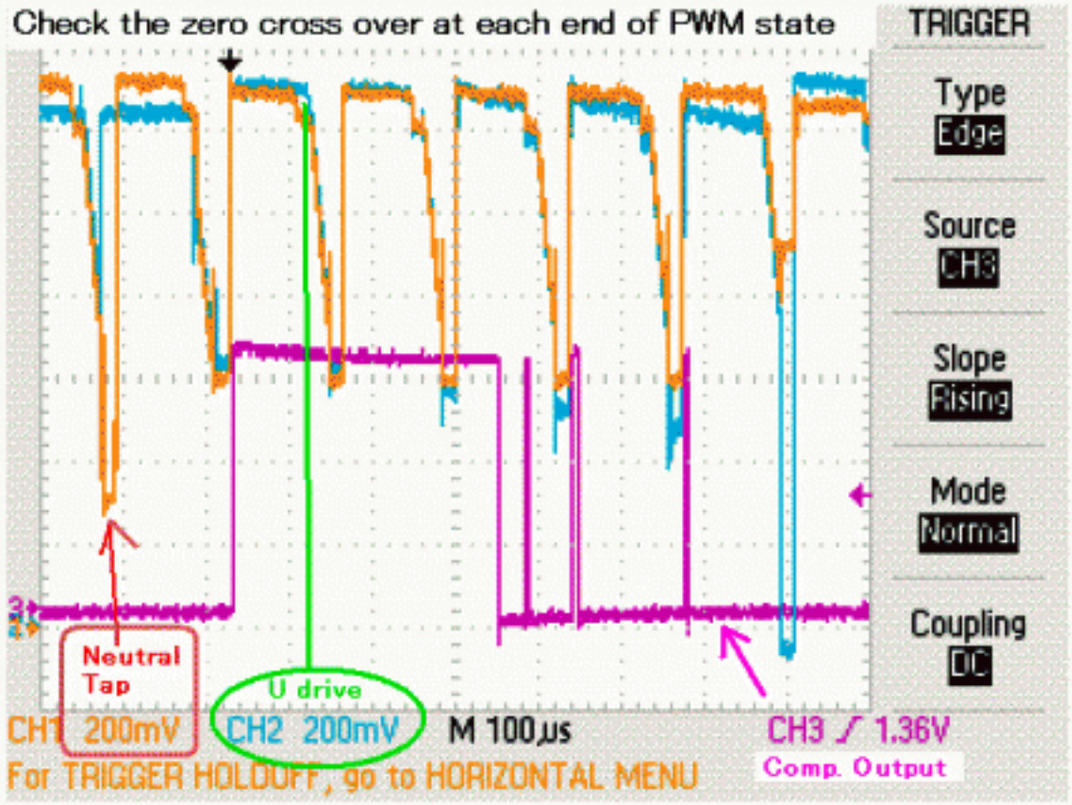
Drive Wave Form



Date	Rev.	Designed by	Title	Page
'07/01/13	0.1	Takao Shimizu	Sensor-less Brush-less Motor starting control image	1/1







Date	Rev.	Designed by	Title	Page
'07/01/20	0.1	Takao Shimizu	Zero Cross sensing while PWM switching	1/1

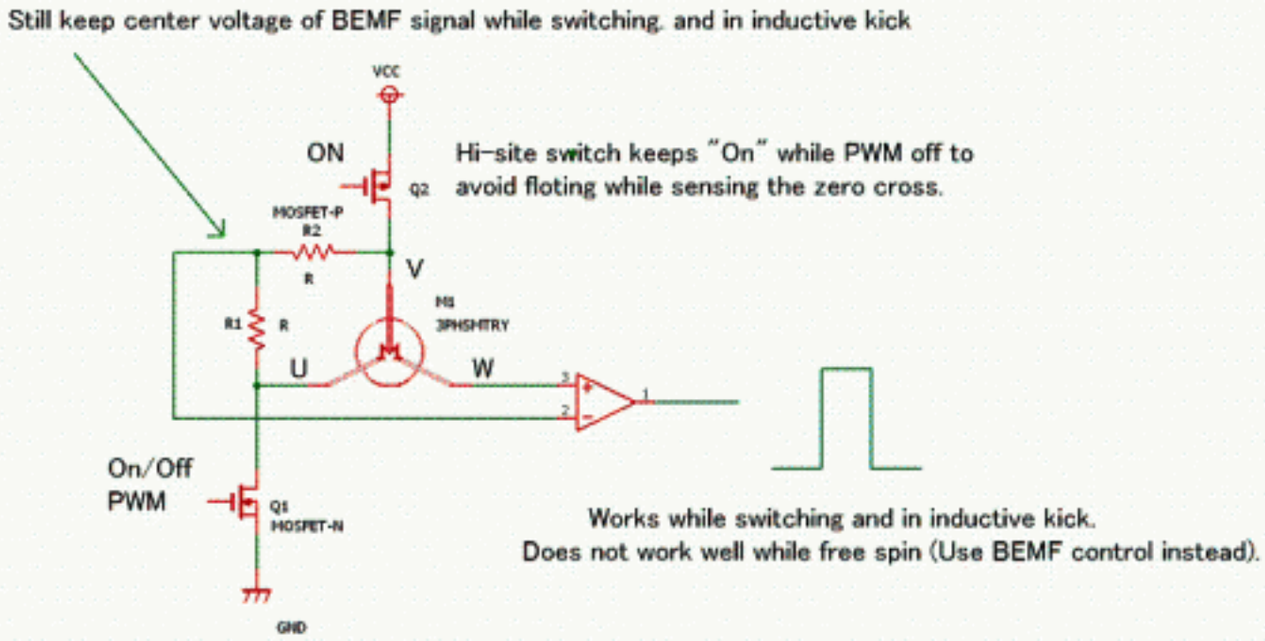
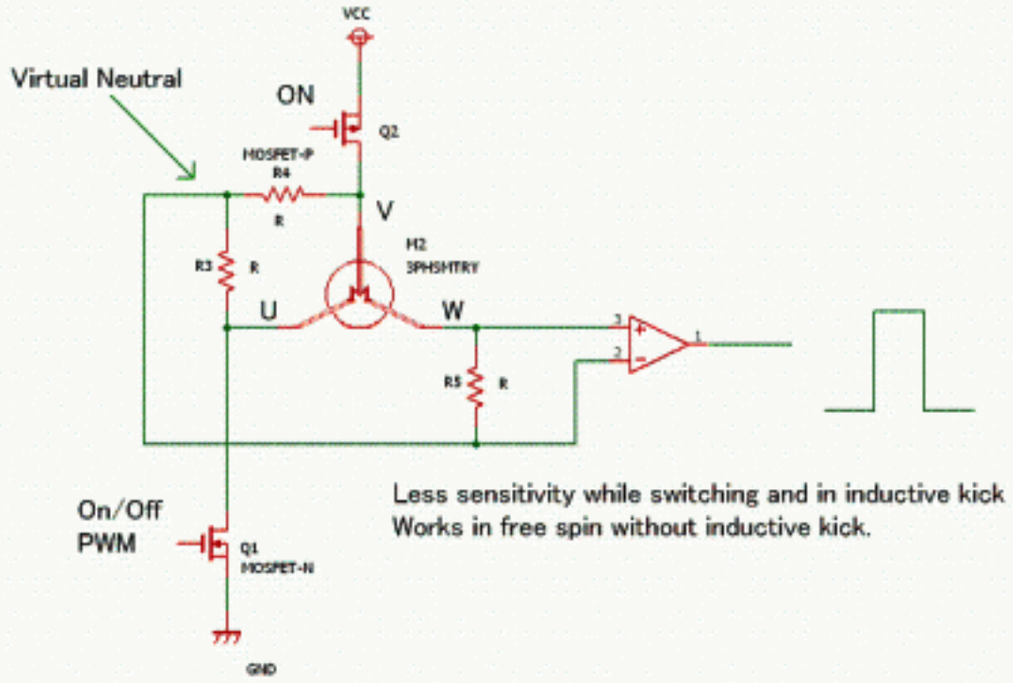
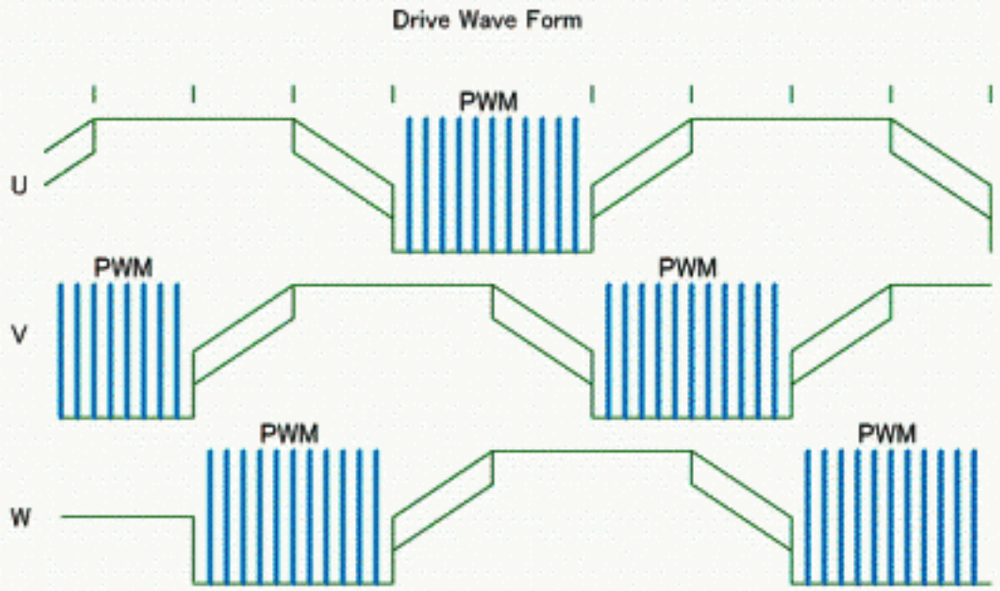


Fig.1: Two wire center tap sensing



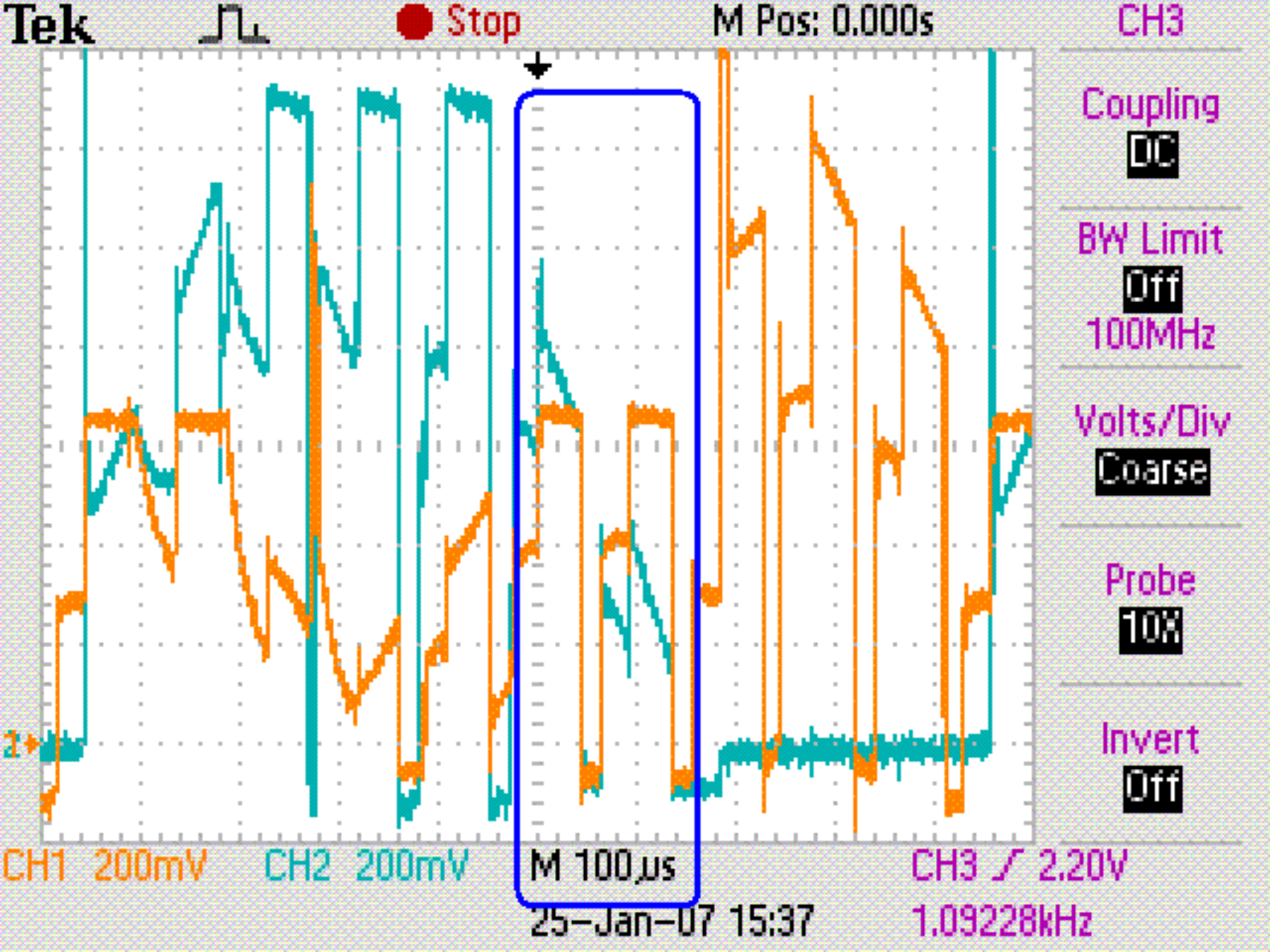
Fog 2: Virtual Neutral sensing

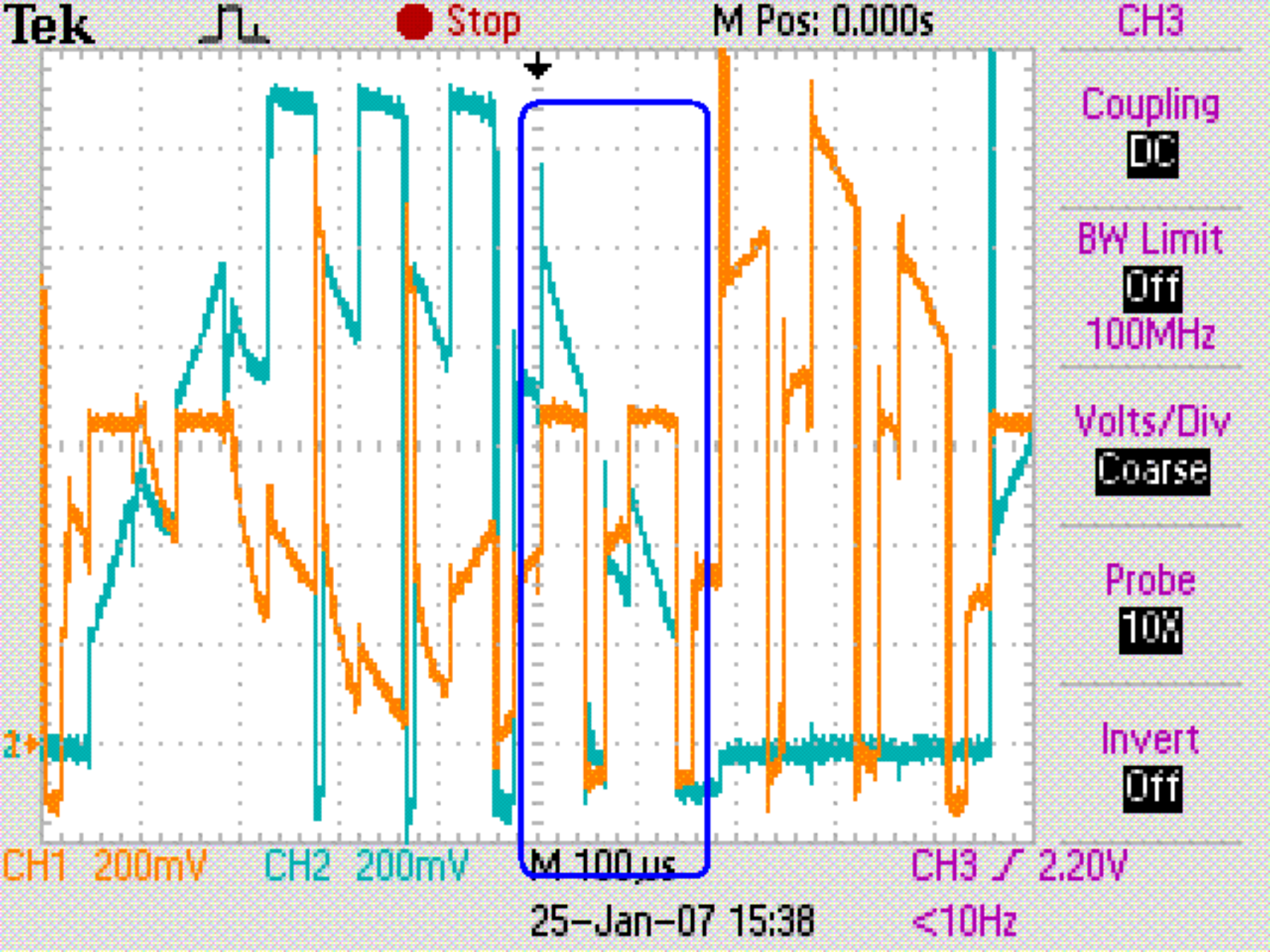


Note:

* Each generative voltage wave is 120 degree difference while PWM off as free spin. But, the activiated lines are 180 degree difference in switching drive mode.
* There is the diffrence of Rds-ON between Q1 and Q2

Date	Rev.	Designed by	Title	Page
'07/01/27	0.2	Takao Shimizu	Zero Cross sensing while PWM switching	1/1


Tek
Stop
M Pos: 0.000s
CH3
Coupling
DC
BW Limit
Off
100MHz
Volts/Div
Coarse
Probe
10X
Invert
Off
CH1 200mV
CH2 200mV
M 100µs
CH3 ∫ 2.20V
25-Jan-07 15:37
1.09228kHz


Tek
Stop
M Pos: 0.000s
CH3
Coupling
DC
BW Limit
Off
100MHz
Volts/Div
Coarse
Probe
10X
Invert
Off
CH1 200mV
CH2 200mV
M 100µs
CH3 ⨍ 2.20V
25-Jan-07 15:38
<10Hz

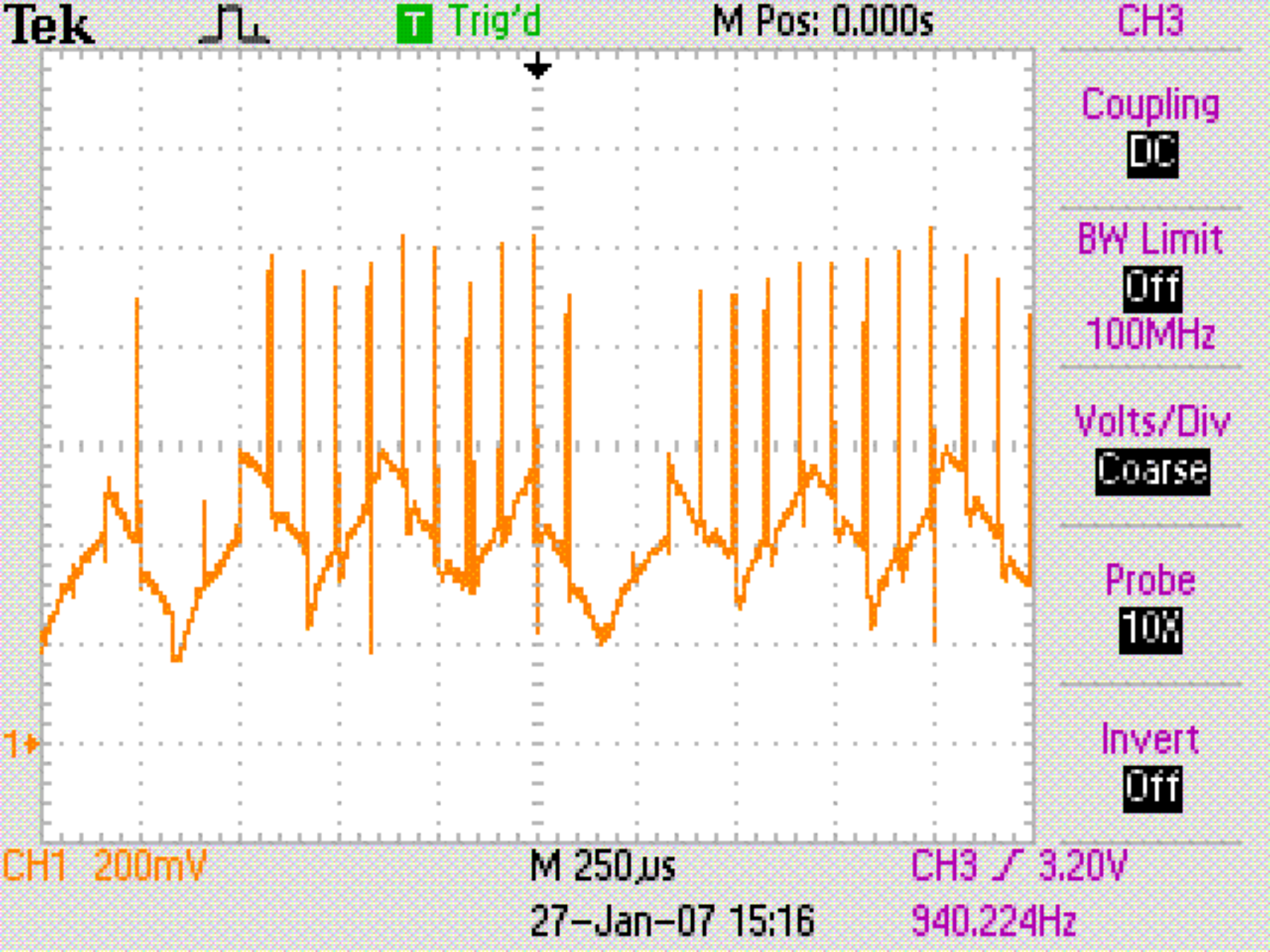
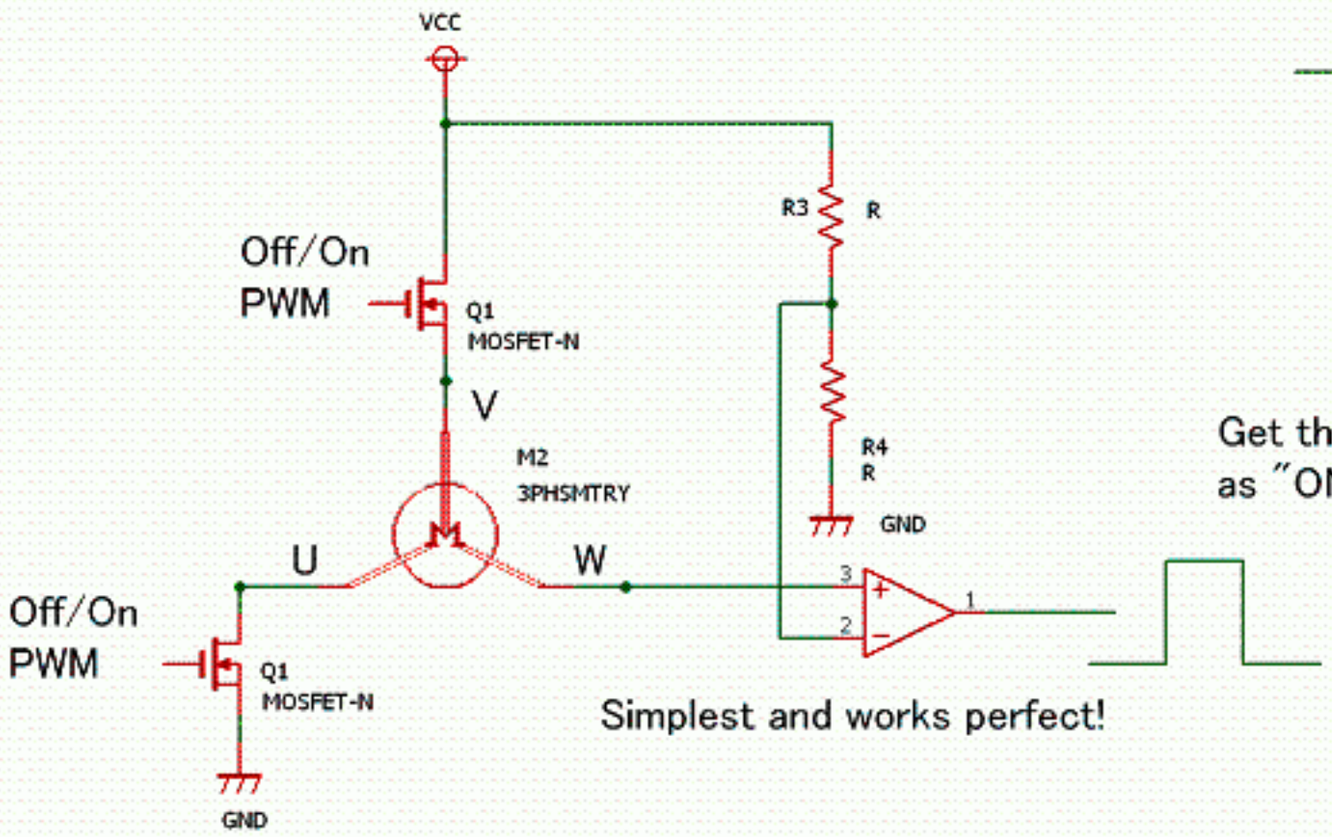
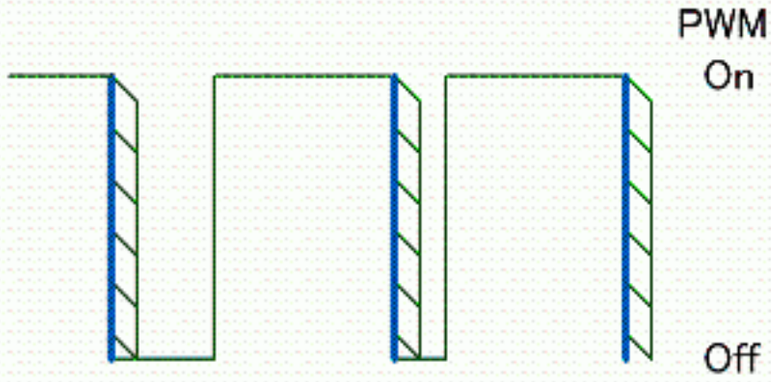

Tek
Trig'd
M Pos: 0.000s
CH3
Coupling
DC
BW Limit
Off
100MHz
Volts/Div
Coarse
Probe
10X
Invert
Off
1
CH1 200mV
M 250µs
CH3 ∫ 3.20V
27-Jan-07 15:16
940.224Hz

Fig : 1/2 VDD sensing



Simplest and works perfect!



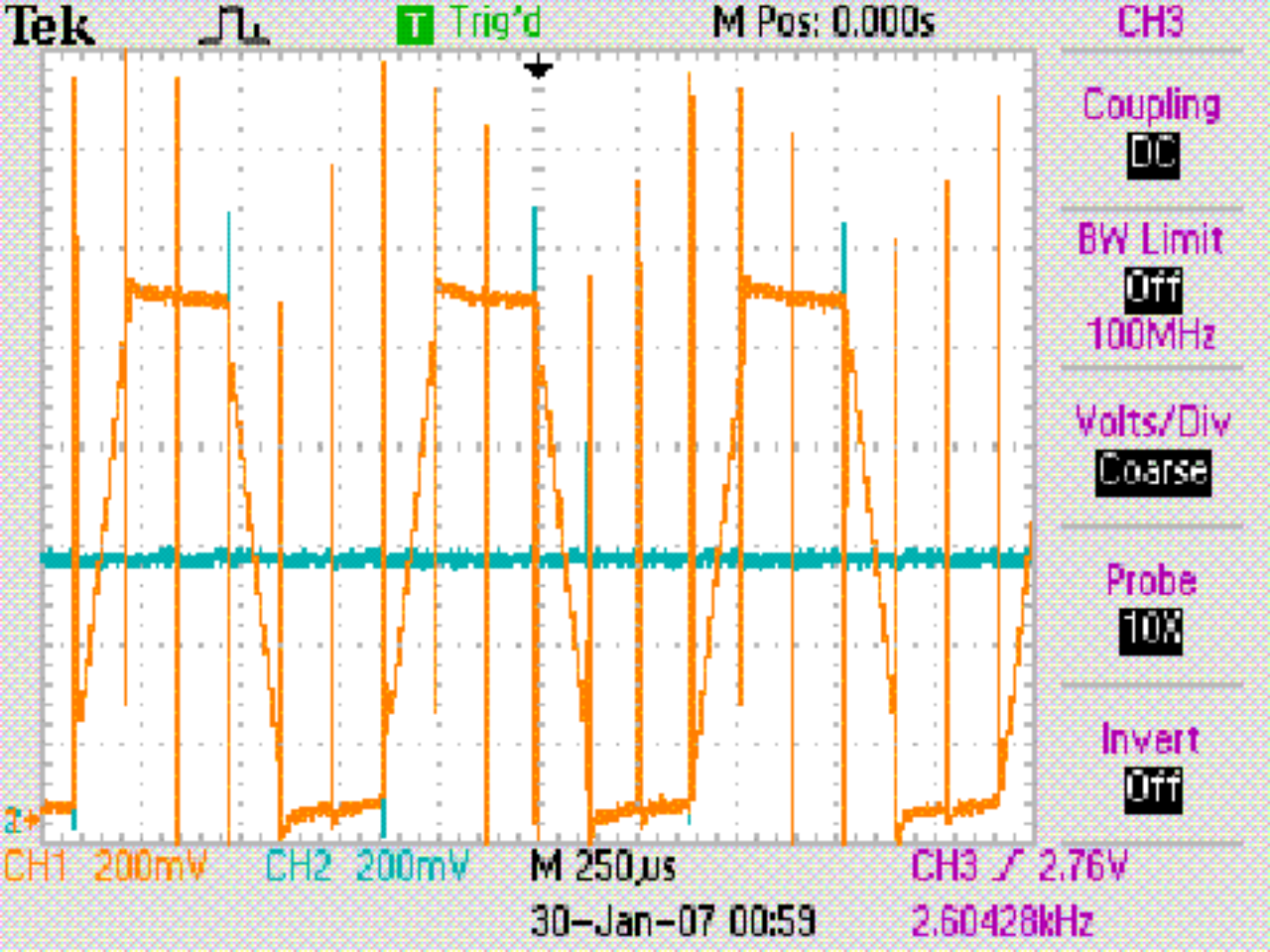
Get the zero cross over at just a little bit before "Off" as "ON" rear edge. You can set "full on" mode as well.

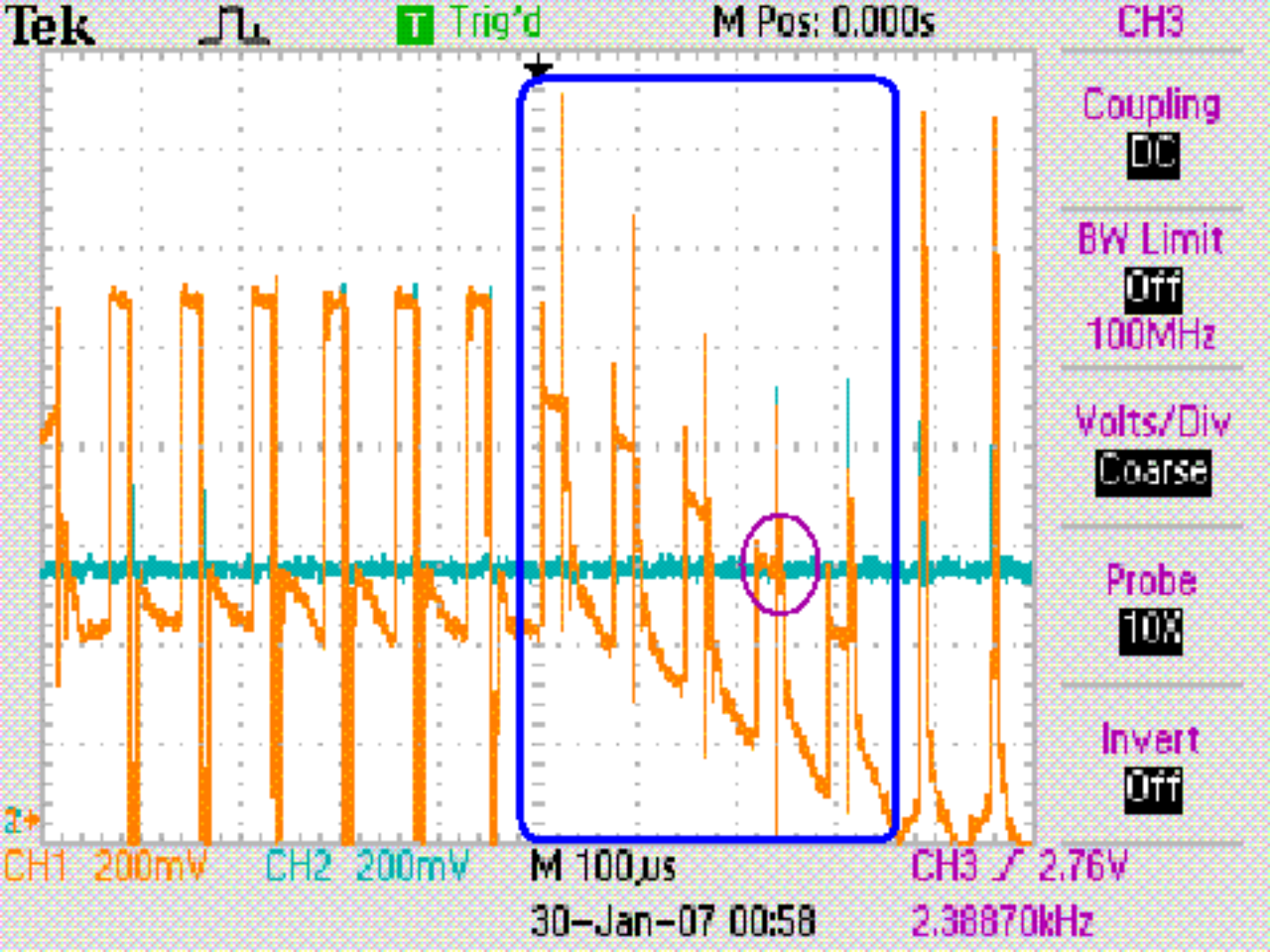
Note:

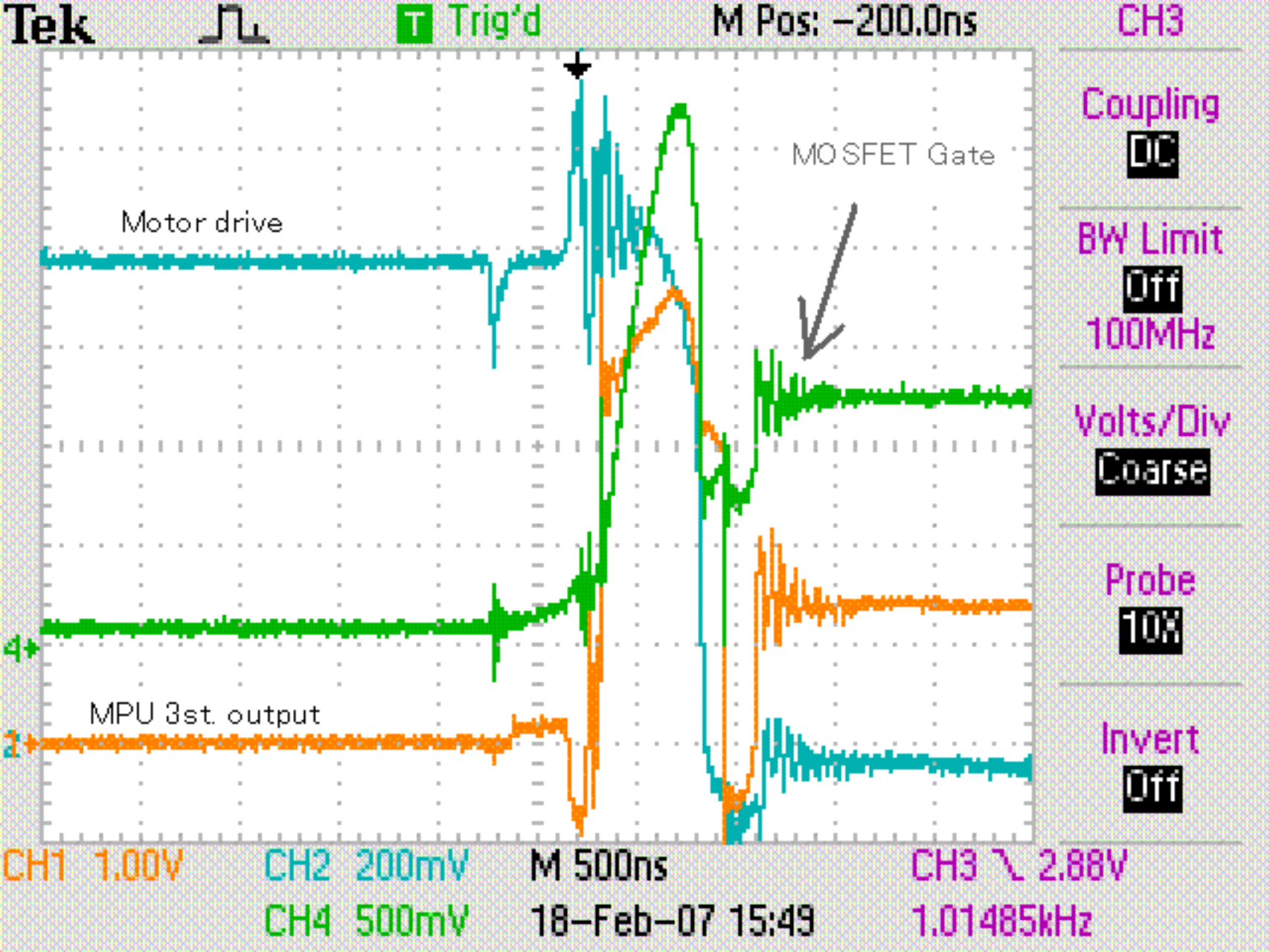
*Use same MOSFET both H/L site.

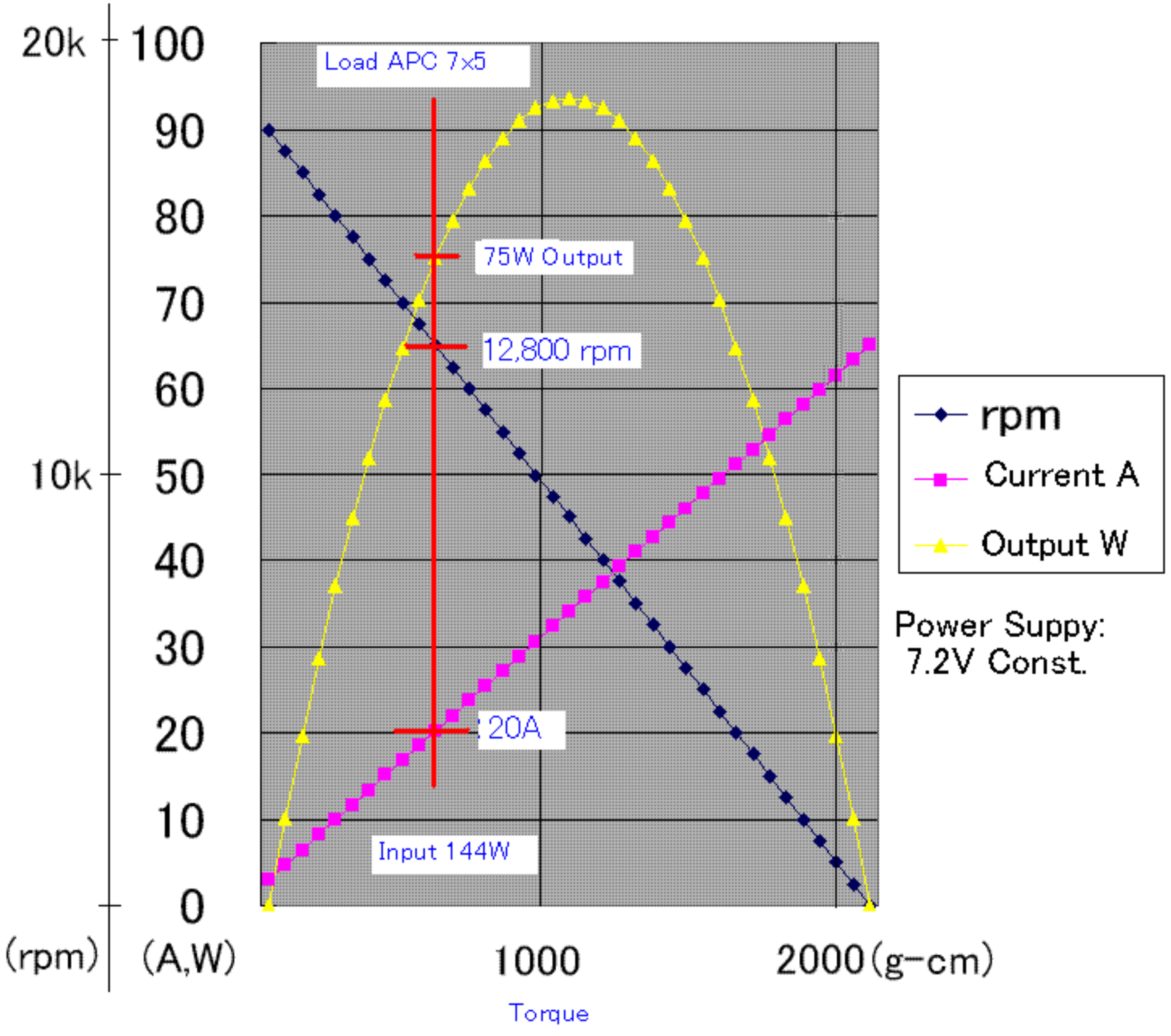
*"Off" first, And "On". Get the zero cross detect result at the of "ON" fall egde for sampling.

Date	Rev.	Designed by	Title	Page
'07/01/27	0.2	Takao Shimizu	Zero Cross sensing while PWM switching	1/1


Tek
Trig'd
M Pos: 0.000s
CH3
Coupling
DC
BW Limit
Off
100MHz
Volts/Div
Coarse
Probe
10X
Invert
Off
CH1 200mV
CH2 200mV
M 250µs
CH3 ⁄ 2.76V
30-Jan-07 00:59
2.60428kHz


Tek
Trig'd
M Pos: 0.000s
CH3
Coupling
DC
BW Limit
Off
100MHz
Volts/Div
Coarse
Probe
10X
Invert
Off
CH1 200mV
CH2 200mV
M 100µs
CH3 ∕ 2.76V
30-Jan-07 00:58
2.38870kHz


Tek
Trig'd
M Pos: -200.0ns
CH3
Coupling
DC
BW Limit
Off
100MHz
Volts/Div
Coarse
Probe
10X
Invert
Off
MOSFET Gate
Motor drive
MPU 3st. output
CH1 1.00V
CH2 200mV
M 500ns
CH3 2.88V
CH4 500mV
18-Feb-07 15:49
1.01485kHz



RS-540 Sports tuned motor

(Tamiya Brand)

8.7.5.3 If the motor is sensored:

It must use a six position JST ZH connector model number ZHR-6 or equivalent connector with 6 JST part number SZH-002T-PO.5 26-28 awg contacts or equivalent.

Wire sequence must be as follows:

Pin #1- Black wire-ground potential

Pin #2- Orange wire-phase C

Pin #3- White wire-phase B

Pin #4- Green wire-phase A

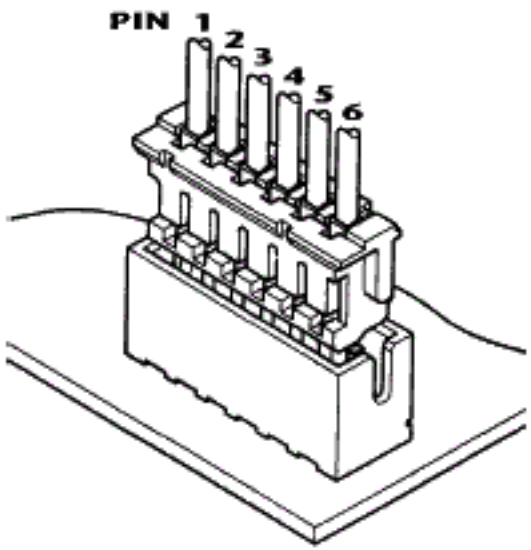
What the meaning of A.B,C?

Coil temp?

Pin #5- Blue wire-temp control, 10 k Thermistor referenced to ground potential

Pin #6- Red wire-+ 5.0 volts =/- 10% Mine is 3.3V operartion CPU. This is over Vdd.

For clarification pin #1 is on the left hand side of the above connector with the wires exiting the top of the connector and the plastic tangs that hold the contacts in the housing are facing forward. See drawing below.



Compatible speed control must use the six position JST header part number X-6B-ZR-SMX-TK (where the X denotes the style of the header), or equivalent.

The power connector has to be clearly marked A, B, C. on both speed control and motor.

A for phase A

B for phase B

C for phase C

The comparator may be installed in the motor?

Gate
Rise Time: 1.5uS
Fall Time: 500nS

For Brushed Motor Braking

Bias for Zero-cross

Pin Socket

U1 TA48033 3.3V,1%

U2 uPC2985A (NEC)

U4 uPC2985A

D1 1SS319

D3 1SS319

D6 1SS319

D7 1SS319

C2 47uF/16V

C3 10uF/6.3V

C4 33uF/6.3V

C5 224/25V

C9 180uF/25V

C11 220uF/25V

R4 2.2k

R5 10k

R16 3.9k

R18 4.7k

R20 909,1%

R21 3.9k

R23 4.7k

R26 18k,1%

R27 3.9k

R29 4.7k

R33 18k,1%

R17 480

R22 480

R28 480

Q1 NPN

Q2 NPN

Q3 PNP

Q4 2SK3014

Q5 2SK3814

Q6 NPN

Q7 NPN

Q8 PNP

Q9 2SK3014

Q10 2SK3814

Q11 NPN

Q12 NPN

Q13 PNP

Q14 2SK3014

Q15 2SK3814

U5 74AC00

CN2 CN-3P

CN5 3HEADER

CN6 CN-2P

GND

+5V

R2 1k,1% Monitor

R11 1k,1%

R18 1k,1%

R13 1k,1%

R15 1k,1%

R14 200,1%

R12 1k,1%

U2 C8051F320D

ZERO_CROSS

UD

VD

MD

AGND

1/11

1/22

CN3 CN-4P

Programming Port

M1 BL Motor

U

V

W

Hi-Bright White LEDs

DC9V, 2.5A

R 100

IRF7205

LED-C

R 12

Turn ON at the drive STATE3.

LED On

Drive Wave Form

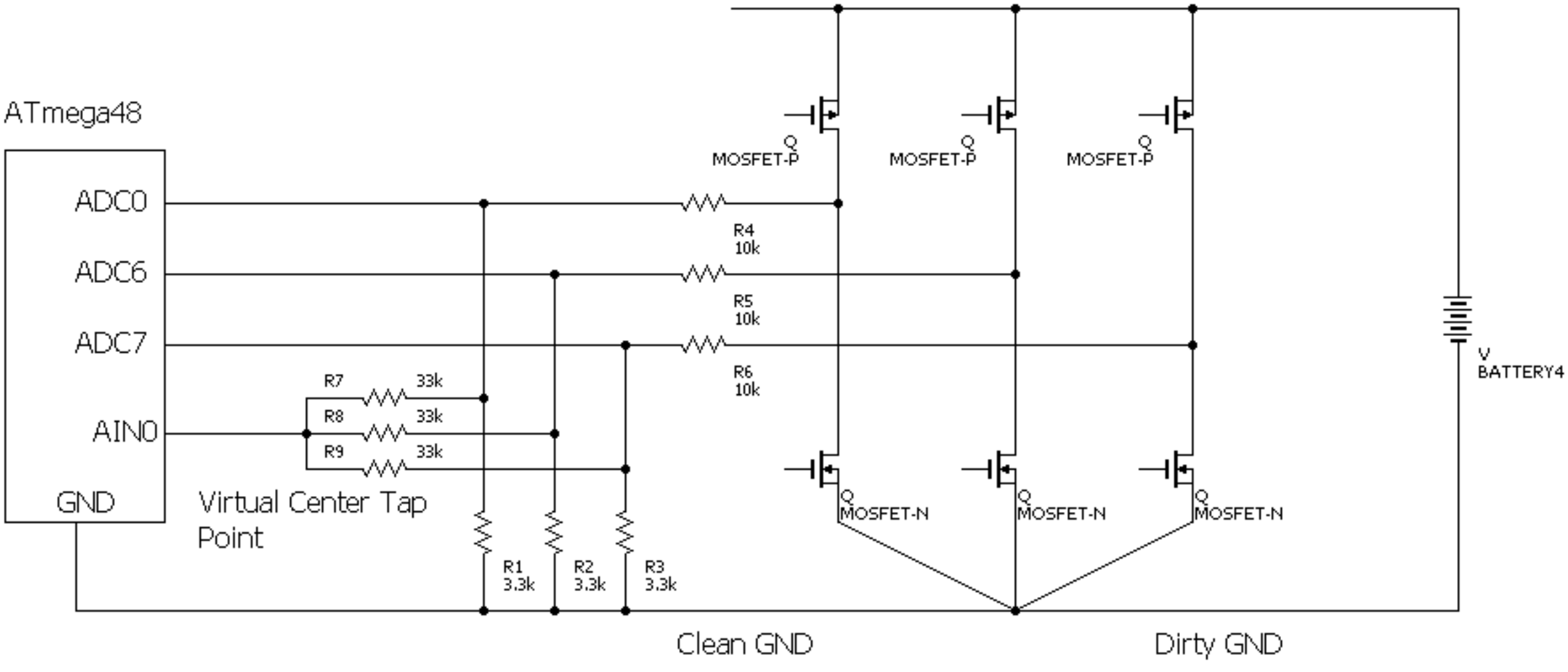
1 2 3 4 5 6 1 2 3

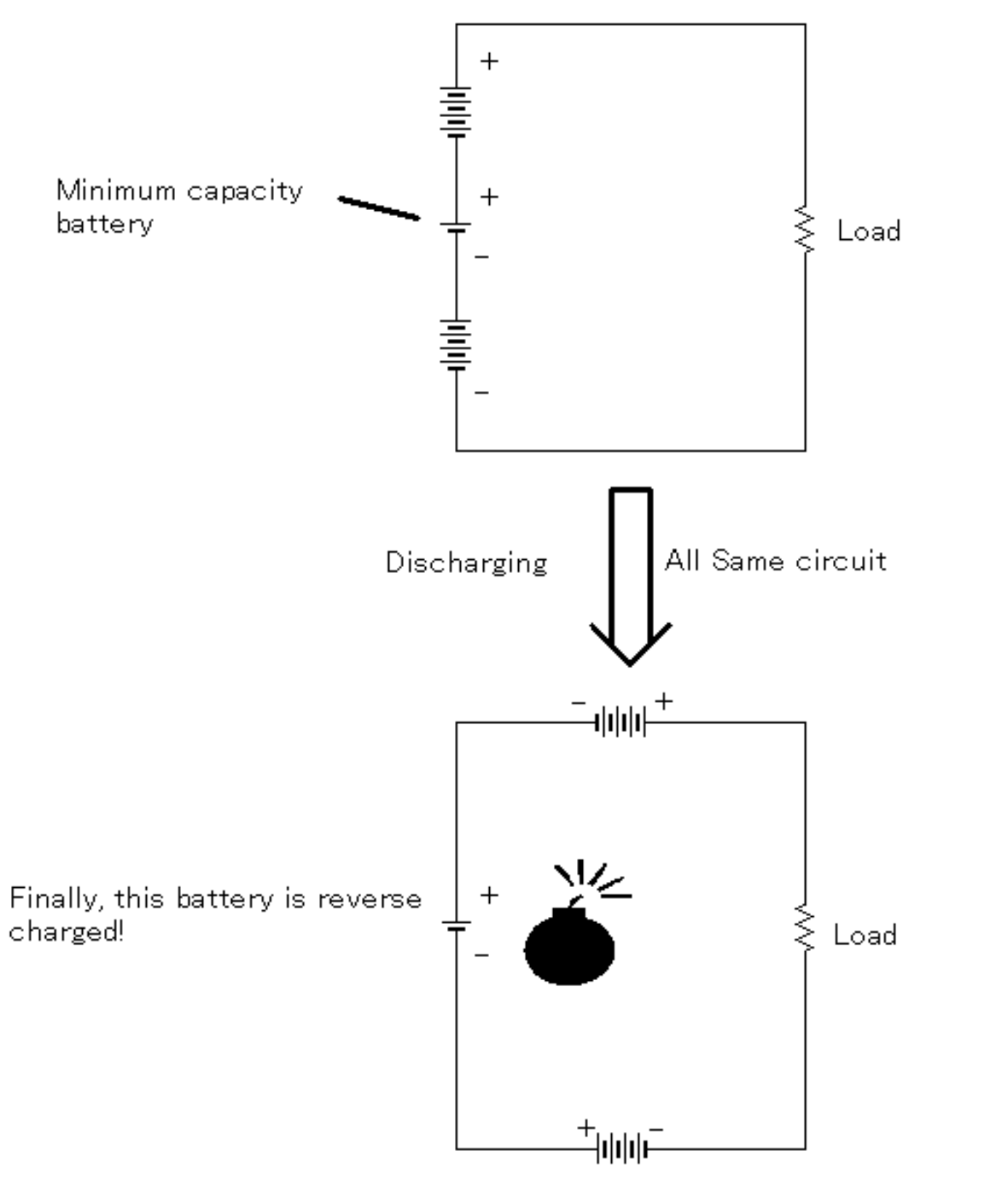
U

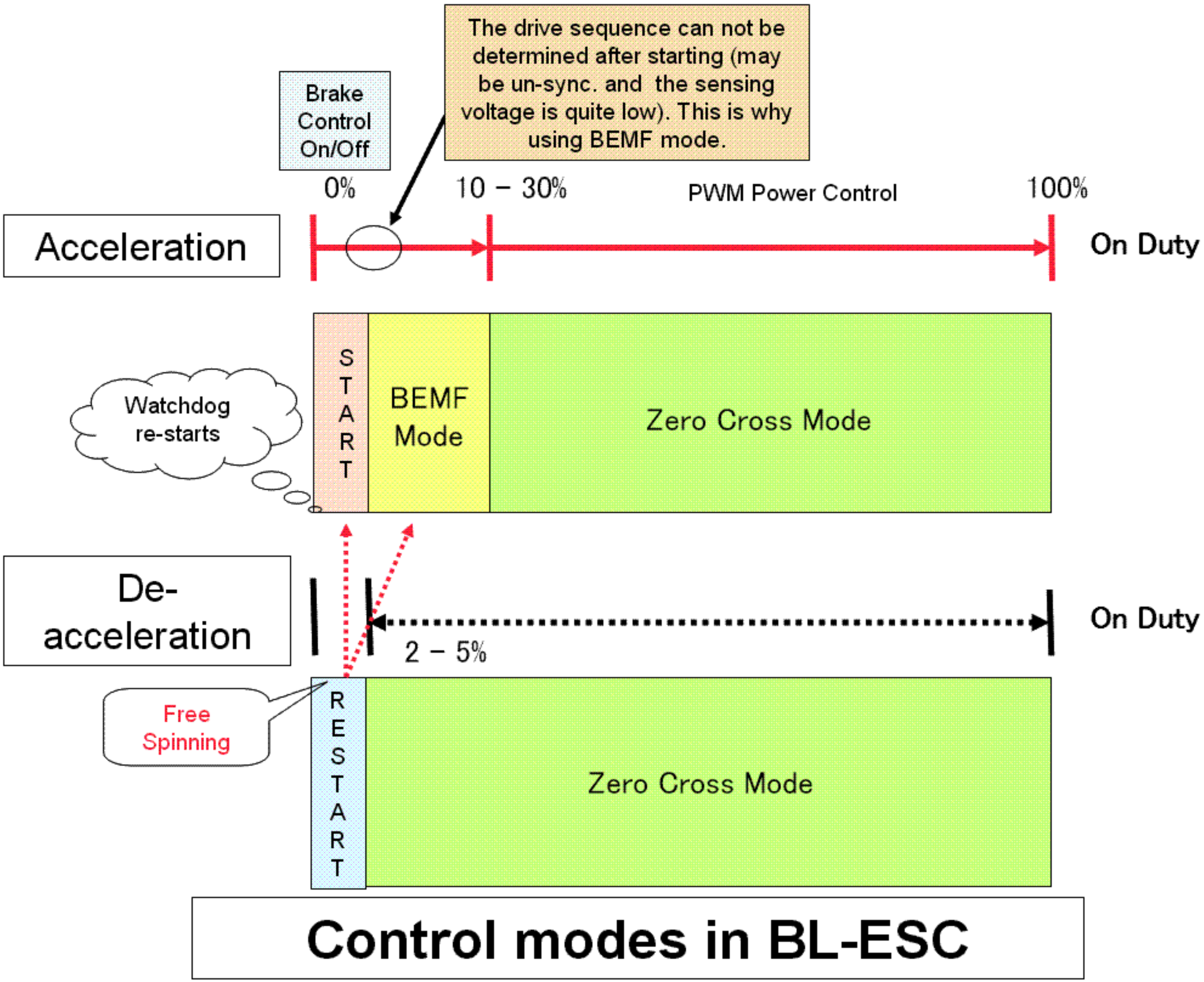
V

W

Date	Rev.	Designed by	Title	Page
'07/12/25	0.1a	Takao Shimizu	Brushless Sensorless Electric Speed Controller Schematic	1/1


ATmega48
ADC0
ADC6
ADC7
AIN0
GND
R7 33k
R8 33k
R9 33k
Virtual Center Tap Point
R1 3.3k
R2 3.3k
R3 3.3k
R4 10k
R5 10k
R6 10k
MOSFET-P
MOSFET-P
MOSFET-P
MOSFET-N
MOSFET-N
MOSFET-N
V BATTERY4
Clean GND
Dirty GND


Minimum capacity battery
Load
Discharging
All Same circuit
Finally, this battery is reverse charged!
Load


The drive sequence can not be determined after starting (may be un-sync. and the sensing voltage is quite low). This is why using BEMF mode.
Brake Control On/Off
0%
10 – 30%
PWM Power Control
100%
Acceleration
On Duty
Watchdog re-starts
START
BEMF Mode
Zero Cross Mode
De-acceleration
2 – 5%
On Duty
Free Spinning
RESTART
Zero Cross Mode
Control modes in BL-ESC

Propo. Rx Interface

Brake Control On/Off

The drive sequence can not be determined after starting (may be un-sync. and the sensing voltage is quite low). This is why using BEMF mode.

0%

10 – 30%

100%

Acceleration

On Duty

PWM Power & Freq. Control

Power Increase Timing Control

Watchdog re-starts

START

BEMF Mode

Zero Cross Mode

(+Timing Advance)

Stick travel adjust at 100% Power

De-acceleration

On Duty

2 – 5%

Free Spinning

RESTART

Power Decrease Timing Control (for PPM Rx)

Zero Cross Mode

(+Timing Advance)

Control modes in BL-ESC

For folding prop.

Brake Control On/Off

0%

The drive sequence can not be determined after starting (may be un-sync. and the sensing voltage is quite low). This is why using BEMF mode.

10 – 30%

100% power setting control

100%

Propo. Rx Interface

Acceleration

On Duty

PWM Power & Freq. Control

Power Increase Timing Control

Watchdog re-starts

START

BEMF Mode

Zero Cross Mode
(+Timing Advance)

Stick travel adjust at 100% Power

Inverse logarithm power proportional control
+ Over current protection

De-acceleration

On Duty

2 – 5%

Free Spinning

RESTART

Power Decrease Timing Control (for PPM Rx)

Zero Cross Mode
(+Timing Advance)

Control modes in BL-ESC

Control modes in BL-ESC

Propo. Rx Interface

Acceleration

For folding prop.

Brake Control On/Off

0%

The drive sequence can not be determined after starting (may be un-sync. and the sensing voltage is quite low). This is why using BEMF mode.

10 – 30%

100% power setting control

100%

On Duty

PWM Power & Freq. Control

Power Increase Timing Control

Watchdog re-starts

START

BEMF Mode

Zero Cross Mode
(+Timing Advance)

Stick travel adjust at 100% Power

De-acceleration

Inverse logarithm power proportional control
+ Over current protection

2 – 5%

On Duty

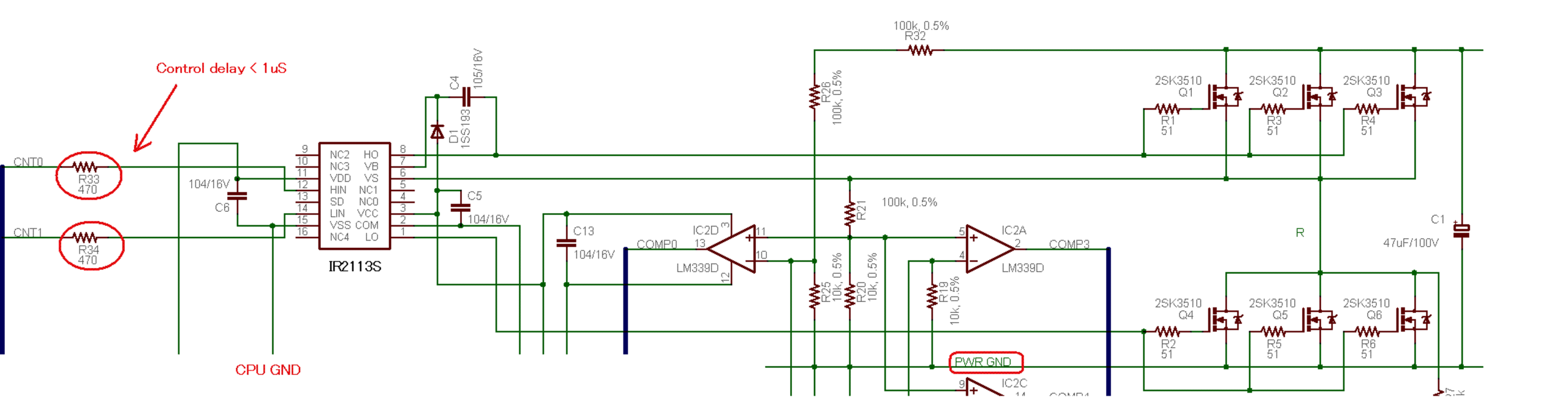
Free Spinning

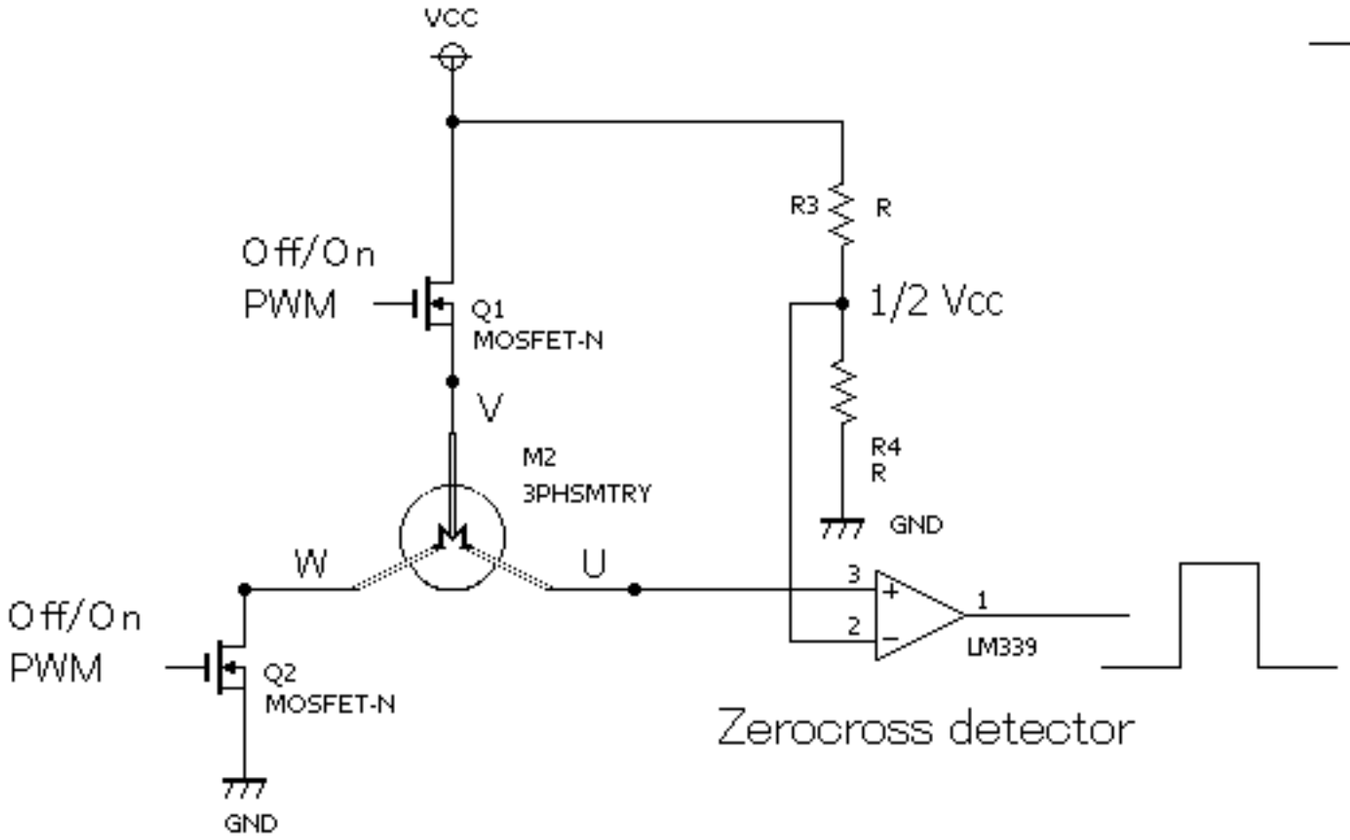
RESTART

Power Decrease Timing Control (for PPM Rx)

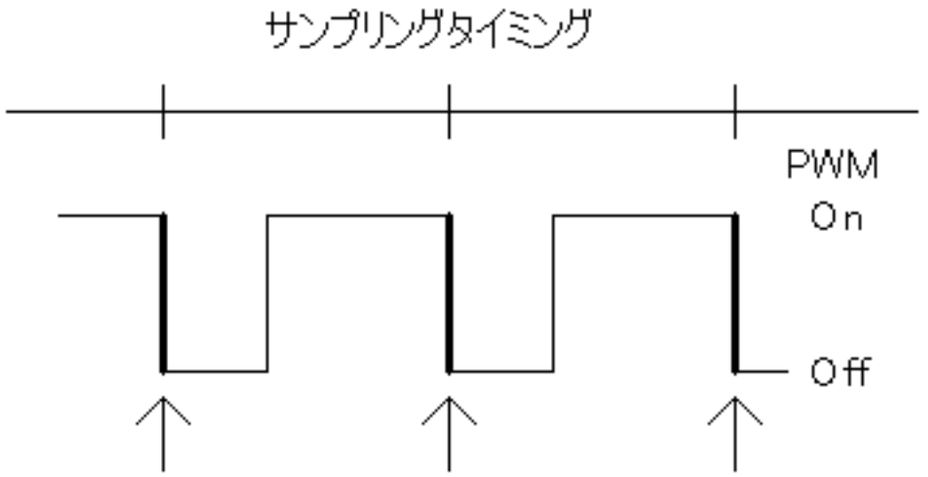
Zero Cross Mode
(+Timing Advance)

The noise filter for unstable PPM Rx


Control delay < 1uS
CNT0
CNT1
R33
470
R34
470
104/16V
C6
CPU GND
NC2 HO
NC3 VB
VDD VS
HIN NC1
SD NC0
LIN VCC
VSS COM
NC4 LO
IR2113S
C4
105/16V
D1
1SS193
C5
104/16V
C13
104/16V
COMP0
IC2D
LM339D
100k, 0.5%
R32
R26
100k, 0.5%
R21
100k, 0.5%
R25
10k, 0.5%
R20
10k, 0.5%
R19
10k, 0.5%
IC2A
LM339D
COMP3
PWR GND
IC2C
2SK3510
Q1
2SK3510
Q2
2SK3510
Q3
R1
51
R3
51
R4
51
2SK3510
Q4
2SK3510
Q5
2SK3510
Q6
R2
51
R5
51
R6
51
R
C1
47uF/100V



Zerocross detector



The Zerocross detection timing is just before PWM off as PWM on rear edge. Also, "Full On" 100% power PWM rear edge timing. This timing does not cause any transient noise problem.
And C8051Fxxx's comparator can be hysteresis level and response timing by software.

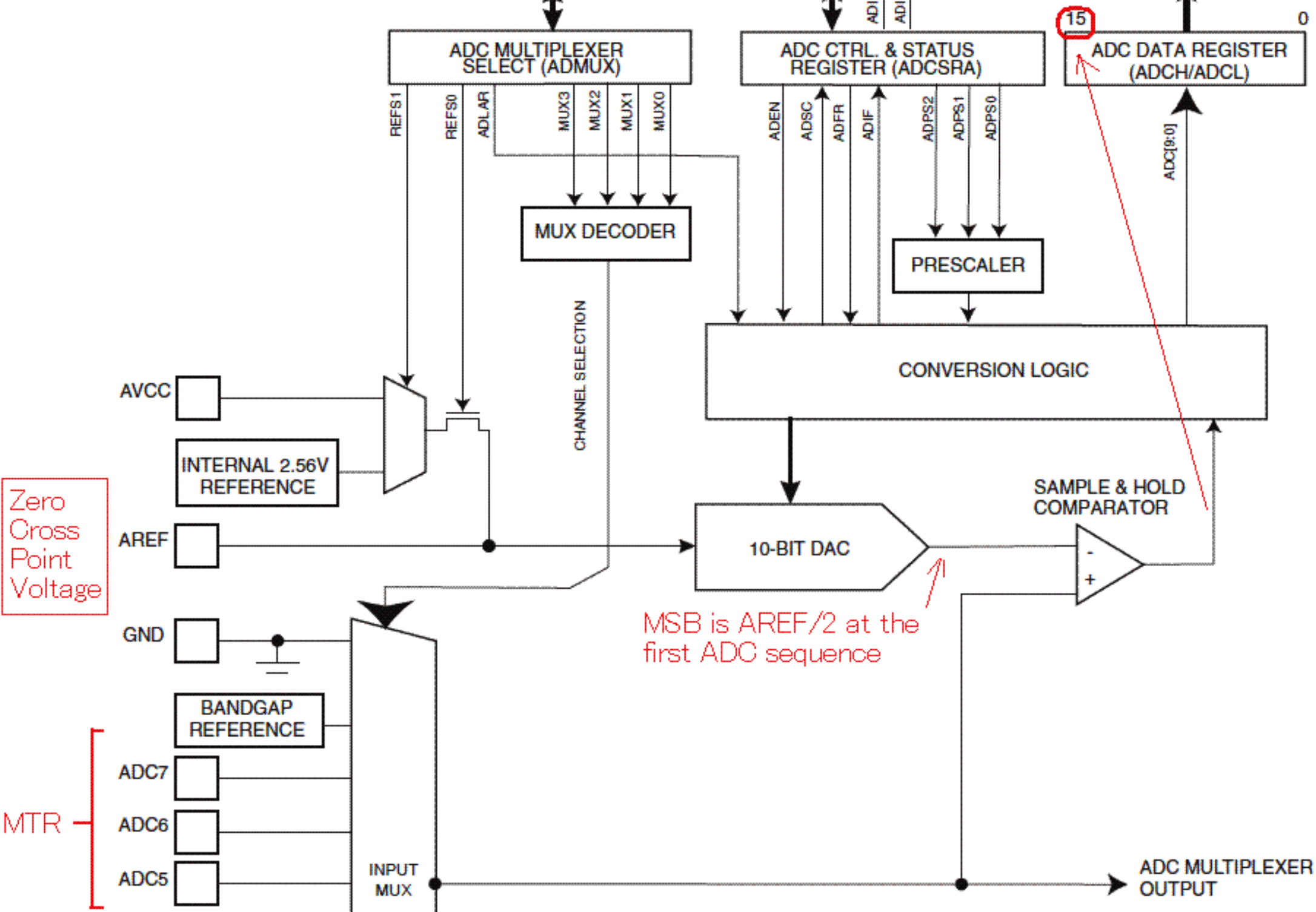
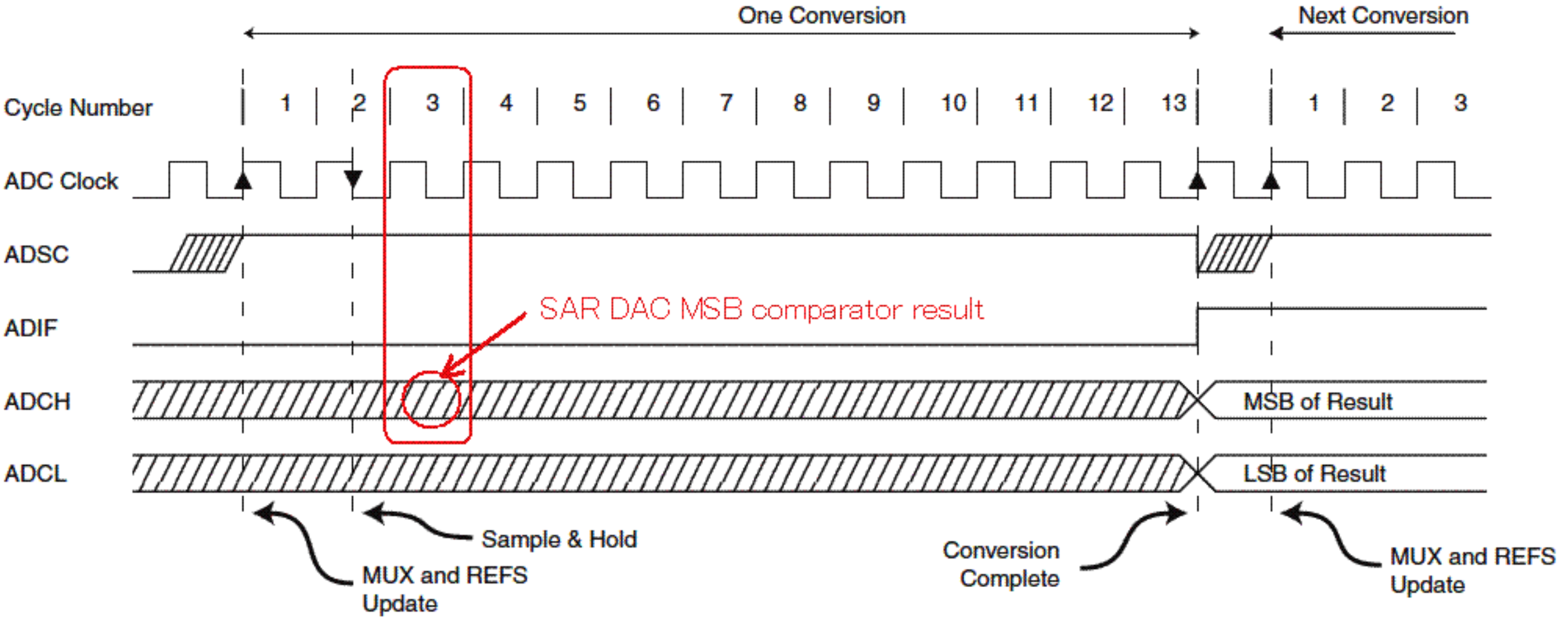

ADC MULTIPLEXER SELECT (ADMUX)
ADC CTRL. & STATUS REGISTER (ADCSRA)
ADC DATA REGISTER (ADCH/ADCL)
15
0
REFS1
REFS0
ADLAR
MUX3
MUX2
MUX1
MUX0
ADEN
ADSC
ADFR
ADIF
ADPS2
ADPS1
ADPS0
ADC[9:0]
MUX DECODER
PRESCALER
CHANNEL SELECTION
CONVERSION LOGIC
AVCC
INTERNAL 2.56V REFERENCE
AREF
GND
BANDGAP REFERENCE
ADC7
ADC6
ADC5
MTR
Zero Cross Point Voltage
10-BIT DAC
SAMPLE & HOLD COMPARATOR
MSB is AREF/2 at the first ADC sequence
INPUT MUX
ADC MULTIPLEXER OUTPUT

Figure 93. ADC Timing Diagram, Single Conversion



Drive State

#5 #6 #1 #2 #3 #4 #5 #6 #1 #2

U

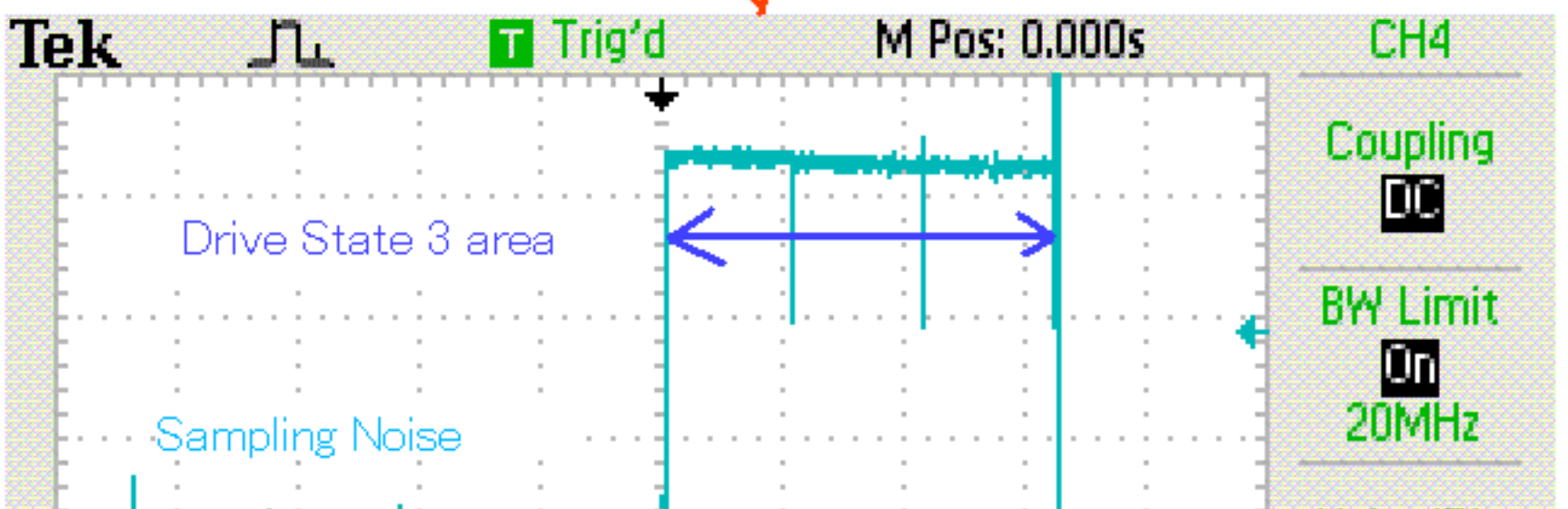
V

Vcc

1/2 Vcc

GND

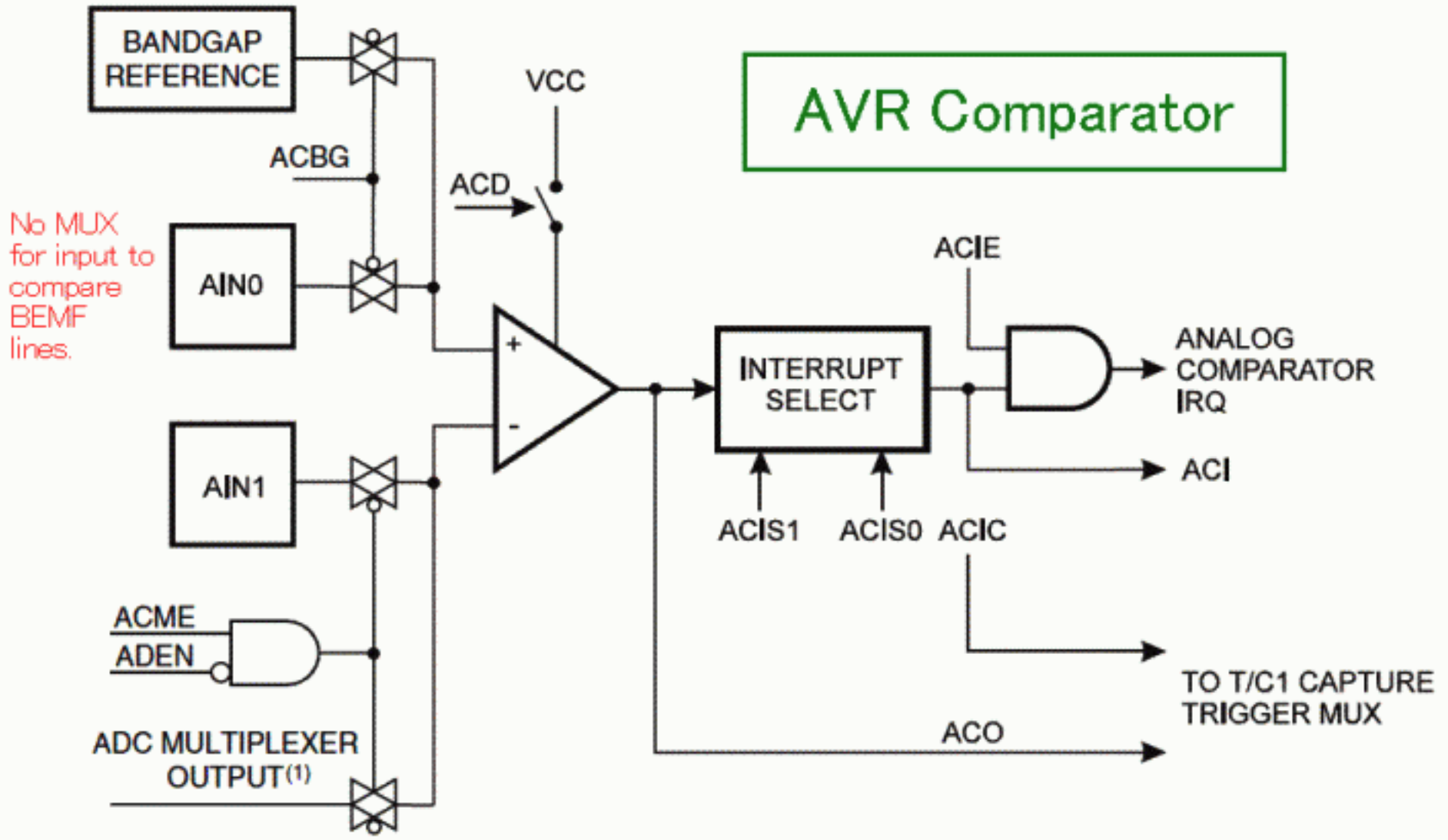
W



10,000 rpm

9 stater, 12 magnets motor.

Figure 89. Analog Comparator Block Diagram[2]



Rs are for Inductive kick protection.

Pin Socket

MPU

C
C

Clean GND

GND

Q1
PNP

Q3
PNP

Q5
PNP

Q2
NPN

Q4
NPN

Q6
NPN

R1
10k

R2
10k

R3
10k

SU

SV

SW

C1
220uF/10V

CN1
2HEADER

CN2
CN-2P

BAT1
Li-Po 2.5-4.3V

High Ripple type.

W

M1

V

BL Motor

U

Pin Socket

MAX 6S Li-Po

CN5 2HEADER

CN6 CN-2P

BAT1 Li-Po 2.5-4.3V

BAT2 Li-Po 2.5-4.3V

BAT3 Li-Po 2.5-4.3V

C10 220uF/25V

Q4 2SK3814

Q5 2SK3814

Q9 2SK3814

Q10 2SK3814

Q14 2SK3814

Q15 2SK3814

R19 10k, 1%

R23 10k, 1%

R28 10k, 1%

High Ripple type.

GND

SU

SV

SW

W

M1

V

U

BL Motor

VCC

C8051F331

U2

GND

P0.0

GND

VDD

/RST/C2CK

P2.0/C2D

P0.1

P0.2

P0.3

P0.4

P0.5

P0.6

P0.7

P1.0

P1.1

P1.2

P1.7

P1.6

P1.5

P1.4

P1.3

ZERO_CROSS

R14 21k, 1%

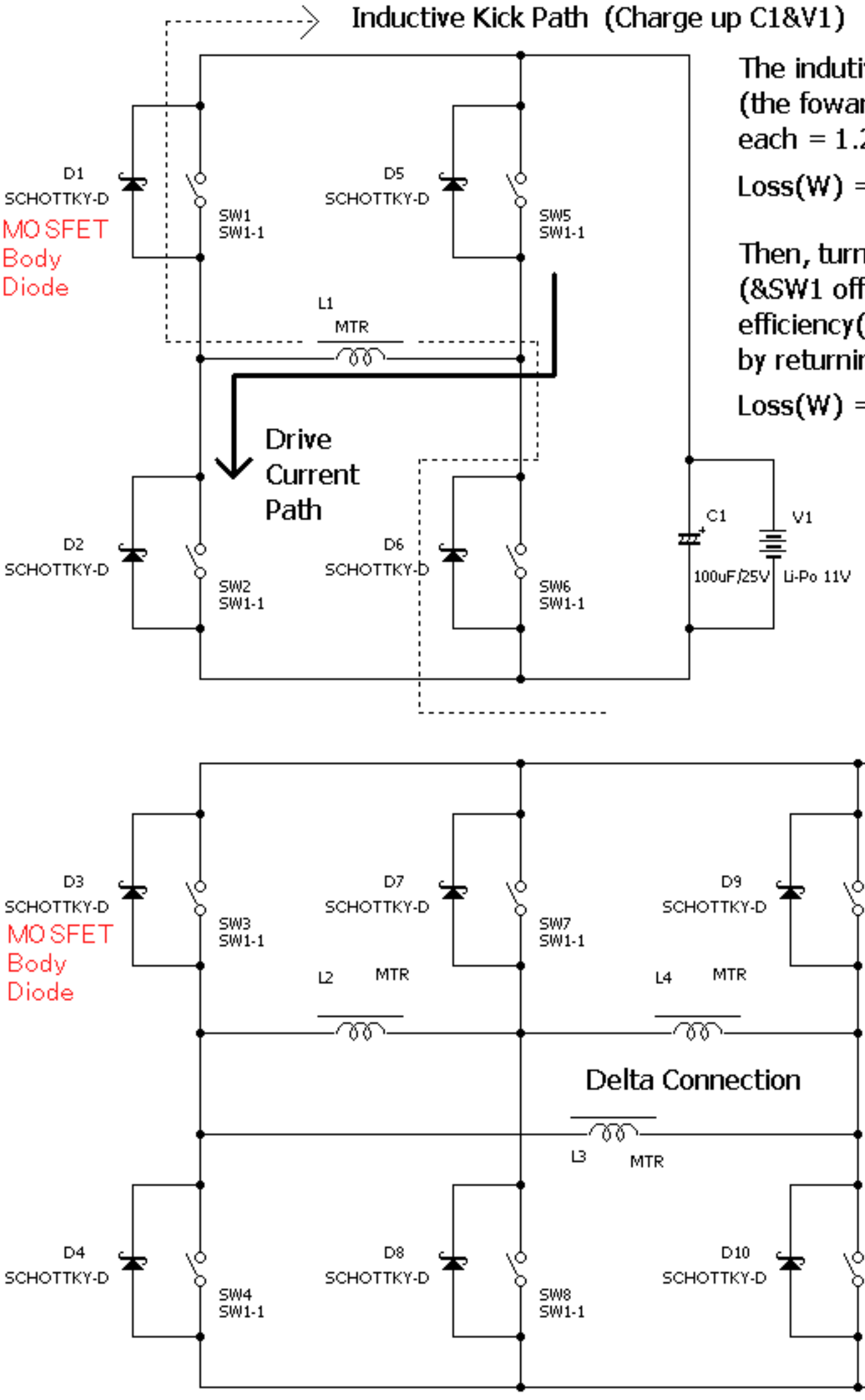
R11 1k, 1%

R10 1k, 1%

R13 1k, 1%

R12 1k, 1%

AGND

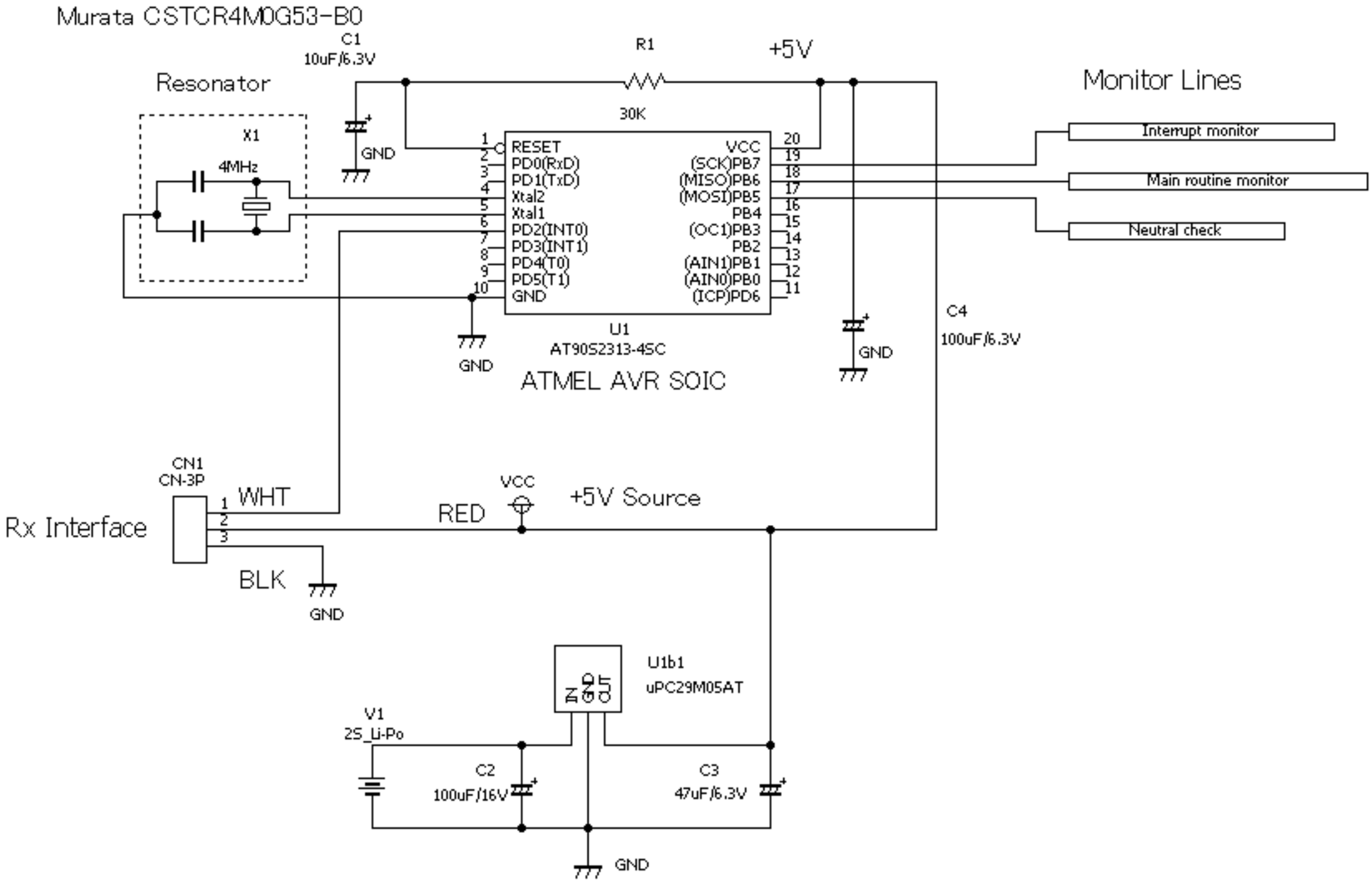


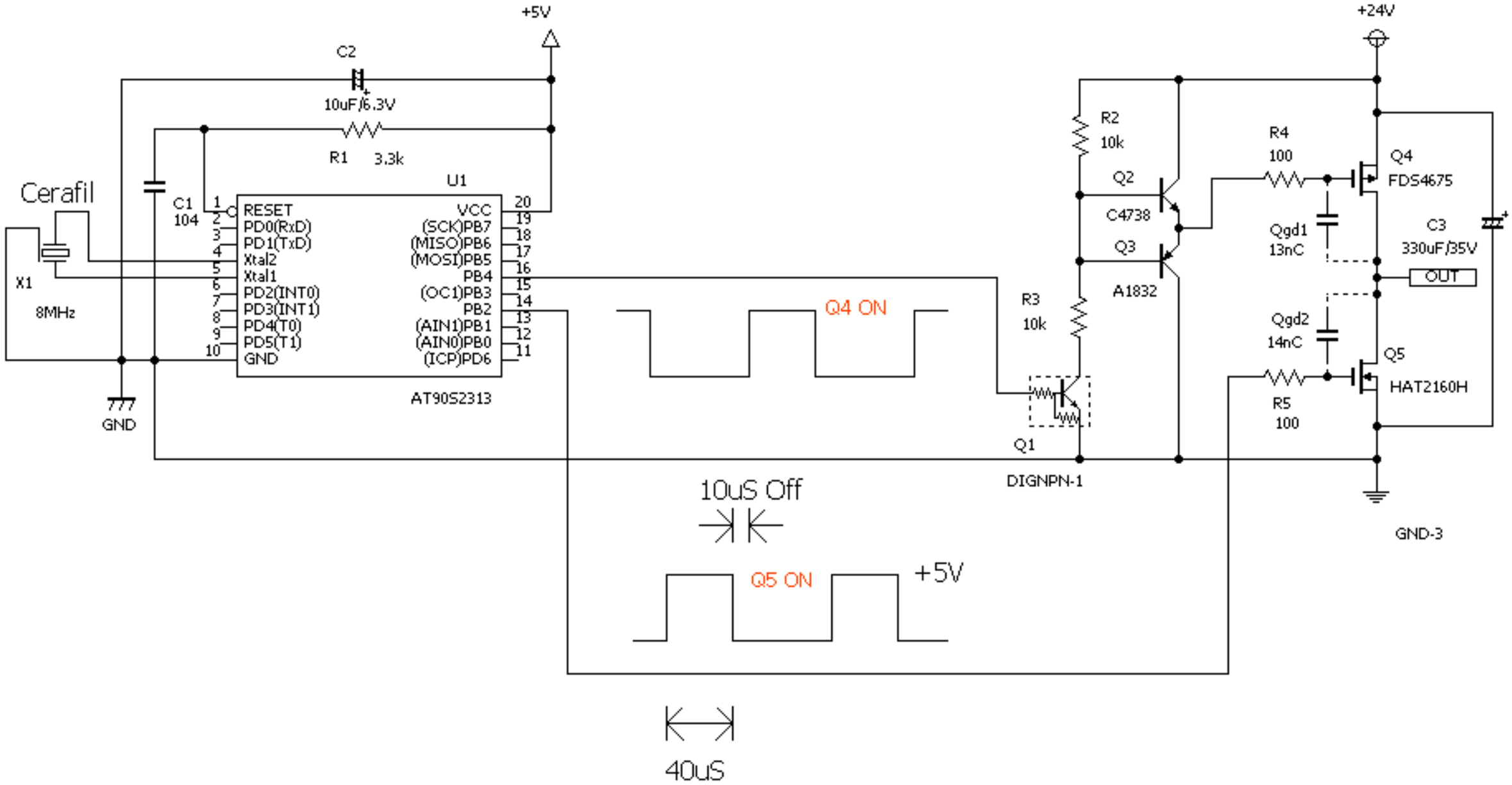
The indutive kick heats up D1&D6
(the foward voltage drop loss is about 0.6V each = 1.2V) just after SW2&SW5 PWM turn-off.

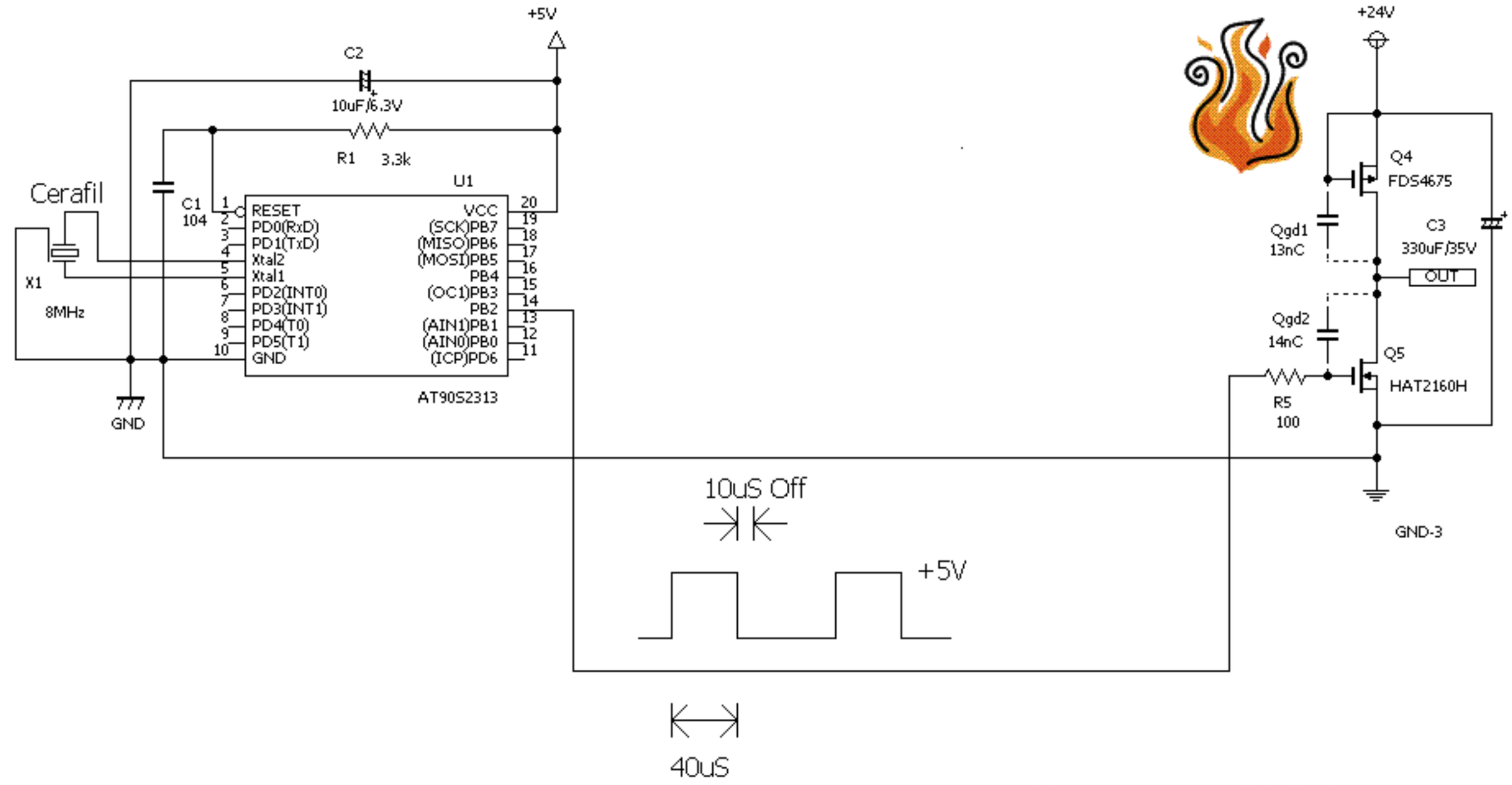
Loss(W) = 1.2V x Kick current

Then, turn-on SW1 on(& SW6 off) or SW6 on (&SW1 off) at PWM-off to get more power efficiency(only one diode voltage drop = 0.6V) by returning the inductive kick energy to C1&V1.

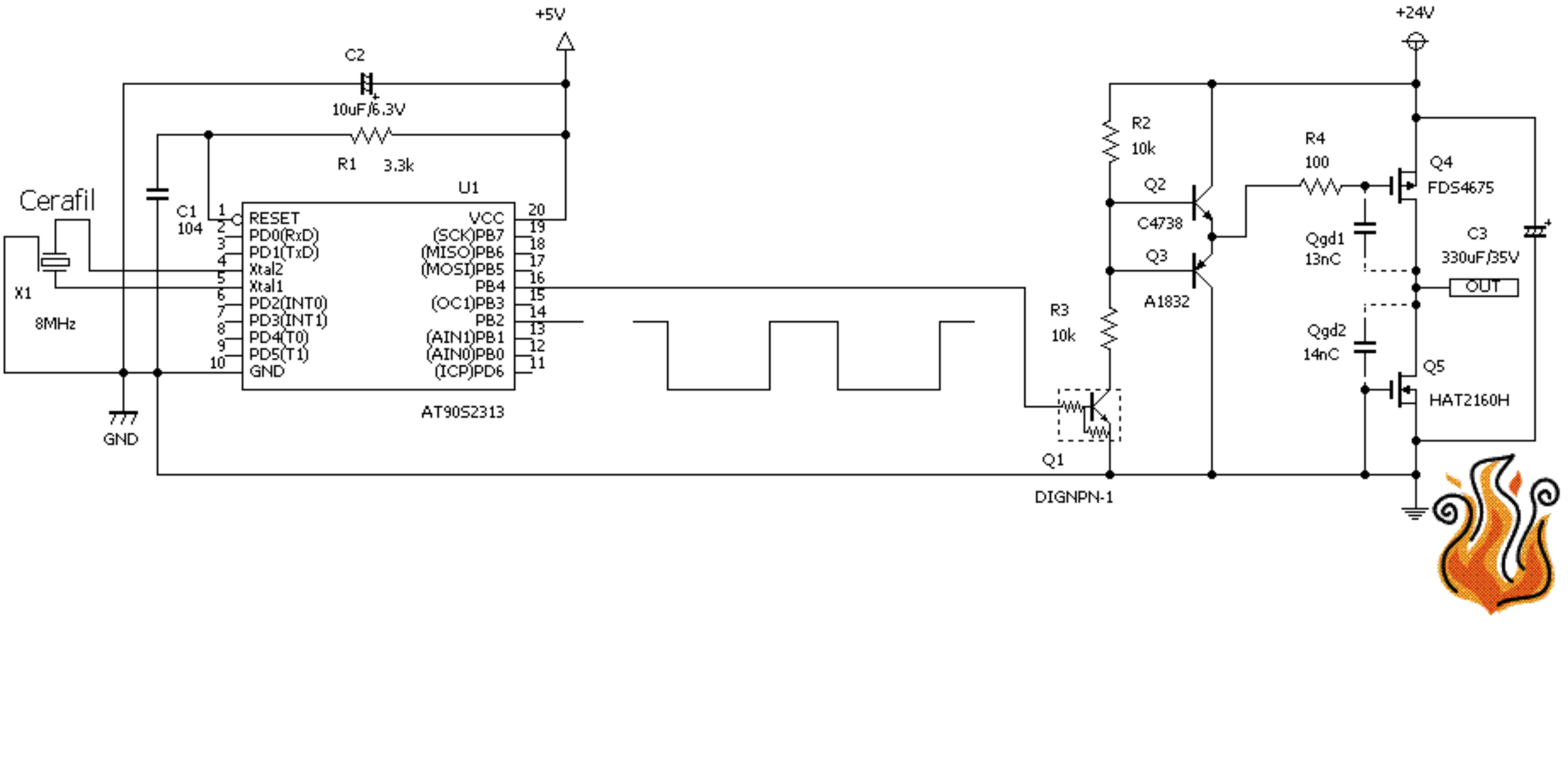
Loss(W) = 0.6V x Kick current

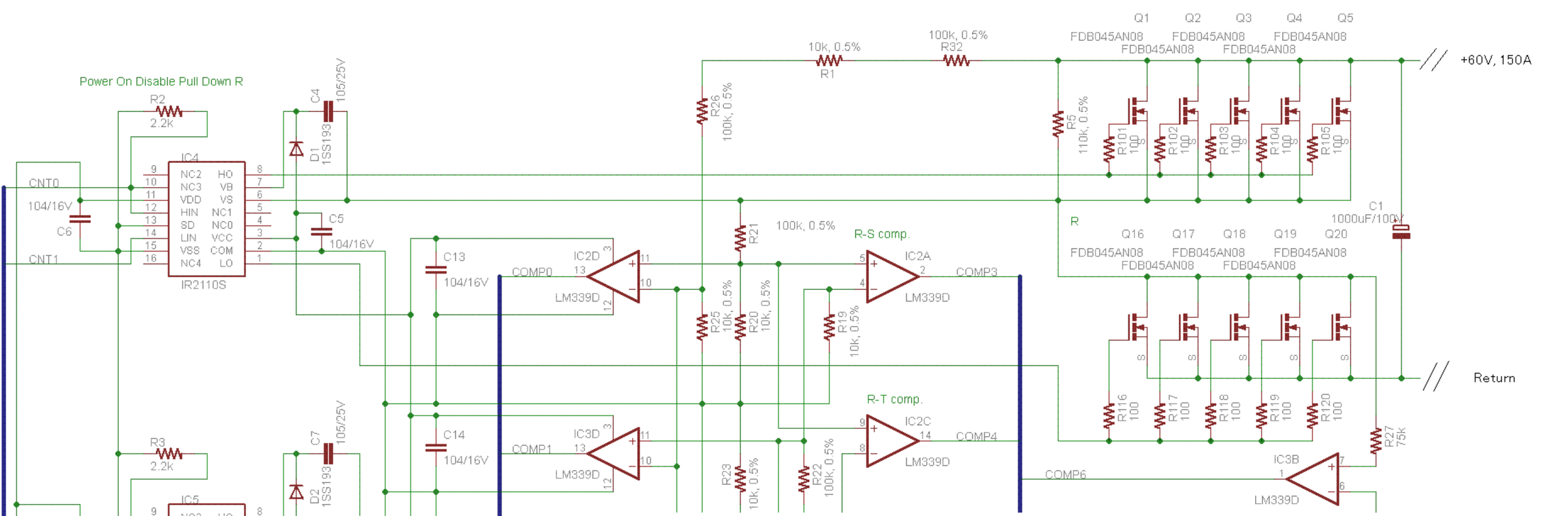

Murata CSTCR4M0G53-B0
C1
10uF/6.3V
R1
+5V
Resonator
Monitor Lines
30K
X1
4MHz
GND
RESET
PD0(RxD)
PD1(TxD)
Xtal2
Xtal1
PD2(INT0)
PD3(INT1)
PD4(T0)
PD5(T1)
GND
VCC
(SCK)PB7
(MISO)PB6
(MOSI)PB5
PB4
(OC1)PB3
PB2
(AIN1)PB1
(AIN0)PB0
(ICP)PD6
Interrupt monitor
Main routine monitor
Neutral check
U1
AT90S2313-4SC
ATMEL AVR SOIC
C4
100uF/6.3V
CN1
CN-3P
WHT
RED
BLK
VCC
+5V Source
Rx Interface
U1b1
uPC29M05AT
V1
2S_Li-Po
C2
100uF/16V
C3
47uF/6.3V

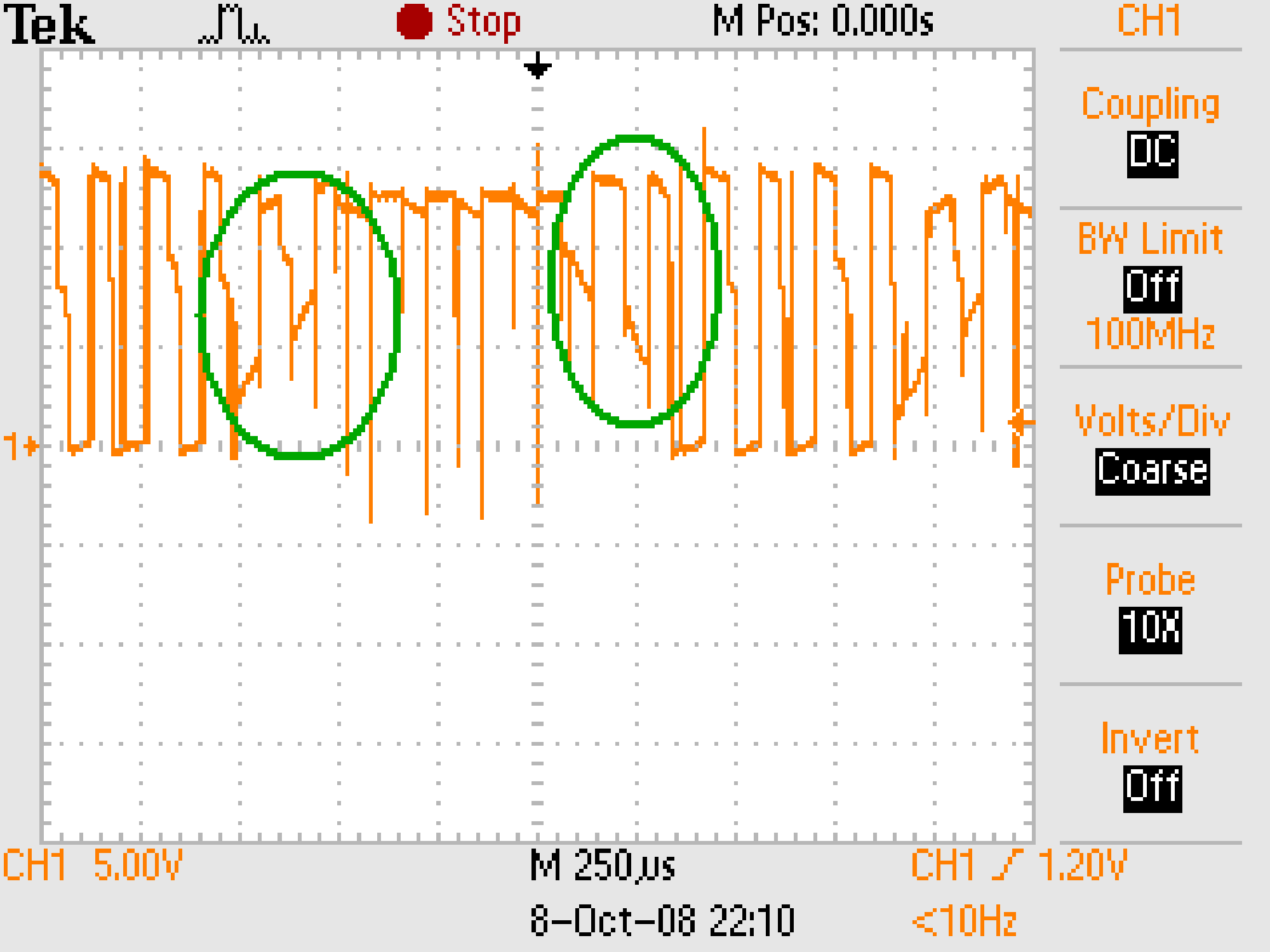

+5V
C2
10uF/6.3V
R1 3.3k
U1
Cerafil
C1
104
X1
8MHz
RESET
PD0(RxD)
PD1(TxD)
Xtal2
Xtal1
PD2(INT0)
PD3(INT1)
PD4(T0)
PD5(T1)
GND
VCC
(SCK)PB7
(MISO)PB6
(MOSI)PB5
PB4
(OC1)PB3
PB2
(AIN1)PB1
(AIN0)PB0
(ICP)PD6
AT90S2313
GND
Q4 ON
+24V
R2
10k
Q2
C4738
Q3
A1832
R3
10k
Q1
DIGNPN-1
R4
100
Q4
FDS4675
Qgd1
13nC
C3
330uF/35V
OUT
Qgd2
14nC
Q5
HAT2160H
R5
100
GND-3
10uS Off
Q5 ON
+5V
40uS

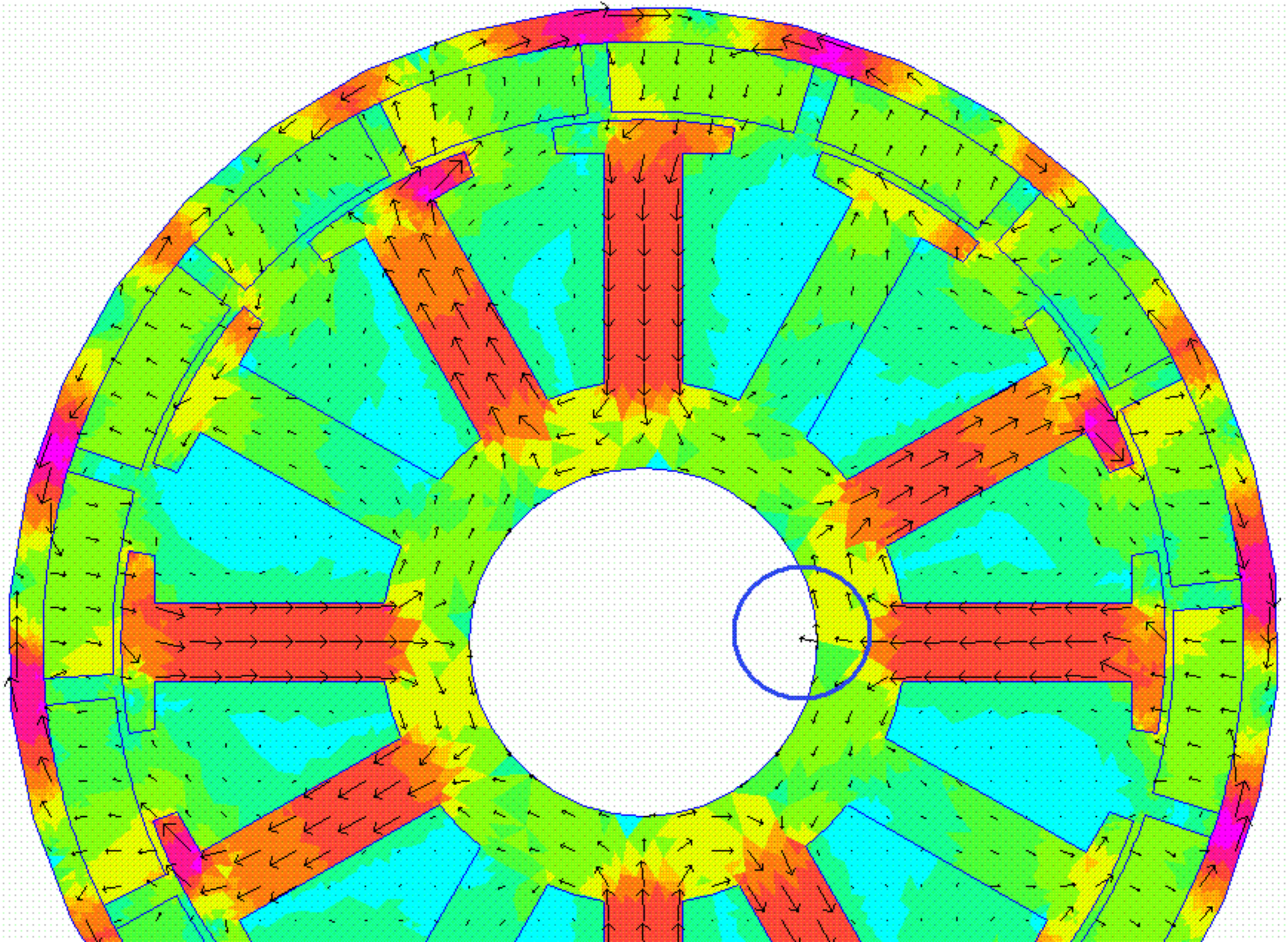


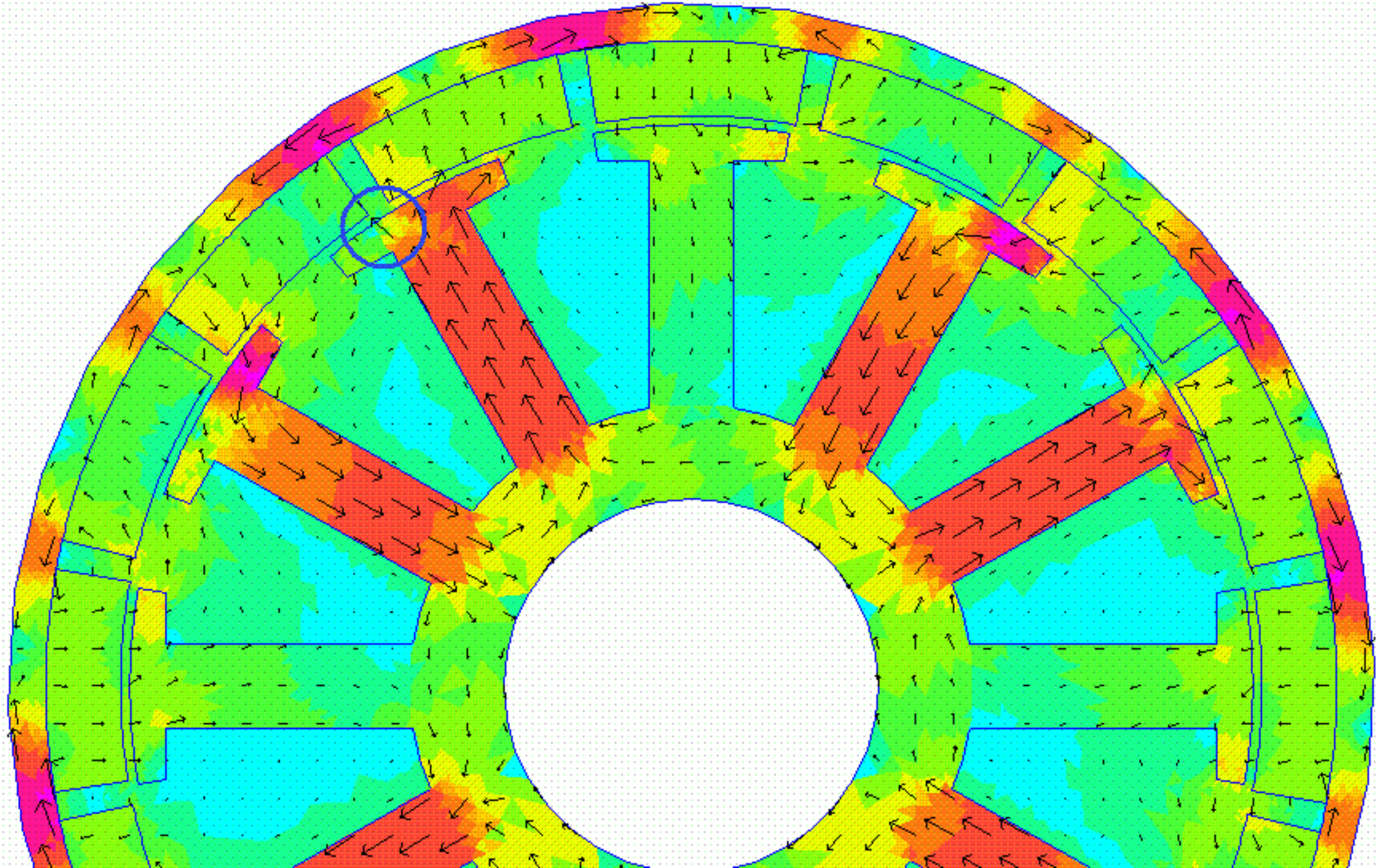
C3: Very Low ESR Cap.

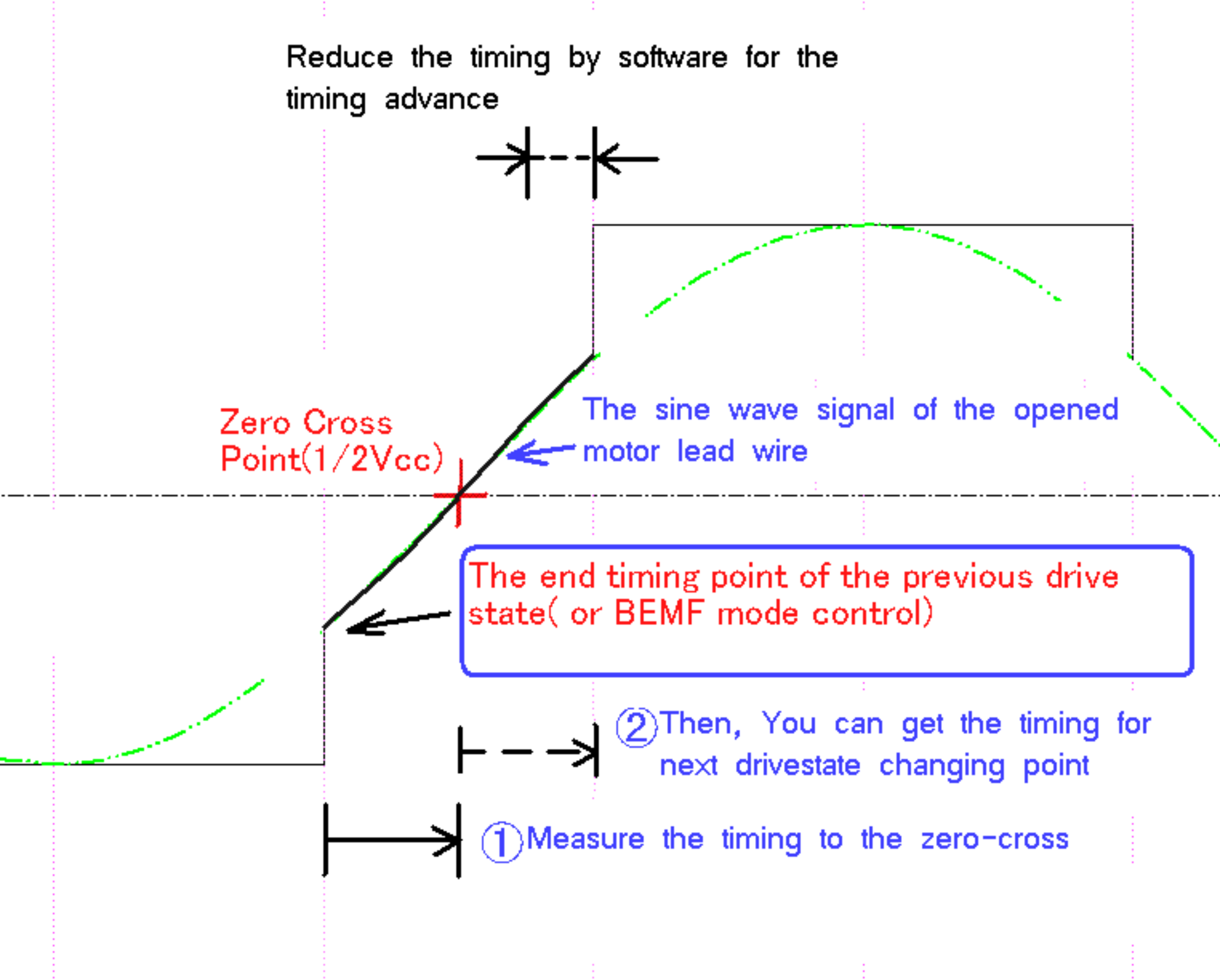


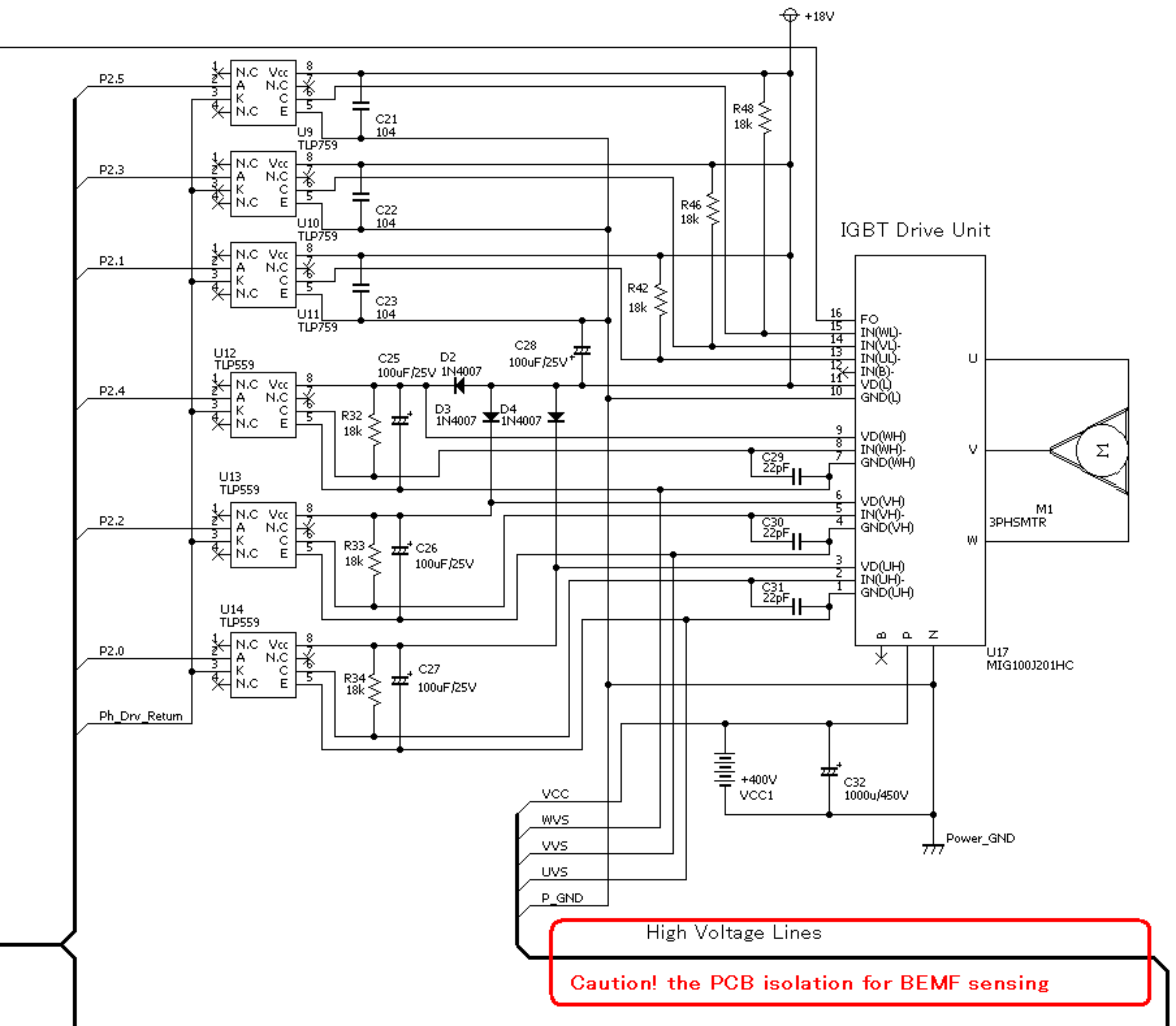

Power On Disable Pull Down R
R2
2.2k
C4
105/25V
D1
1SS193
IC4
NC2
NC3
VDD
HIN
SD
LIN
VSS
NC4
HO
VB
VS
NC1
NC0
VCC
COM
LO
IR2110S
CNT0
CNT1
104/16V
C6
C5
104/16V
C13
104/16V
C14
104/16V
R3
2.2k
C7
105/25V
D2
1SS193
IC5
IR2110S
10k, 0.5%
R1
100k, 0.5%
R32
R26
100k, 0.5%
R5
110k, 0.5%
Q1
Q2
Q3
Q4
Q5
FDB045AN08
R101
R102
R103
R104
R105
100
+60V, 150A
C1
1000uF/100V
R
Q16
Q17
Q18
Q19
Q20
R116
R117
R118
R119
R120
R27
75k
Return
R21
100k, 0.5%
R-S comp.
IC2D
IC2A
COMP0
COMP3
LM339D
R25
10k, 0.5%
R20
10k, 0.5%
R19
10k, 0.5%
R-T comp.
IC3D
IC2C
COMP1
COMP4
R23
10k, 0.5%
R22
100k, 0.5%
COMP6
IC3B

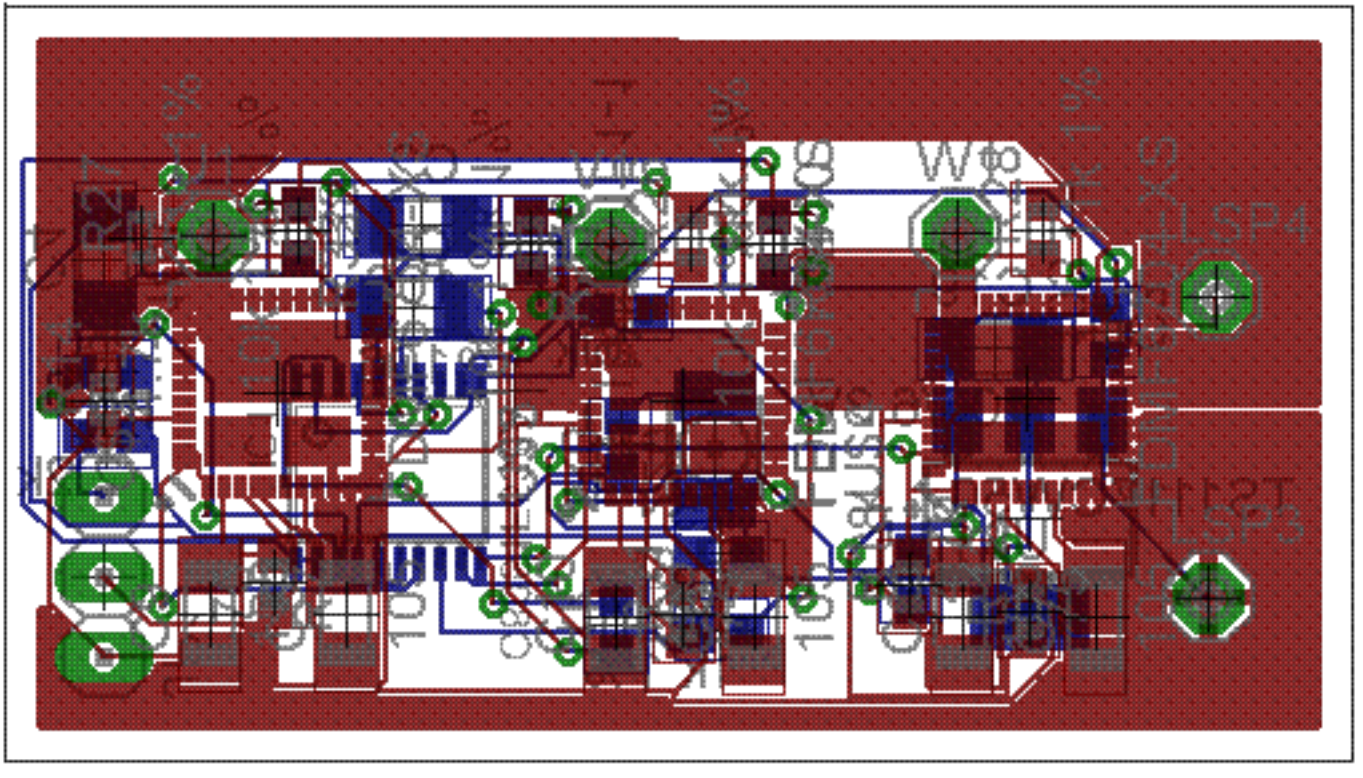

Tek
Stop
M Pos: 0.000s
CH1
Coupling
DC
BW Limit
Off
100MHz
Volts/Div
Coarse
Probe
10X
Invert
Off
CH1 5.00V
M 250µs
CH1 1.20V
8-Oct-08 22:10
<10Hz

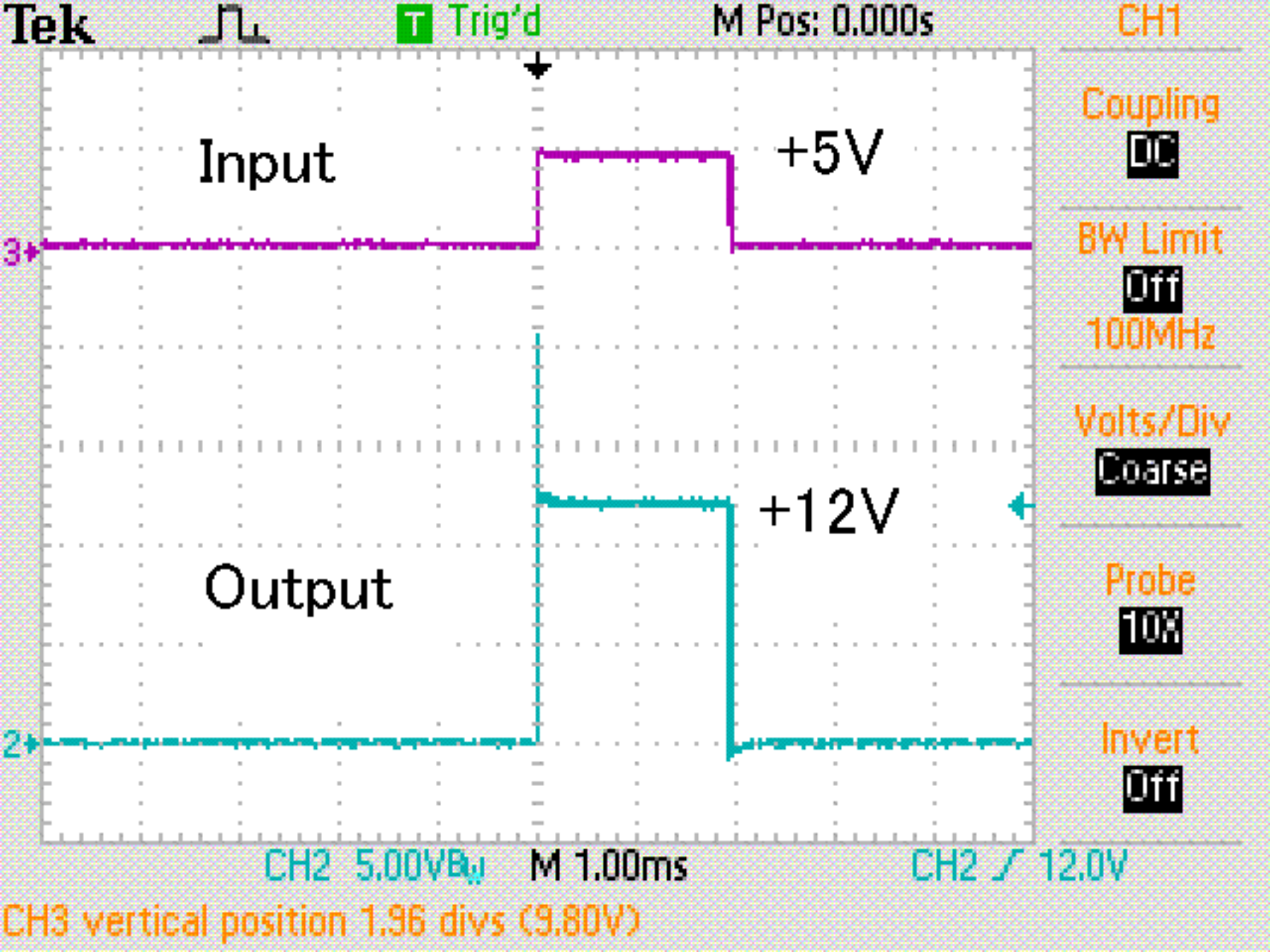




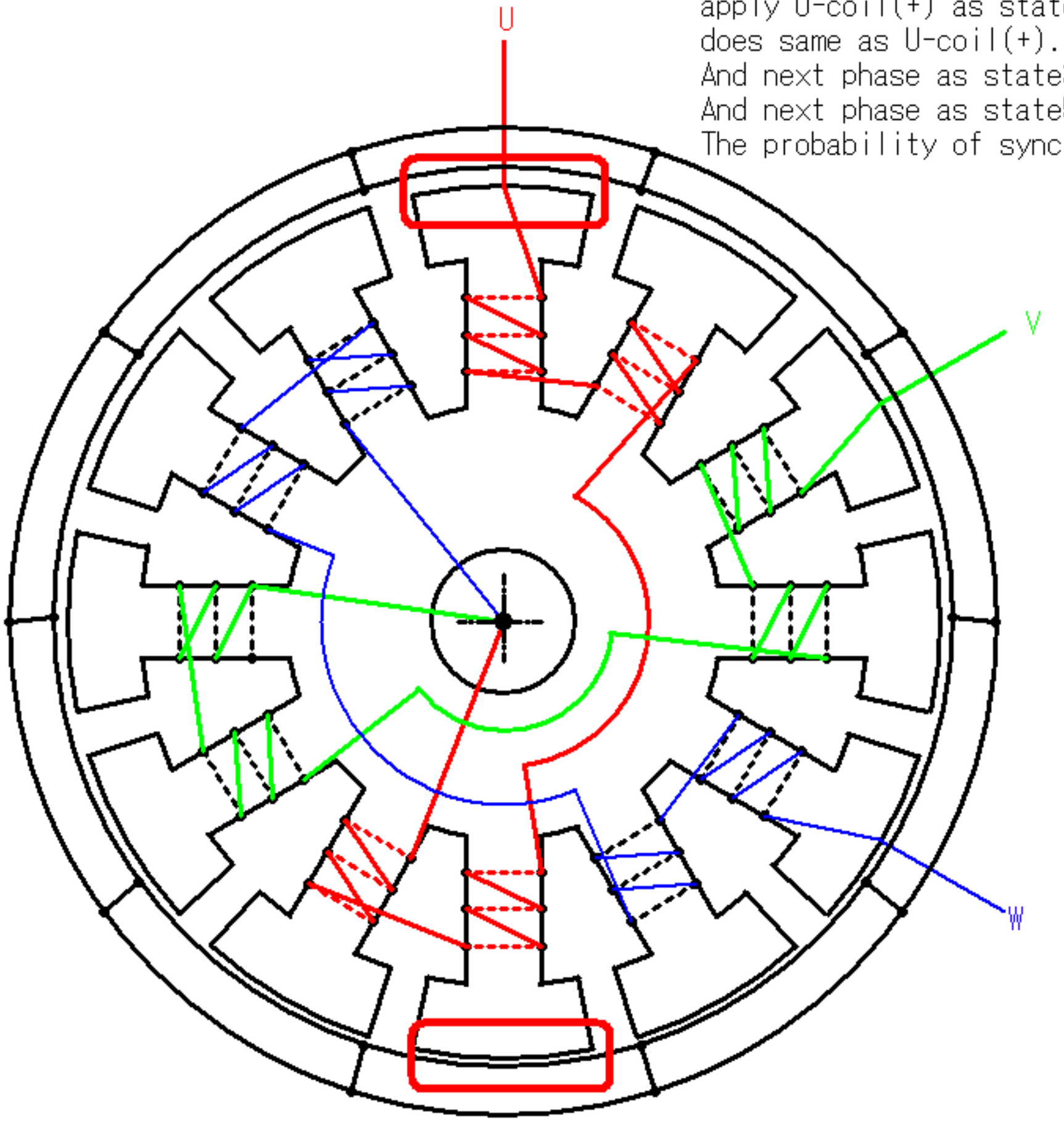

Reduce the timing by software for the timing advance
Zero Cross Point(1/2Vcc)
The sine wave signal of the opened motor lead wire
The end timing point of the previous drive state(or BEMF mode control)
②Then, You can get the timing for next drivestate changing point
①Measure the timing to the zero-cross

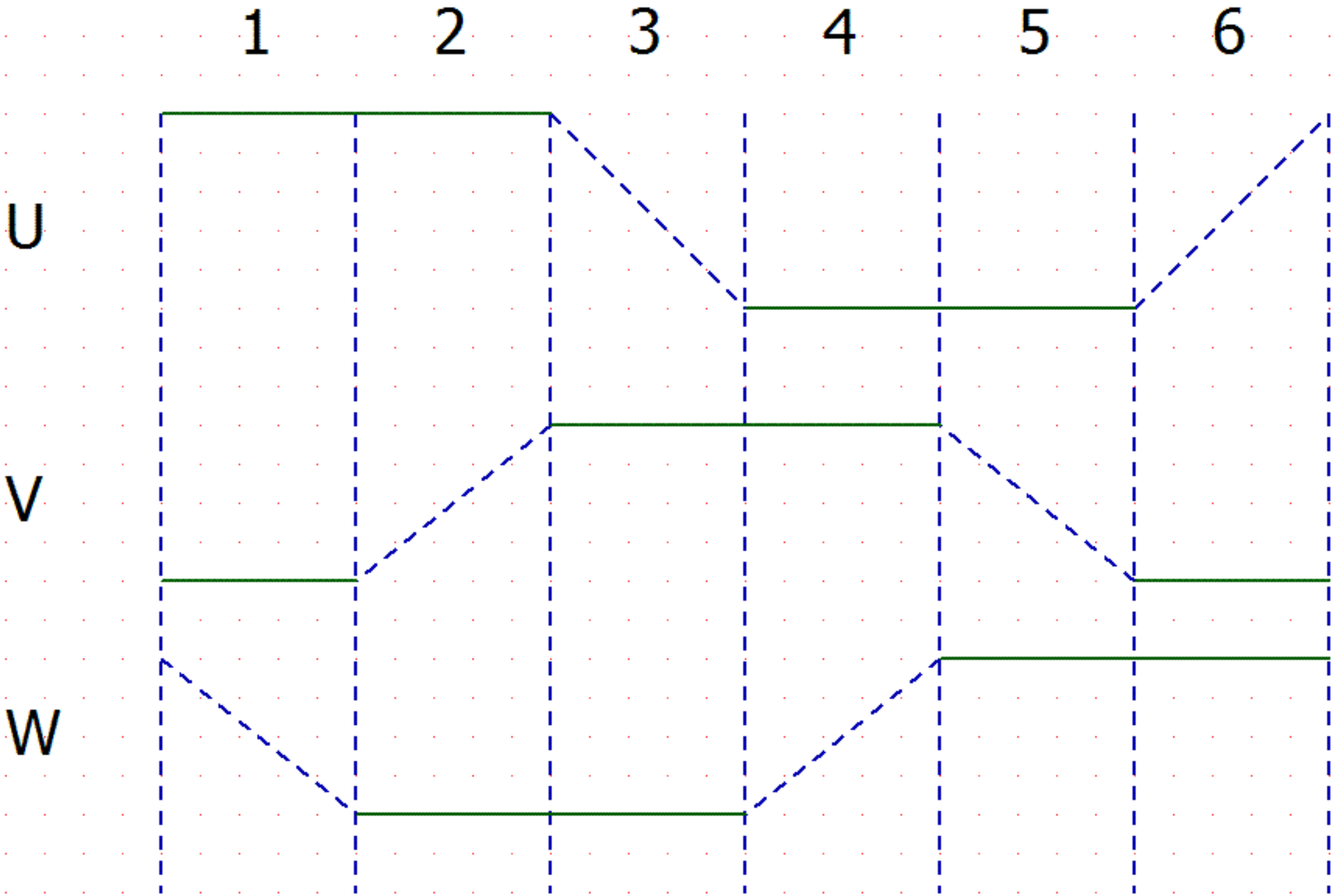

+18V
P2.5
P2.3
P2.1
P2.4
P2.2
P2.0
Ph_Drv_Return
U9
TLP759
U10
TLP759
U11
TLP759
U12
TLP559
U13
TLP559
U14
TLP559
C21
104
C22
104
C23
104
C25
100uF/25V
C26
100uF/25V
C27
100uF/25V
C28
100uF/25V
C29
22pF
C30
22pF
C31
22pF
D2
1N4007
D3
1N4007
D4
1N4007
R32
18k
R33
18k
R34
18k
R42
18k
R46
18k
R48
18k
IGBT Drive Unit
FO
IN(WL)-
IN(VL)-
IN(UL)-
IN(B)-
VD(L)
GND(L)
VD(WH)
IN(WH)-
GND(WH)
VD(VH)
IN(VH)-
GND(VH)
VD(UH)
IN(UH)-
GND(UH)
U
V
W
M1
3PHSMTR
U17
MIG100J201HC
+400V
VCC1
C32
1000u/450V
Power_GND
VCC
WVS
VVS
UVS
P_GND
High Voltage Lines
Caution! the PCB isolation for BEMF sensing


R2
LSP4
LSP3

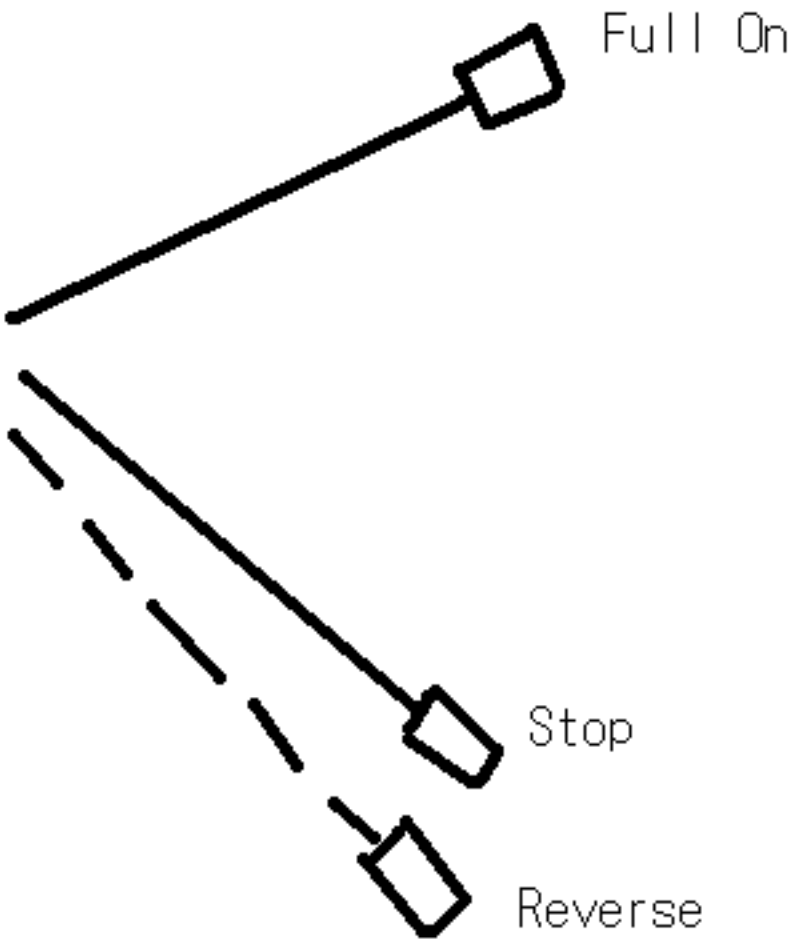

Tek
Trig'd
M Pos: 0.000s
CH1
Coupling
DC
BW Limit
Off
100MHz
Volts/Div
Coarse
Probe
10X
Invert
Off
Input
+5V
Output
+12V
3
2
CH2 5.00V
M 1.00ms
CH2 12.0V
CH3 vertical position 1.96 divs (9.80V)

To suck-in the red part of magnet, ex.
apply U-coil(+) as state1, and state2
does same as U-coil(+).
And next phase as state3,4 V-coil(+)
And next phase as state5,6 W-coil(+).
The probability of sync. is x2 better.




1
2
3
4
5
6
U
V
W

Stick Position

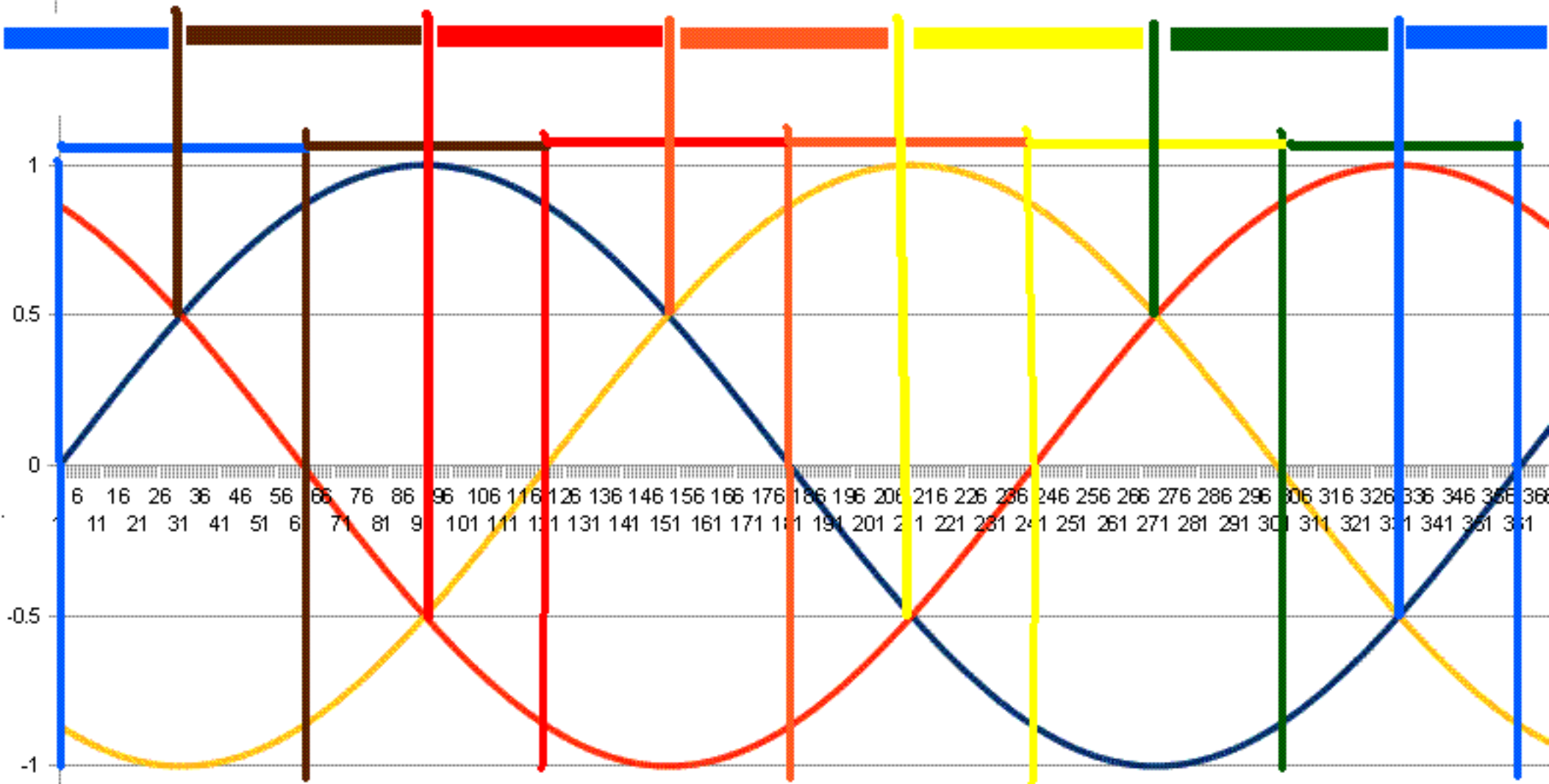


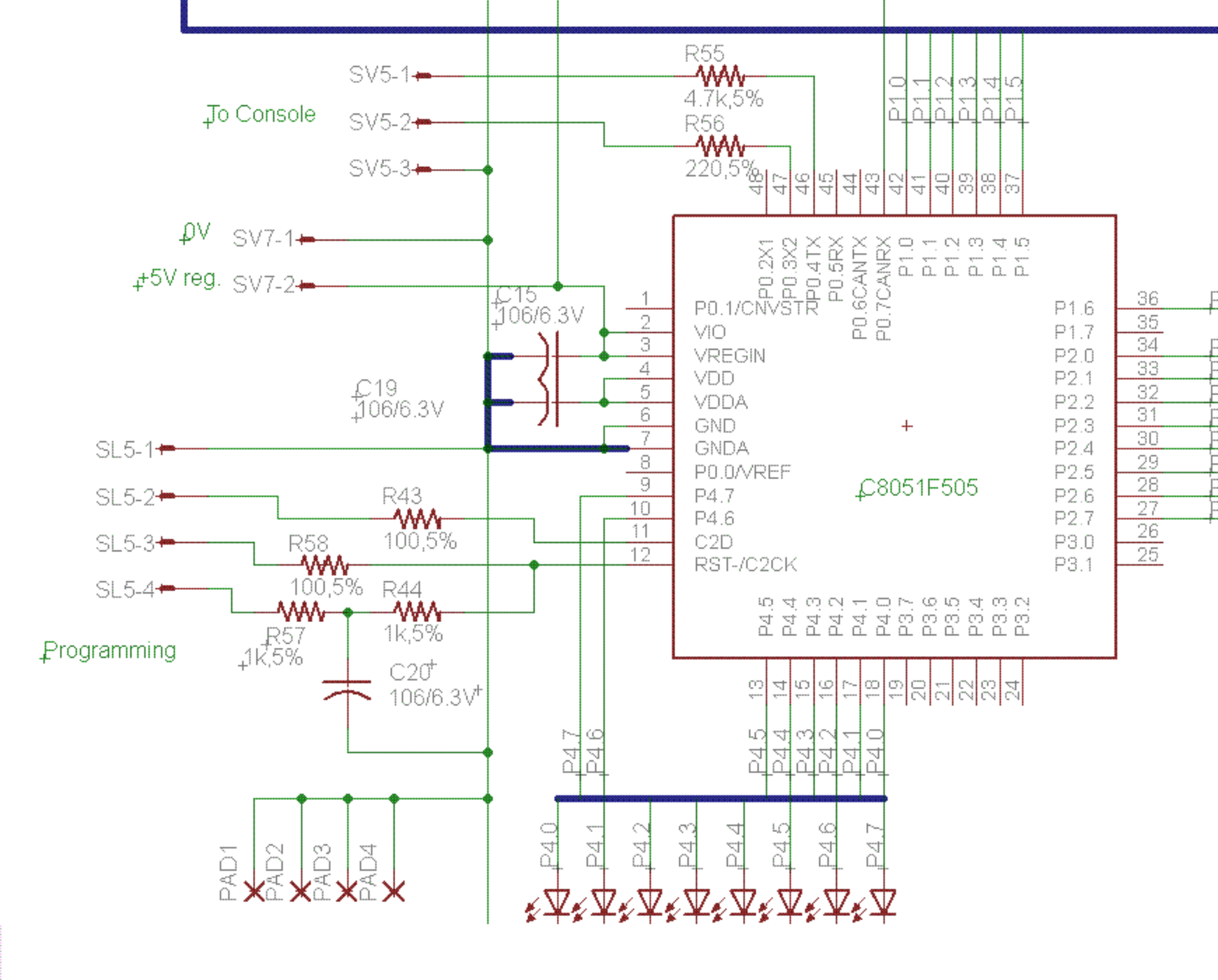
1 2 3 4 5 6

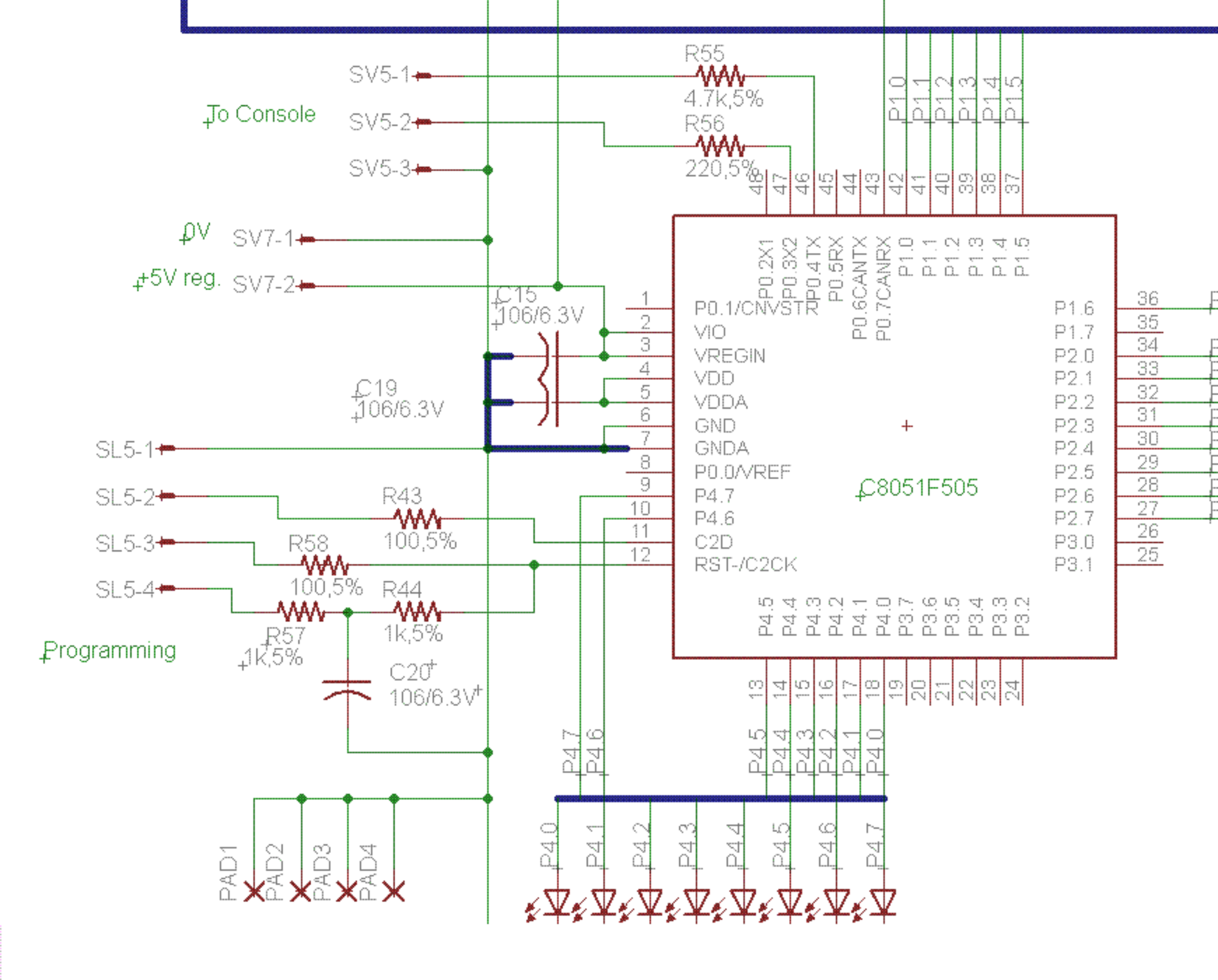
U

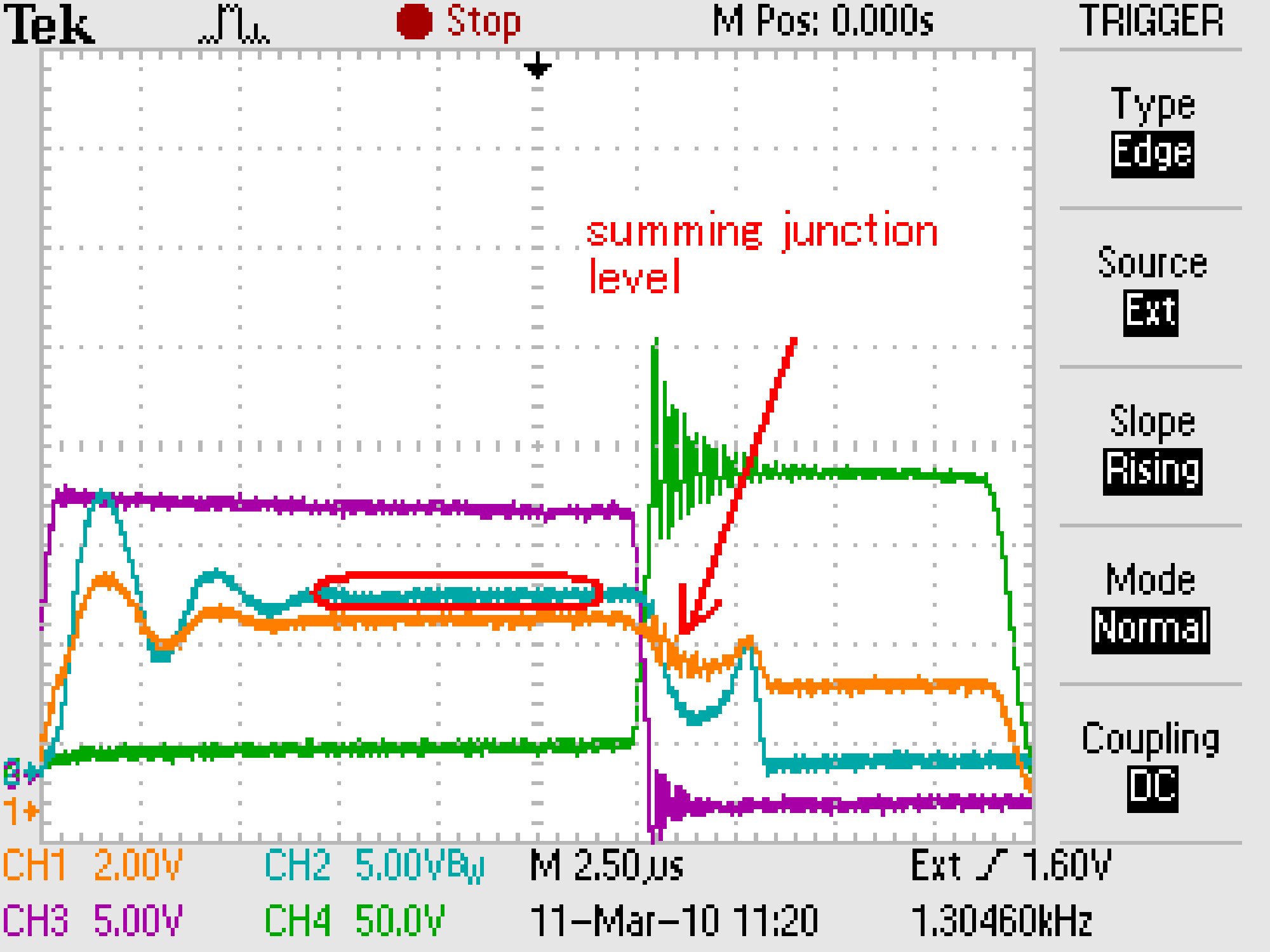
V

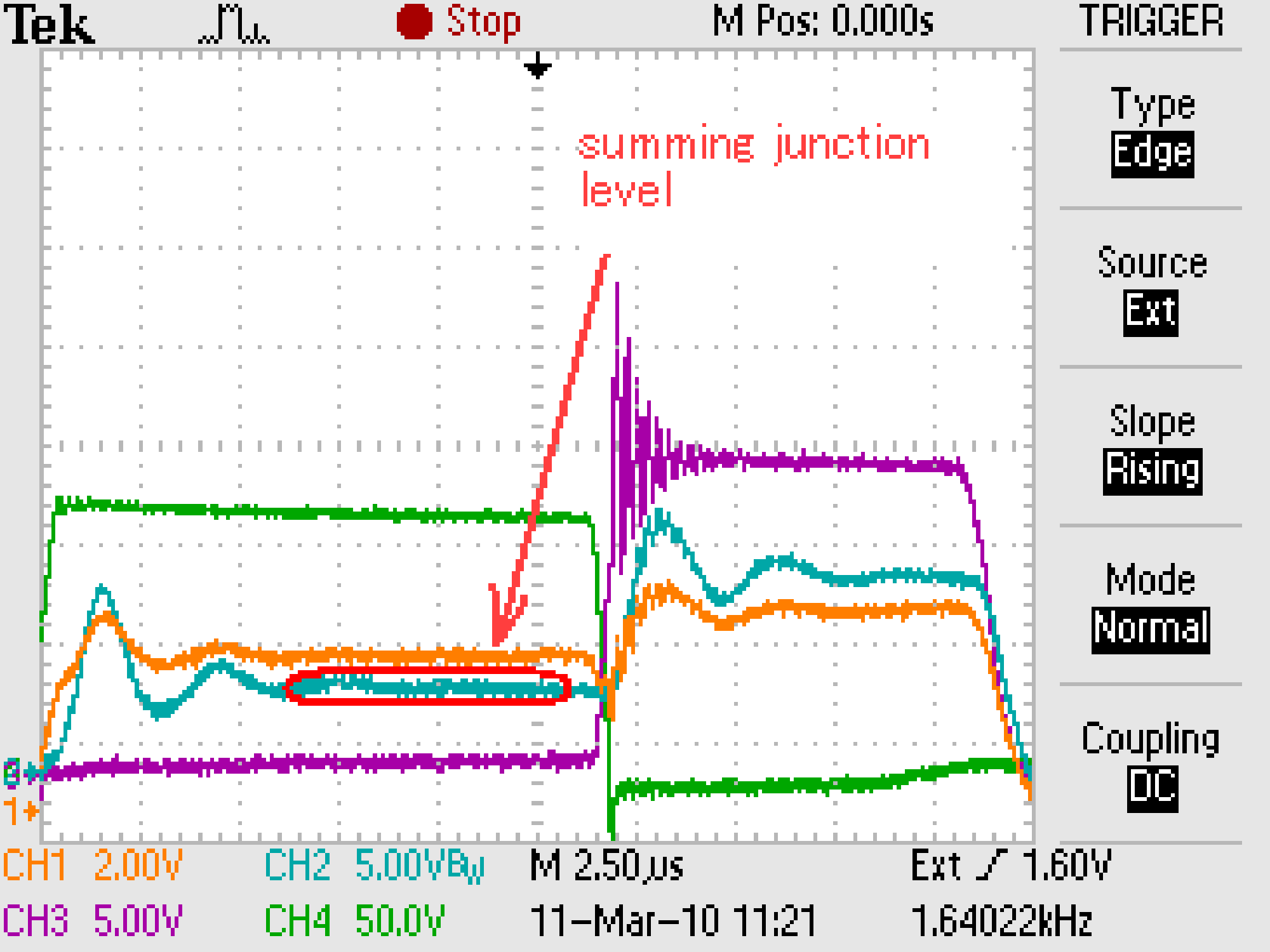
W

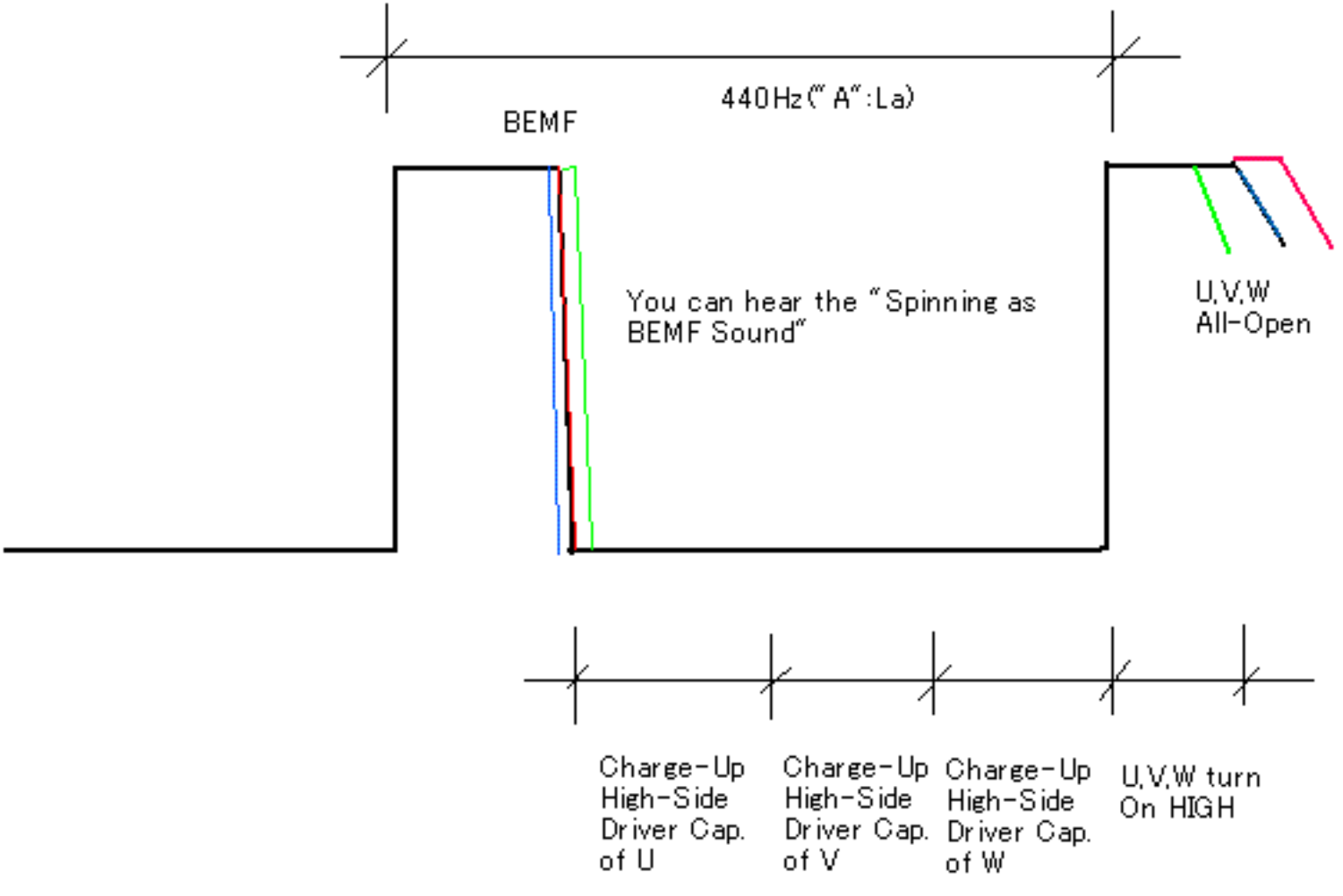

1
0.5
0
-0.5
-1
6 16 26 36 46 56 66 76 86 96 106 116 126 136 146 156 166 176 186 196 206 216 226 236 246 256 266 276 286 296 306 316 326 336 346 356 366
11 21 31 41 51 6 71 81 9 101 111 1 131 141 151 161 171 1 191 201 2 1 221 231 24 1 251 261 271 281 291 30 311 321 3 1 341 351 361

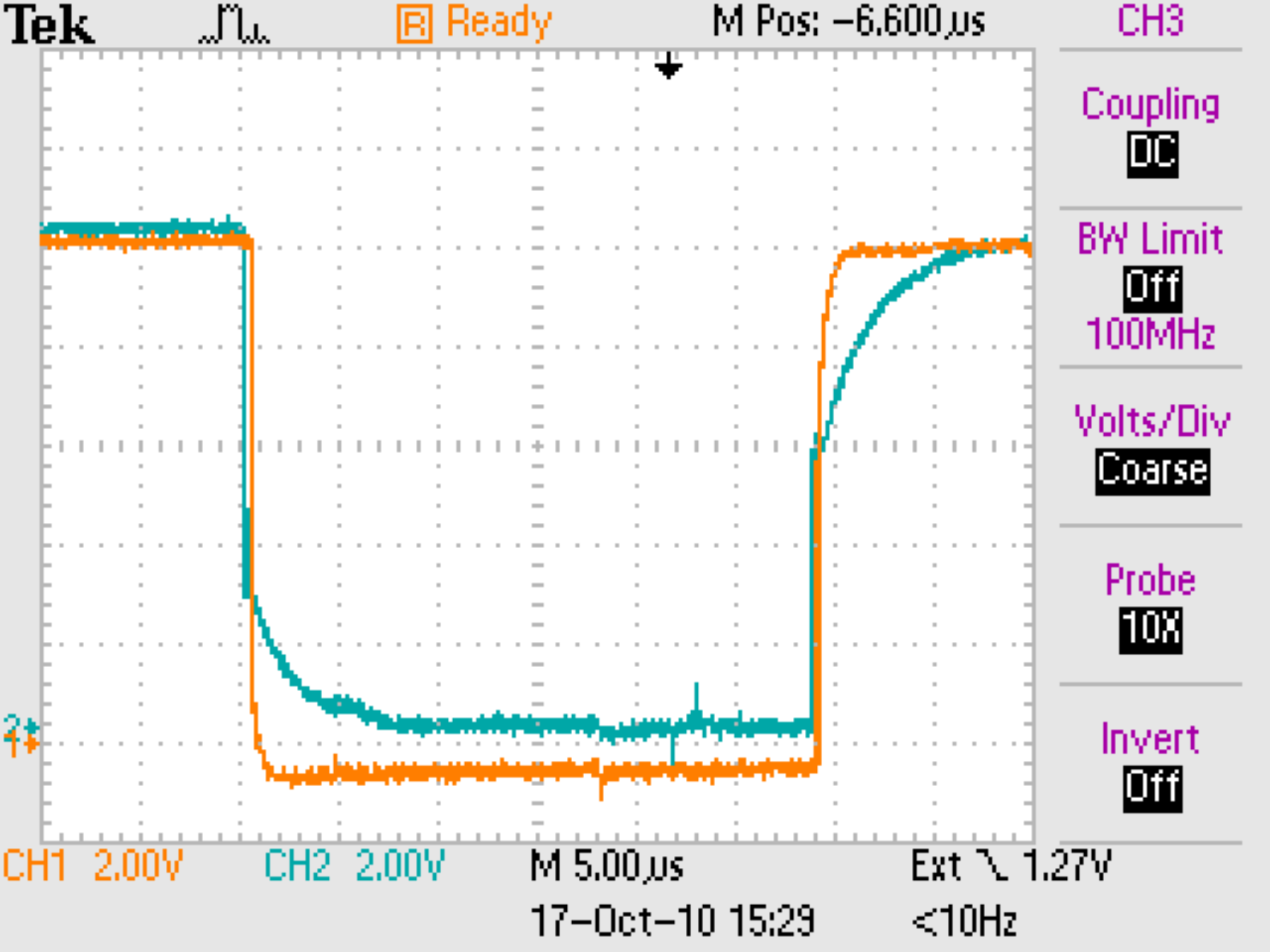

To Console
SV5-1
SV5-2
SV5-3
0V
SV7-1
+5V reg.
SV7-2
R55
4.7k,5%
R56
220,5%
C15
106/6.3V
C19
106/6.3V
SL5-1
SL5-2
SL5-3
SL5-4
R43
100,5%
R58
100,5%
R44
1k,5%
R57
1k,5%
C20
106/6.3V
Programming
C8051F505
P0.1/CNVSTR
VIO
VREGIN
VDD
VDDA
GND
GNDA
P0.0/VREF
P4.7
P4.6
C2D
RST-/C2CK
P0.2/XTAL1
P0.3/XTAL2
P0.4/TX
P0.5/RX
P0.6/CANTX
P0.7/CANRX
P1.0
P1.1
P1.2
P1.3
P1.4
P1.5
P1.6
P1.7
P2.0
P2.1
P2.2
P2.3
P2.4
P2.5
P2.6
P2.7
P3.0
P3.1
P3.2
P3.3
P3.4
P3.5
P3.6
P3.7
P4.0
P4.1
P4.2
P4.3
P4.4
P4.5
PAD1
PAD2
PAD3
PAD4

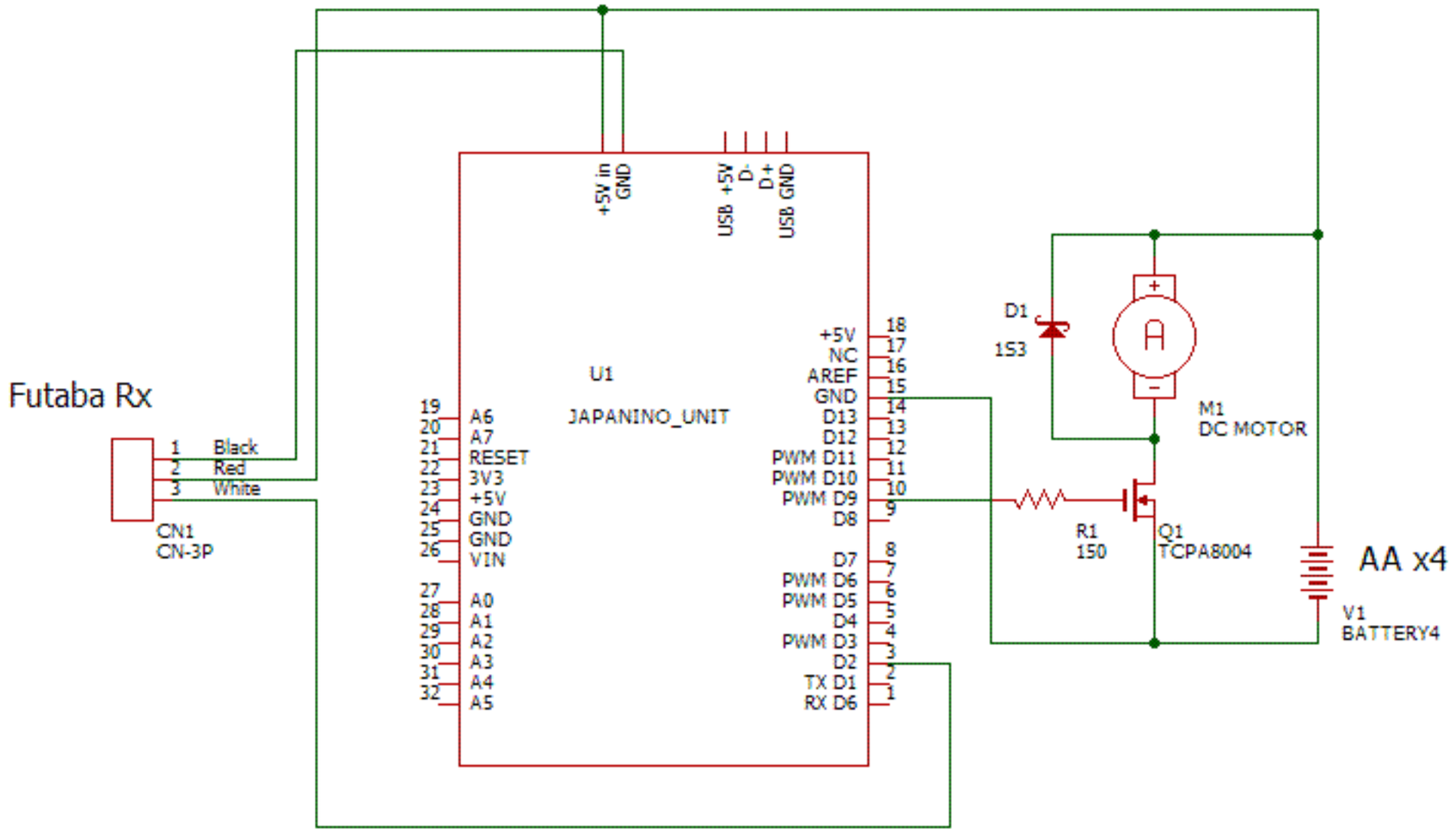

To Console
SV5-1
SV5-2
SV5-3
0V
SV7-1
+5V reg.
SV7-2
R55
4.7k,5%
R56
220,5%
C15
106/6.3V
C19
106/6.3V
SL5-1
SL5-2
SL5-3
SL5-4
R43
100,5%
R58
100,5%
R44
1k,5%
R57
1k,5%
C20
106/6.3V
Programming
C8051F505
P0.1/CNVSTR
VIO
VREGIN
VDD
VDDA
GND
GNDA
P0.0/VREF
P4.7
P4.6
C2D
RST-/C2CK
P0.2/XTAL1
P0.3/XTAL2
P0.4/TX
P0.5/RX
P0.6/CANTX
P0.7/CANRX
P1.0
P1.1
P1.2
P1.3
P1.4
P1.5
P1.6
P1.7
P2.0
P2.1
P2.2
P2.3
P2.4
P2.5
P2.6
P2.7
P3.0
P3.1
P3.2
P3.3
P3.4
P3.5
P3.6
P3.7
P4.0
P4.1
P4.2
P4.3
P4.4
P4.5
PAD1
PAD2
PAD3
PAD4


Tek
Stop
M Pos: 0.000s
TRIGGER
Type
Edge
Source
Ext
Slope
Rising
Mode
Normal
Coupling
DC
summing junction
level
CH1 2.00V
CH2 5.00VBW
M 2.50µs
Ext 1.60V
CH3 5.00V
CH4 50.0V
11-Mar-10 11:20
1.30460kHz


Tek
Stop
M Pos: 0.000s
TRIGGER
summing junction level
Type
Edge
Source
Ext
Slope
Rising
Mode
Normal
Coupling
DC
CH1 2.00V
CH2 5.00VBW
M 2.50µs
Ext ⨍ 1.60V
CH3 5.00V
CH4 50.0V
11-Mar-10 11:21
1.64022kHz

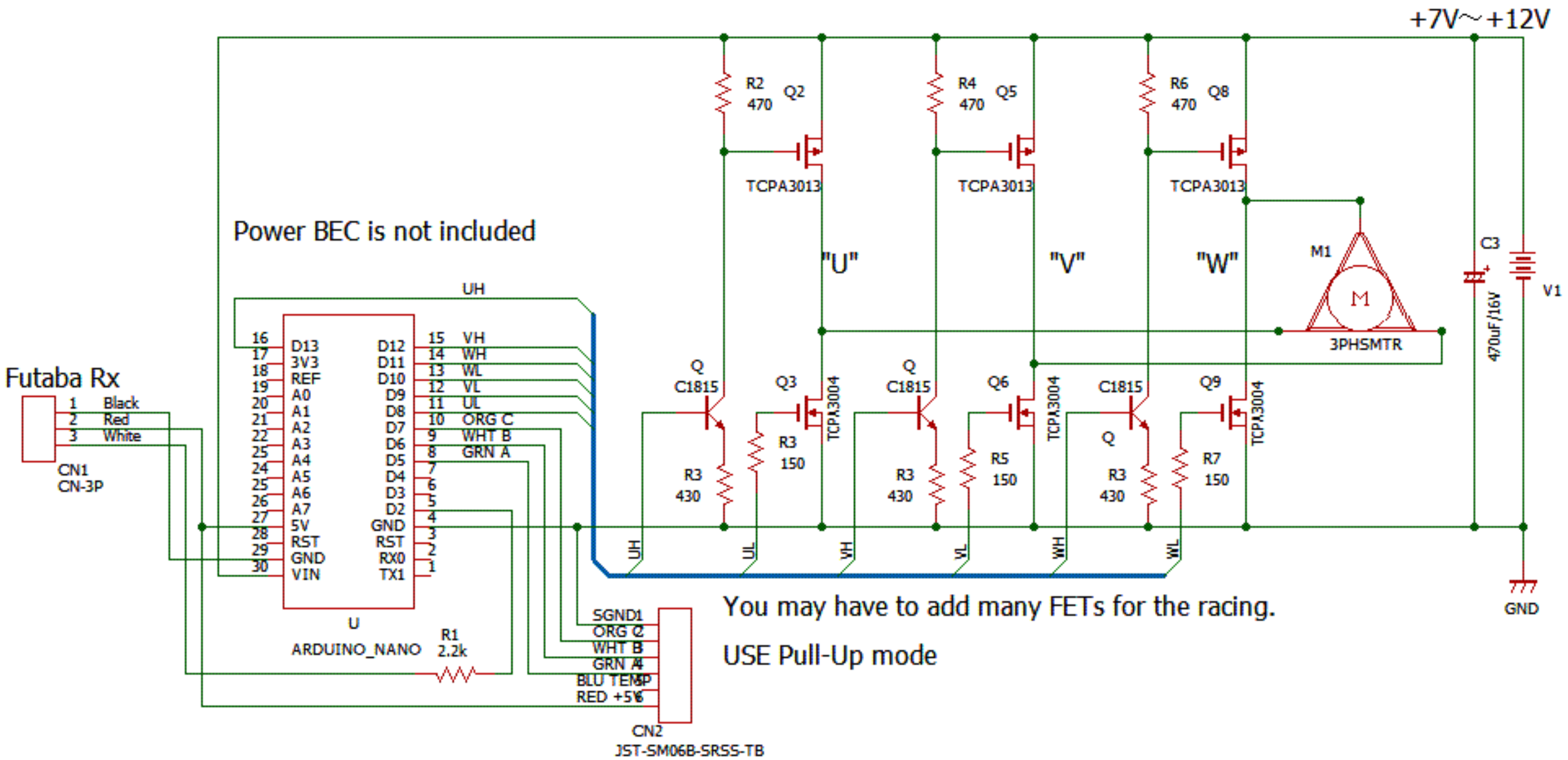

440Hz("A":La)
BEMF
You can hear the "Spinning as BEMF Sound"
U,V,W All-Open
Charge-Up High-Side Driver Cap. of U
Charge-Up High-Side Driver Cap. of V
Charge-Up High-Side Driver Cap. of W
U,V,W turn On HIGH


Tek
Ready
M Pos: -6.600µs
CH3
Coupling
DC
BW Limit
Off
100MHz
Volts/Div
Coarse
Probe
10X
Invert
Off
CH1 2.00V
CH2 2.00V
M 5.00µs
Ext ⌥ 1.27V
17-Oct-10 15:29
<10Hz



Designed	Date	Title	Page
大王怒	'10/10/31	Japanino Speed Controller	1/1

Ver.1.0



You may have to add many FETs for the racing.

USE Pull-Up mode

http://www.rcgroups.com/forums/attachment.php?attachmentid=1244043
But, the blue line is connected to +5V at Hobby king BL540ST.

Designed	Date	Title	Page
大王怒	'10/12/16	Auduino NANO Sensoerd BLDC	1/1

Ver.1.0