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1. Design specification
   1. Basic value

Battery voltage: 10~16.5V

Max Current: 10.9A

Highest PWM driving frequency: 10K

* 1. Design spec

System input voltage: 24V

Max Current: 20A

* 1. Limit

Battery max current limit: 18A per cell

Motor cut off current: 21A

Surge cut off time: 30ms

* 1. Motors:

Driving Motor: 770-8525F

<http://www.nichibo-motor.com/proType_e.php?proType=65>

Flipper motor: HD3SFN-6035

http://www.nichibo-motor.com/proType\_e.php?proType=53

1. Calculation
   1. Power Analysis
      1. 16V
      2. 5V

L\_Encoder: 5/1K\*2=10mA

R\_Encoder: 5/1K\*2=10mA

USB V\_Bus: 5/200K=0.025mA

Total: 10+10+0.025=20.025mA

* + 1. 3.3V

Microcontroller: <250mA

Others: 0.2mA

Mosfet Driver1: 4mA

Mosfet Driver2: 4mA

Mosfet Driver3: 4mA

Total:250+0.2+12=262.2mA

* + 1. Heat
       1. Power Diode
       2. Microcontroller
       3. Passive components circuit
       4. H-bridge

Current : 20A

Field discharge time:<5us

Power: (assume current change is linear)

U-voltage drop on the diode

I-max current flowing into the diode

T-field collapse time

f- driving PWM signal frequency

* 1. Mosfet

Max stall current of motors is 10.9A, so the mosfet should be able to support 20A at least. Drain-to-source voltage should be around 30V.

* 1. H-bridge cap
  2. Back emf sensing

Voltage divider:

Scale battery voltage to 3.3 logic level:

R12=10K(5%)

R11=39K(5%)

R12=10K(5%)

R11=43K(5%)

* 1. Big-Cap Charging circuit

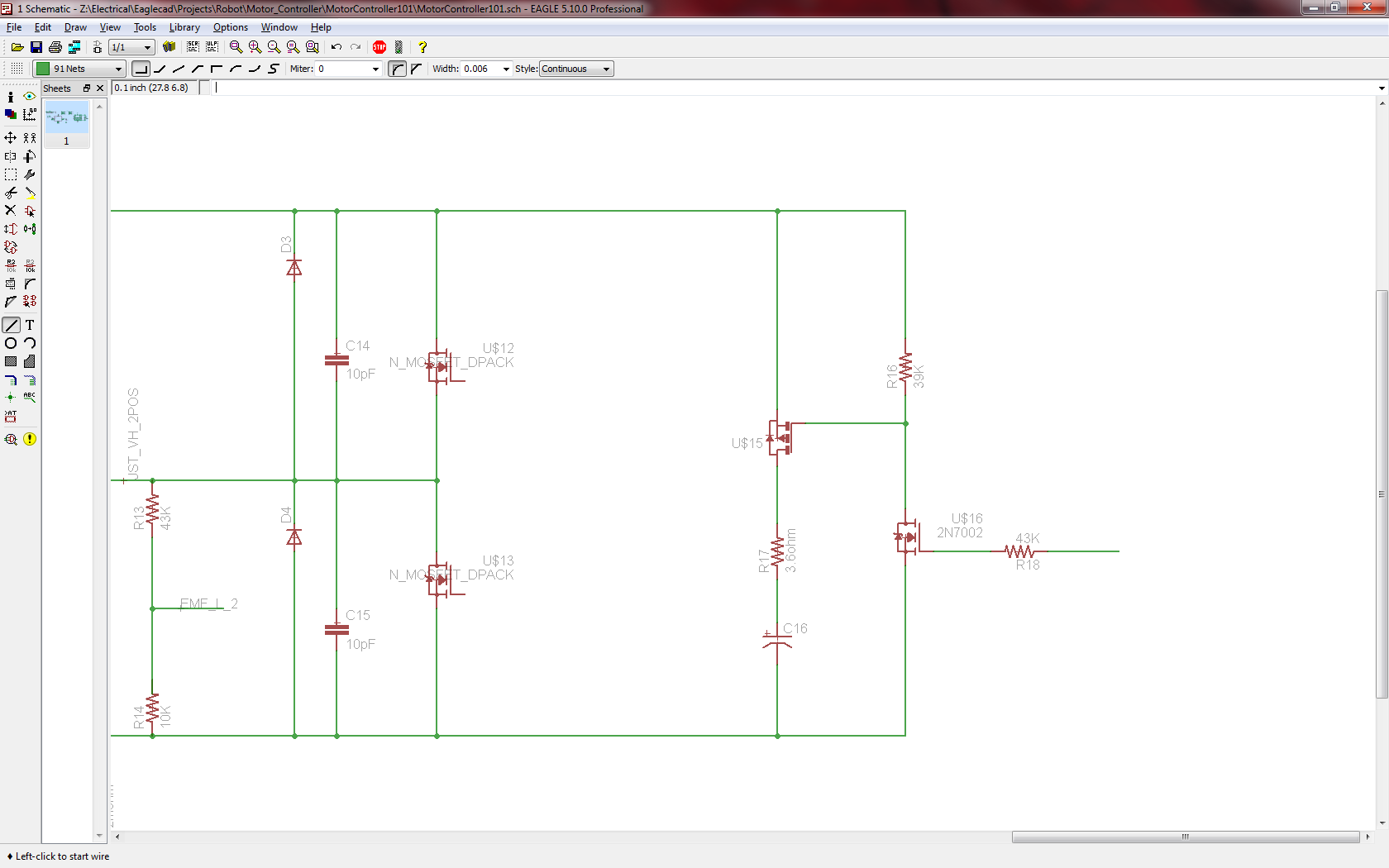
R=3.6 ohm

Choose C=10mF

Rising time:

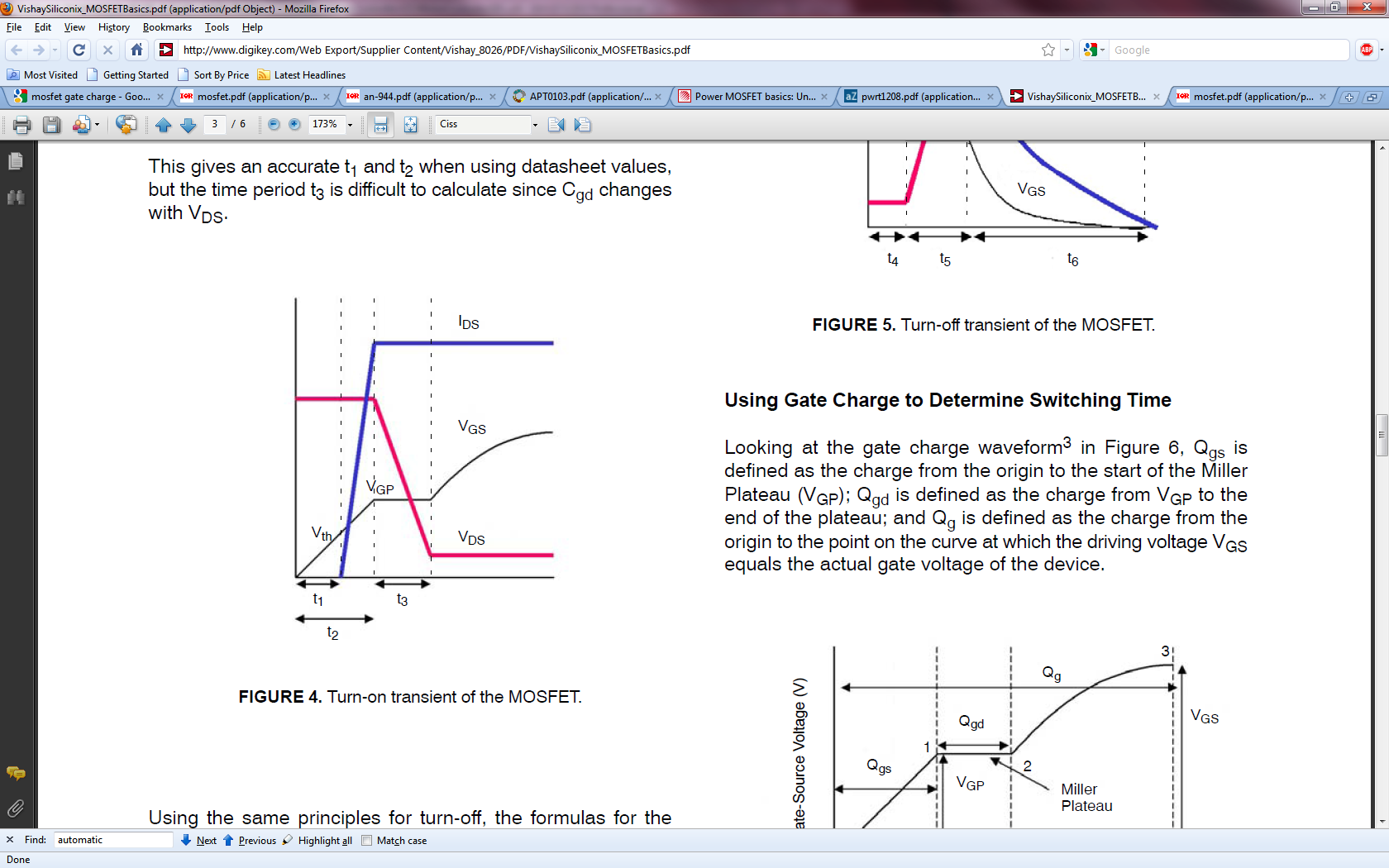
Fully charge time

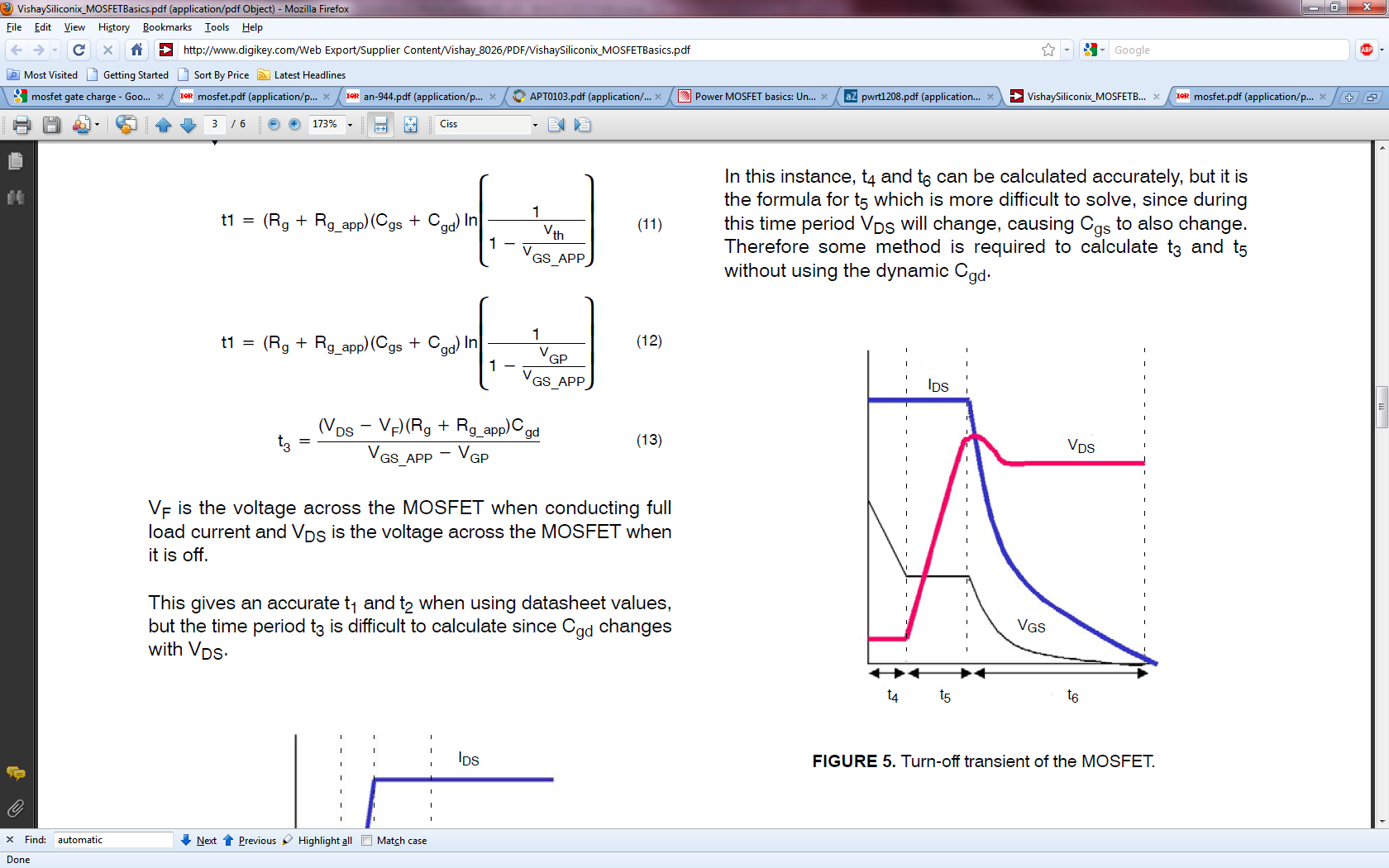
Try 1mF,10mF,100mF,1000mF,

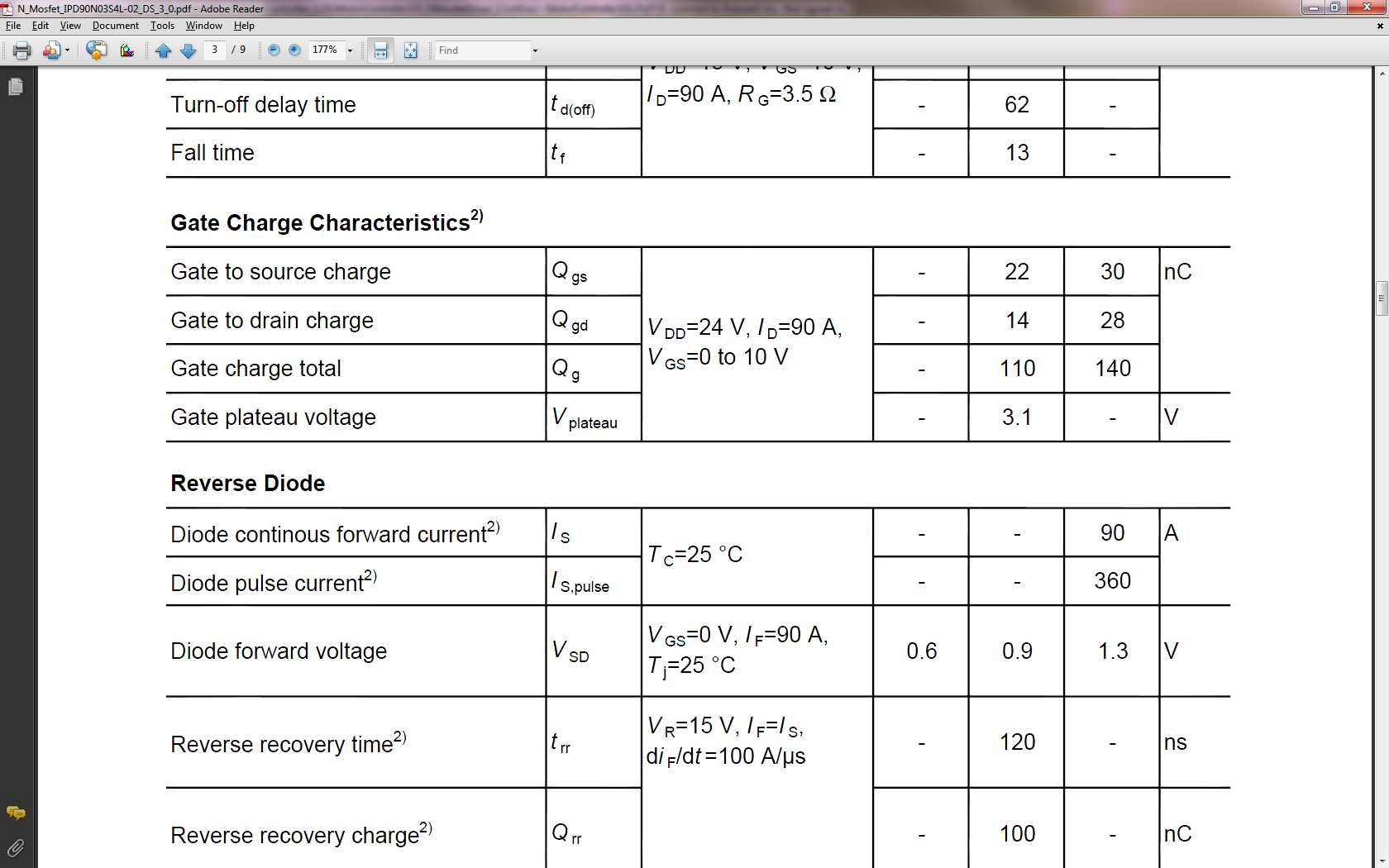


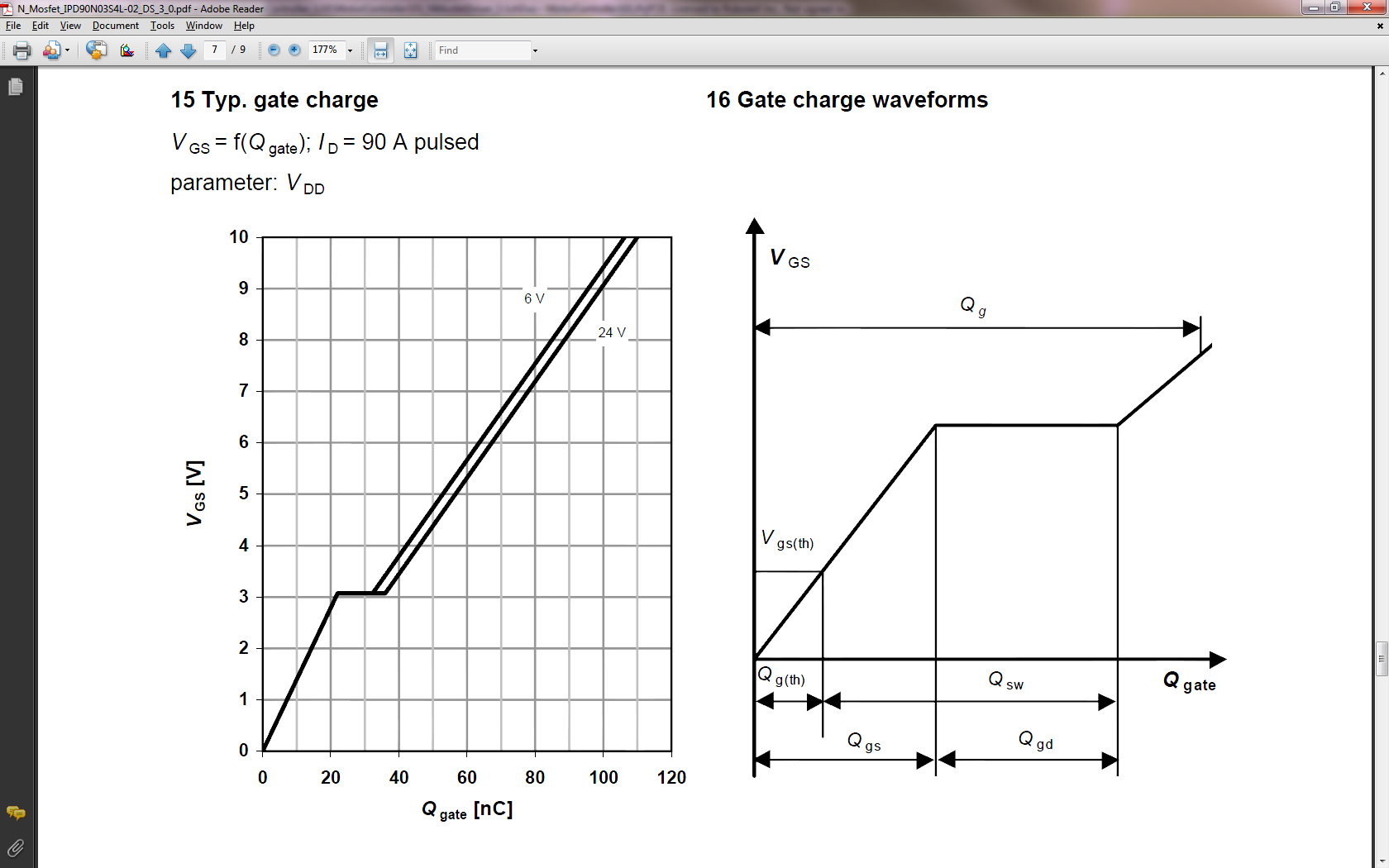
* 1. H-bridge driver circuit

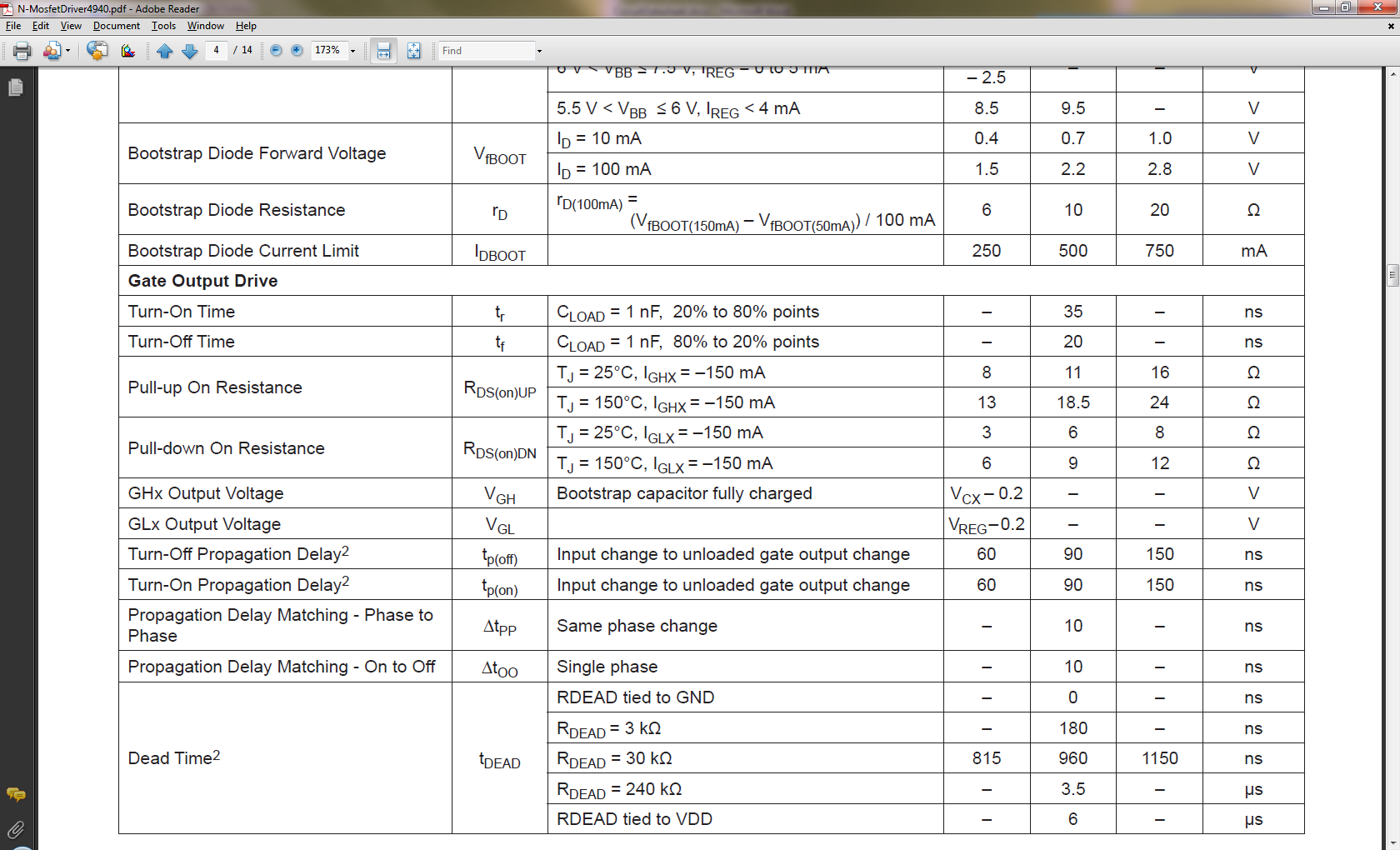












(20 is not enough according to experiment)

* 1. Zener Diode

Voltage drop: smaller than N-mosfet Vds 30V, bigger than the max battery voltage plus two catch diodes’ voltage drop: 16.5+0.5\*2=17.5V

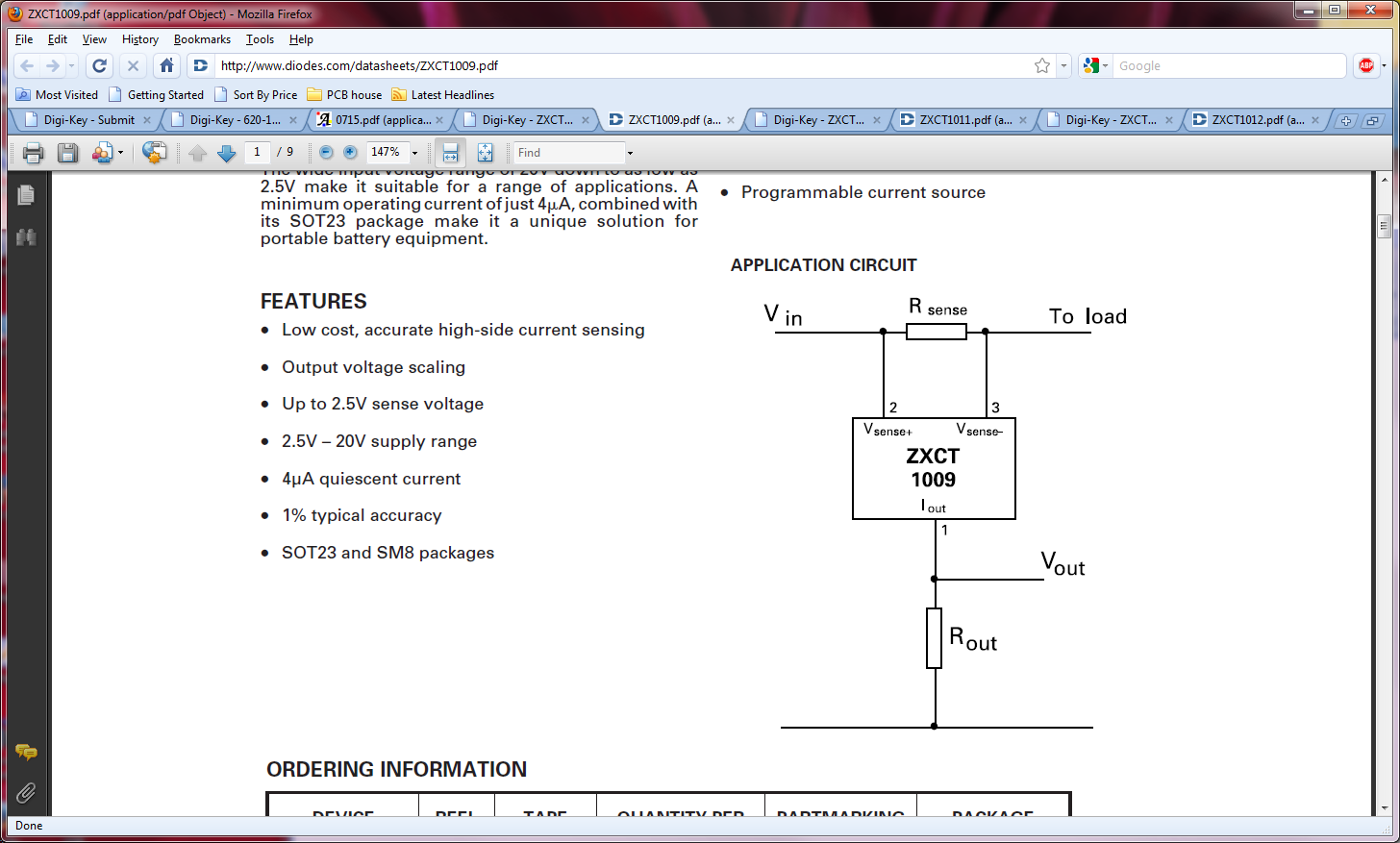
* 1. Pre charge circuit calculation

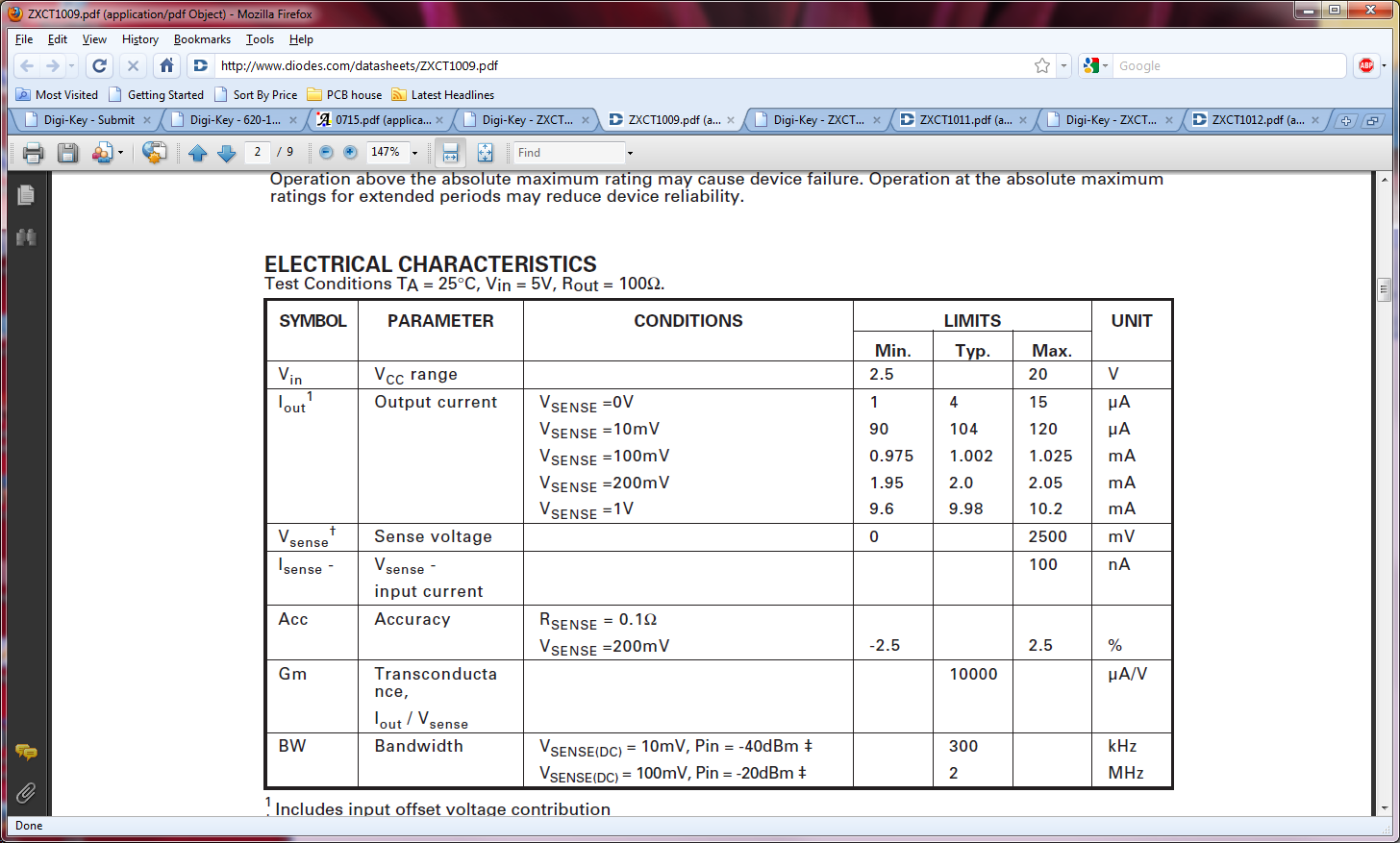


1. Components choice
   1. Current sensing

Accuracy, speed, range, repeatability, cost

* + 1. ZXCT1009





When I=20A, R\_sense=0.001 ohm, V\_sense=20mV, I\_out\_max=240uA,

R\_out=3.3/I\_out\_max=13750 ohm,

Choose R\_out=130K ohm

Testing result:

R=43K, 1.3V-2.38A

R=43K/(22/3.3/(2.38/1.3))=11.8K

* + 1. ZXCT1012

1. Data variables

Typedef struct {int16\_t data[3]; } MOTOR\_DATA\_3EL\_16BI;

Typedef struct {int16\_t data[2]; } MOTOR\_DATA\_2EL\_16BI;

Typedef struct {int32\_t data[3]; } MOTOR\_DATA\_3EL\_32BI;

Typedef struct {int32\_t data[2]; } MOTOR\_DATA\_3EL\_32BI;

Typedef struct {int8\_t data[3];} MOTOR\_DATA\_3EL\_8BI;

Typedef struct{float data[4][3]; } MOTOR\_DATA\_CTRL;

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| # | Variable Name | Comments | Read/Write | Type | Range/Element Range |
|  | REG\_MOTOR\_VELOCITY | 1. Motor 1 velocity 2. Motor 2 velocity 3. Motor 3 velocity | DEVICE\_WRITE | MOTOR\_DATA\_3EL\_16BI | -1023~+1023 |
|  | REG\_FAN\_VELOCITY | 1. Fan 1 velocity 2. Fan 2 velocity | DEVICE\_WRITE | MOTOR\_DATA\_2EL\_16BI | 0~1023 |
|  | REG\_MOTOR\_FB\_RPM | 1. Motor1 RPM 2. Motor2 RPM | DEVICE\_READ | MOTOR\_DATA\_2EL\_32BI |  |
|  | REG\_FLIPPER\_FB\_POSITION | 1. Pot 1 2. Pot 2 | DEVICE\_READ | MOTOR\_DATA\_2EL\_16BI | 0~1023 |
|  | REG\_MOTOR\_FB\_CURRENT | 1. Motor 1 current 2. Motor 2 current 3. Motor 3 current | DEVICE\_READ | MOTOR\_DATA\_3EL\_16BI | 0~1023 |
|  | REG\_MOTOR\_ENCODER\_COUNT | 1. Motor 1 Encoder Count 2. Motor 2 Encoder Count | DEVICE\_READ | MOTOR\_DATA\_2EL\_32BI |  |
|  | REG\_MOTOR\_KP | REG\_MOTOR\_KP[i][j]  i: control mode  j: 0-Motor1, 1-Motor 2, 2-Motor 3 | DEVICE\_WRITE | MOTOR\_DATA\_CTRL |  |
|  | REG\_MOTOR\_KI | REG\_MOTOR\_KI[i][j]  i: control mode  j: 0-Motor1, 1-Motor 2, 2-  Motor 3 | DEVICE\_WRITE | MOTOR\_DATA\_CTRL |  |
|  | REG\_MOTOR\_KD | REG\_MOTOR\_KD[i][j]  i: control mode  j: 0-Motor1, 1-Motor 2, 2-  Motor 3 | DEVICE\_WRITE | MOTOR\_DATA\_CTRL |  |
|  | REG\_MOTOR\_CTRL\_MODE | 1. Motor 1 ctrl mode 2. Motor 2 ctrl mode 3. Motor 3 ctrl mode | DEVICE\_WRITE | MOTOR\_DATA\_3EL\_16BI |  |
|  | REG\_MOTOR\_FAULT\_FLAG | 1. Motor 1 driver fault 2. Motor 2 driver fault | DEVICE\_READ | MOTOR\_DATA\_2EL\_8BI |  |
|  | REG\_MOTOR\_TEMP | 1. Thermistor 1 2. Thermistor 2 3. On board thermal chip | DEVICE\_READ | MOTOR\_DATA\_3EL\_16BI |  |
|  | REG\_PWR\_BAT\_VOLTAGE | 1. CELL\_A voltage 2. CELL\_B voltage | DEVICE\_READ | MOTOR\_DATA\_2EL\_16BI |  |
|  | REG\_PWR\_TOTAL\_CURRENT |  | DEVICE\_READ | Uint16\_t | 0~1023 |

1. Pin Configuration

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | Pin Name | Pin # | Description | Funtion | Input/Output | Digital/Analog | Comment |
| 1 | **RP20**/PMRD/CN14/RD5 | 53 | L\_Encoder\_A | IC | Input | Digital | IC1 |
| 2 | **RP25**/PMWR/CN13/RD4 | 52 | L\_Encoder\_B | IC | Input | Digital | IC2 |
| 3 | AN14/CTPLS/**RP14**/PMA1/CN32/RB14 | 29 | M1\_AHI | IO | Output | Digital |  |
| 4 | **RP16**/USBID/CN71/RF3 | 33 | M1\_ALO | PWM | Output | Digital | OC1 |
| 5 | RTCC/DMLN/**RP2**/CN53/RD8 | 42 | M1\_BHI | IO | Output | Digital |  |
| 6 | AN15/**RP29**/REFO/PMA0/CN12/RB15 | 30 | M1\_BLO | PWM | Output | Digital | OC2 |
| 7 | VCPCON/**RP24**/CN50/RD1 | 49 | M1\_Fault | IO | Input | Digital |  |
| 8 | TMS/CVREF/AN10/PMA13/CN28/RB10 | 23 | M1\_LeftBackEMF | A/D | Input | Analog |  |
| 9 | TDO/AN11/PMA12/CN29/RB11 | 24 | M1\_RightBackEMF | A/D | Input | Analog |  |
| 10 | TCK/AN12/PMA11/CTED2/CN30/RB12 | 27 | M1\_Current | A/D | Input | Analog |  |
| 11 | **RP22**/PMBE/CN52/RD3 | 51 | R\_Encoder\_A | IC | Input | Digital | IC3 |
| 12 | DPH/**RP23**/CN51/RD2 | 50 | R\_Encoder\_B | IC | Input | Digital | IC4 |
| 13 | C1IND/**RP21**/PMA5/CN8/RG6 | 4 | M2\_AHI | IO | Output | Digital |  |
| 14 | C1INC/**RP26**/PMA4/CN9/RG7 | 5 | M2\_ALO | PWM | Output | Digital | OC3 |
| 15 | C2IND/**RP19**/PMA3/CN10/RG8 | 6 | M2\_BHI | IO | Output | Digital |  |
| 16 | **RP27**/PMA2/C2INC/CN11/RG9 | 8 | M2\_BLO | PWM | Output | Digital | OC4 |
| 17 | PMD5/CN63/RE5 | 1 | M2\_Fault | IO | Input | Digital |  |
| 18 | PGEC3/AN5/C1INA/VBUSON/**RP18**/CN7/RB5 | 11 | M2\_LeftBackEMF | A/D | Input |  |  |
| 19 | PGED3/AN4**/**C1INB/USBOEN/**RP28**/CN6/RB4 | 12 | M2\_RightBackEMF | A/D | Input |  |  |
| 20 | AN3/C2INA/VPIO/CN5/RB3 | 13 | M2\_Current | A/D | Input |  |  |
| 21 | SOSCI/C3IND/CN1/RC13 | 47 | M3\_AHI | IO | Output | Digital |  |
| 22 | DMH/**RP11**/INT0/CN49/RD0 | 46 | M3\_ALO | PWM | Output | Digital | OC5 |
| 23 | SOSCO/T1CK/C3INC/**RPI37**/CN0/RC14 | 48 | M3\_BHI | IO | Output | Digital |  |
| 24 | **RP12**/PMCS1/CN56/RD11 | 45 | M3\_BLO | PWM | Output | Digital | OC6 |
| 25 | AN8/**RP8**/CN26/RB8 | 21 | M3\_Current | A/D | Input | Analog |  |
| 26 | AN9/**RP9**/PMA7/CN27/RB9 | 22 | M3\_POSFB\_1 | A/D | Input | Analog |  |
| 27 | TDI/AN13/PMA10/CTED1/CN31/RB13 | 28 | M3\_POSFB\_2 | A/D | Input | Analog |  |
| 28 | C3INA/CN16/RD7 | 55 | Fan1\_Fail | IO | Input | Digital |  |
| 29 | C3INB/CN15/RD6 | 54 | Fan2\_Fail | IO | Input | Digital |  |
| 30 | SCL3/PMD6/CN64/RE6 | 2 | FAN\_I2C\_SCL | I2C | Output | Digital |  |
| 31 | SDA3/PMD7/CN65/RE7 | 3 | FAN\_I2C\_SDA | I2C | Output | Digital |  |
| 32 | VCMPST2/CN69/RF1 | 59 | Cell\_A\_MOS | IO | Output | Digital |  |
| 33 | VBUSST/VCMPST1/CN68/RF0 | 58 | Cell\_B\_MOS | IO | Output | Digital |  |
| 34 | AN2/C2INB/VMIO**/RP13**/CN4/RB2 | 14 | Total\_Cell\_Current | AD | Input | Analog |  |
| 35 | PGEC1/AN1/VREF-/**RP1**/CN3/RB1 | 15 | V\_Cell\_A | AD | Input | Analog |  |
| 36 | PGED1/AN0/VREF+/**RP0**/PMA6/CN2/RB0 | 16 | V\_Cell\_B | AD | Input | Analog |  |
| 37 | SDA2/**RP10**/PMA9/CN17/RF4 | 31 | SMBUS\_A\_DA | I2C | Output | Digital |  |
| 38 | SCL2/**RP17**/PMA8/CN18/RF5 | 32 | SMBUS\_A\_CL | I2C | Output | Digital |  |
| 39 | DPLN/SDA1/**RP4**/CN54/RD9 | 43 | SMBUS\_B\_DA | I2C | Output | Digital |  |
| 40 | SCL1/**RP3**/PMCS2/CN55/RD10 | 44 | SMBUS\_B\_CL | I2C | Output | Digital |  |
|  |  |  | Servo2\_Input | IC | Input | Digital | IC6 |
|  |  |  | Servo1\_Input | IC | Input | Digital | IC5 |
|  |  |  | UART\_TX | TX | Output | Digital |  |
|  |  |  | UART\_RX | RX | Input | Digital |  |
|  |  |  | M3\_Fault | IO | Input | Digital |  |
|  |  |  |  |  |  |  |  |

Available Pins:

|  |  |  |  |
| --- | --- | --- | --- |
|  |  |  |  |
| 1 |  |  |  |
| 2 |  |  |  |

Reserved Pins:

|  |  |  |  |
| --- | --- | --- | --- |
|  |  |  |  |
| 1 | MCLR | 7 |  |
| 2 | VSS | 9 |  |
| 3 | VDD | 10 |  |
| 4 | PGEC2/AN6/**RP6**/CN24/RB6 | 17 |  |
| 5 | PGED2/AN7/**RP7**/RCV/CN25/RB7 | 18 |  |
| 6 | AVDD | 19 |  |
| 7 | AVSS | 20 |  |
| 8 | VSS | 25 |  |
| 9 | VDD | 26 |  |
| 10 | VBUS | 34 |  |
| 11 | VUSB | 35 |  |
| 12 | D-/RG3 | 36 |  |
| 13 | D+/RG2 | 37 |  |
| 14 | VDD | 38 |  |
| 15 | OSCI/CLKI/CN23/RC12 | 39 |  |
| 16 | OSCO/CLKO/CN22/RC15 | 40 |  |
| 17 | VSS | 41 |  |
| 18 | VCAP/VDDCORE | 56 |  |
| 19 | ENVREG | 57 |  |
| 20 | PMD0/CN58/RE0 | 60 |  |
| 21 | PMD1/CN59/RE1 | 61 |  |
| 22 | PMD2/CN60/RE2 | 62 |  |
| 23 | PMD3/CN61/RE3 | 63 |  |
| 24 | PMD4/CN62/RE4 | 64 |  |

Analog Register:

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| AN15 | AN14 | AN13 | AN12 | AN11 | AN10 | AN9 | AN8 | AN7 | AN6 | AN5 | AN4 | AN3 | AN2 | AN1 | AN0 |
| 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |

I/O pin mapping:

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| \_TRISB15 | \_TRISB14 | \_TRISB13 | \_TRISB12 | \_TRISB11 | \_TRISB10 | \_TRISB9 | \_TRISB8 | \_TRISB7 | \_TRISB6 | \_TRISB5 | \_TRISB4 | \_TRISB3 | \_TRISB2 | \_TRISB1 | \_TRISB0 |
| 0 | 0 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| \_TRISC15 | \_TRISC14 | \_TRISC13 | \_TRISC12 | \_TRISC11 | \_TRISC10 | \_TRISC9 | \_TRISC8 | \_TRISC7 | \_TRISC6 | \_TRISC5 | \_TRISC4 | \_TRISC3 | \_TRISC2 | \_TRISC1 | \_TRISC0 |
|  | 0 | 0 |  |  |  |  |  |  |  |  |  |  |  |  |  |

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| \_TRISD15 | \_TRISD14 | \_TRISD13 | \_TRISD12 | \_TRISD11 | \_TRISD10 | \_TRISD9 | \_TRISD8 | \_TRISD7 | \_TRISD6 | \_TRISD5 | \_TRISD4 | \_TRISD3 | \_TRISD2 | \_TRISD1 | \_TRISD0 |
|  |  |  |  | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| \_TRISE15 | \_TRISE14 | \_TRISE13 | \_TRISE12 | \_TRISE11 | \_TRISE10 | \_TRISE9 | \_TRISE8 | \_TRISE7 | \_TRISE6 | \_TRISE5 | \_TRISE4 | \_TRISE3 | \_TRISE2 | \_TRISE1 | \_TRISE0 |
|  |  |  |  |  |  |  |  | 0 | 0 | 1 |  |  |  |  |  |

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| \_TRISF15 | \_TRISF14 | \_TRISF13 | \_TRISF12 | \_TRISF11 | \_TRISF10 | \_TRISF9 | \_TRISF8 | \_TRISF7 | \_TRISF6 | \_TRISF5 | \_TRISF4 | \_TRISF3 | \_TRISF2 | \_TRISF1 | \_TRISF0 |
|  |  |  |  |  |  |  |  |  |  | 0 | 0 | 0 |  | 0 | 0 |

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| \_TRISG15 | \_TRISG14 | \_TRISG13 | \_TRISG12 | \_TRISG11 | \_TRISG10 | \_TRISG9 | \_TRISG8 | \_TRISG7 | \_TRISG6 | \_TRISG5 | \_TRISG4 | \_TRISG3 | \_TRISG2 | \_TRISG1 | \_TRISG0 |
|  |  |  |  |  |  | 0 | 0 | 0 | 0 |  |  |  |  |  |  |

1. Part list