Digital Comm

USB_B_Micro

VBUS — 1 — V_USB
D+ — 3 — USB_D+
D− — 2 — USB_D−
ID — 4
Shield
GND — 6
J105
GNDD

CAN

4 — CAN_H
3 — 2 — CAN_L
1
J101
GNDD

5V switching regulator, up to 50V input, maximum 600mA output current. The regulator is short circuit protected.
A P-Channel MOSFET is used as an ideal diode with a 18v zener diode to protect the MOSFET gate. The 10K resistor limits the zener diode current to 3mA at 48V input. A Schotty diode is used to protect the USB 5V line from reverse current.

+BATT   +5V

V_USB   D_USB   D102

Vin   Q101   C103   U102
Q_PMOS_GDS   33u   4 — SHDN
D101   3 — Vin
18V Zener   2 — GND
R102   1 — Vout
10K   D36V6F5
GNDD   GNDD   GNDD

3.3V linear voltage regulator for the low voltage electronics. The selected regulator can supply 1A of output current, which is more than what the 5V switching regulator can supply. The 4.7uF output capacitor should have a fairly low ESR.

+5V   U101   +3.3V
AP7361C−33
1 — Vin   Vout — 3
C101   C102   GND   C104   C105
4u7   100n   2   4u7   10u
GNDD

PWM_Ax, PWM_Bx, and PWM_Cx correspond to the A, B, and C phases of a three phase motor. The PWM_Dx lines are for a "extra" fourth phase. Note that the A, B, and C lines may be labeled U, V, and W elsewhere which are their european designation.

+5V

J111
Trinamic−Bridge

43 — GND   GND — 44
41 — DIO19   +5V — 42
39 — DIO17   DIO18 — 40   En_Out
37 — DIO15   DIO16 — 38
35 — DIO13   DIO14 — 36   Brake
33 — SPI1_SDO   DIO12 — 34   PWM_Idle_H
31 — SPI1_SCK   SPI1_SD — 32   SPI_MOSI
29 — SPI2_SDI   SPI1_CSN — 30
27 — SPI2_SCK   SPI2_SDO — 28   SPI_MISO
25 — SPI2_CSN1   SPI2_CSN2 — 26   PWM_DH
23 — CLK16   SPI2_CSN0 — 24   SPI_SS
21 — DIO10   DIO11 — 22   PWM_CH
19 — DIO8   DIO9 — 20   PWM_BH
17 — DIO6   DIO7 — 18   PWM_AH
15 — AIN1   AIN2 — 16   Batt_Current
13 — DIO5   AIN0 — 14   ADC_I_B
11 — DIO3   DIO4 — 12
9 — DIO1   DIO2 — 10
7 — D_CH1   DIO0 — 8
5 — +5V_USB   CS_CH0 — 6
3 — GND   IO_CLK — 4
1 — V_MOT   GND — 2

PWM_Idle_L
SPI_SCK
PWM_DL
PWM_CL
PWM_BL
PWM_AL
ADC_I_A
Vin
GNDD   GNDD

Analog IO   +5V

Throttle   50mA PTC   F101
4
3
2   Throttle
1
J102
GNDD

Motor Temp
2   MotorTemp
1
J103
GNDD

Transistor Temp
2   TransistorTemp
1
J104
GNDD

Encoders   +5V

ABN Encoder
5
4 — ENC_A_in
3 — ENC_B_in
2 — ENC_N_in
1
J109
GNDD

+5V   +3.3V
R101
10K

Hall Sensors
6 — MotorTemp
5
4 — HallA_in
3 — HallB_in
2 — HallC_in
1
J107
GNDD

Extra IO   50mA PTC
+5V   +3.3V
F102   F103
1 — 8
2 — 9 — A_Out1
A_in1 — 3 — 10 — A_Out1
A_in2 — 4 — 11 — A_Out2
D_in1 — 5 — 12 — D_Out1
D_in2 — 6 — 13 — D_Out2
D_in3 — 7 — 14 — D_in4
J106
GNDD

Power supply test points

+BATT   +5V   +3.3V
TP101   TP102   TP103
5v_TP   5v_TP   3v3_TP
1 — 2   1 — 2   1 — 2
GND_TP   GND_TP
TP104   TP105
GNDD   GNDD   GNDD   GNDD   GNDD

+3.3V +5V

IO Protection
5.0v
3.3v
USB_D+ — USB_D+_i
USB_D− — USB_D−_i
CAN_H — CAN_H
CAN_L — CAN_L
Throttle — Throttle_i
MotorTemp — MotorTemp_i
TransistorTemp — TransistorTemp_i
A_In1 — A_In1_i
A_In2 — A_In2_i
D_In1 — D_In1_i
D_In2 — D_In2_i
D_In3 — D_In3_i
D_In4 — D_In4_i
A_Out1 — A_Out1_i
A_Out2 — A_Out2_i
D_Out1 — D_Out1_i
D_Out2 — D_Out2_i
HallA_in — Phase_A_HAL_i
HallB_in — Phase_B_HAL_i
HallC_in — Phase_C_HAL_i
ENC_A_in — ENC_A_i
ENC_B_in — ENC_B_i
ENC_N_in — ENC_N_i
D_GND
IO.sch
GNDD

CAN_DBG   +3.3V
J108
1   2
3.3v
USB_D+   USB_D+
USB_D−   USB_D−
CAN_Rx   CAN_Rx
CAN_Tx   CAN_Tx
Throttle   Throttle
MotorTemp   MotorTemp
TransistorTemp   TransistorTemp
A_In1   A_In1
A_In2   A_In2
D_In1   D_In1
D_In2   D_In2
D_In3   D_In3
D_In4   D_In4
A_Out1   A_Out1
A_Out2   A_Out2
D_Out1   D_Out1
D_Out2   D_Out2
Phase_A_HAL   HallA
Phase_B_HAL   HallB
Phase_C_HAL   HallC
ENC_A   ENC_A
ENC_B   ENC_B
ENC_N   ENC_N

STM32
DGND
microcontroller.sch
GNDD

SPI_DBG
J110
1   2   3   4

TMC4671
TMC4671_EN — En_In
TMC4671_Status — Status
TMC4671_SS — SPI_CS
TMC4671_SCK — SPI_SCK
TMC4671_MISO — SPI_MISO
TMC4671_MOSI — SPI_MOSI
SPI_MOSI — SPI_MISO
SPI_MISO — SPI_MOSI
SPI_SCK — SPI_SCK
SPI_SS — SPI_SS
HallA — HALL_A
HallB — HALL_B
HallC — HALL_C
ENC_A — ENC_A
ENC_B — ENC_B
ENC_N — ENC_N
DGND
TMC4671.sch
GNDD

+BATT

VBatt
En_Out — En_Out
PWM_Idle_H — PWM_Idle_H
PWM_Idle_L — PWM_Idle_L
PWM_Phase_AHD — PWM_AH
PWM_Phase_ALD — PWM_AL
PWM_Phase_BHD — PWM_BH
PWM_Phase_BLD — PWM_BL
PWM_Phase_CHD — PWM_CH
PWM_Phase_CLD — PWM_CL
PWM_Phase_DHD — PWM_DH
PWM_Phase_DLD — PWM_DL
Brake_Chopper — Brake
Phase_A_Current — ADC_I_A
Phase_B_Current — ADC_I_B
Batt_Current — Batt_Current

Samuel Ellicott
Senior Design 2018−2019
Supermileage Motor Controller
Cedarville University
Sheet: /
File: motor−controller−hw.sch
Title: Motor Controller Control Board

Size: USLetter	Date: 2018−11−28	**Rev: 1.0**
KiCad E.D.A. kicad (5.0.0−rc2−dev−670−ga3770bf6e)		Id: 1/4

Input Buffers

Buffer input stage

Attenuator and Filter
Selected for 750Hz cutoff
1.5Khz Sampling rate

Buffer output stage

MCP6004 — U201C
Throttle_i
10 / 9 / 8

R201 2K
R206 3K9
C203 160n
GNDD GNDD

MCP6004 — U201D
12 / 13 / 14
Throttle

MCP6004 — U202A
Motor_Temp_i
3 / 2 / 1

R202 2K
C204 100n
GNDD

MCP6004 — U202B
5 / 6 / 7
Motor_Temp

MCP6004 — U202C
Transistor_Temp_i
10 / 9 / 8

R203 2K
C205 100n
GNDD

MCP6004 — U202D
12 / 13 / 14
Transistor_Temp

MCP6004 — U203A
A_in1_i
3 / 2 / 1

R204 2K
C206 100n
GNDD

MCP6004 — U203B
5 / 6 / 7
A_in1

MCP6004 — U203C
A_in2_i
10 / 9 / 8

R205 2K
C207 100n
GNDD

MCP6004 — U203D
12 / 13 / 14
A_in2

Output Buffers

MCP6004 — U201B
A_out1_i
7 / 5 / 6
A_out1

MCP6004 — U201A
A_out2_i
1 / 3 / 2
A_out2

Input Buffers

U204A 74HC7014
D_in1_i 1 / 2 D_in1

U204B 74HC7014
D_in2_i 3 / 4 D_in2

U204C 74HC7014
D_in3_i 5 / 6 D_in3

U204D 74HC7014
D_in4_i 9 / 8 D_in4

Output Buffers

U204E 74HC7014
D_out1_i 10 / 11 D_out1

U204F 74HC7014
D_out2_i 12 / 13 D_out2

CAN Transciever PHY

MCP2562 may be replaced with a
TJF1051T/3. Pin 5 on the TJF1051T/3
is a silent mode enable pin which is
active high, so the circuit still works.

U206 mcp2562
+5V / +3.3V
Vdd 3 / VIO 5
CAN_H — CANH 7
CAN_L — CANL 6
TXD 1 — CAN_Tx
RXD 4 — CAN_Rx
STBY 8
Vss 2

JP201 R216 120R
CAN Termination

R220 10K
GNDD GNDD

Hall Input Filtering

Schmitt trigger inputs for taking out noise

+5V
R210 4K7
Phase_A_HALL_i
R207 100R
C215 100p
GNDD
U205A 74HC7014
1 / 2 Phase_A_HALL

+5V
R211 4K7
Phase_B_HALL_i
R208 100R
C216 100p
GNDD
U205B 74HC7014
3 / 4 Phase_B_HALL

+5V
R212 4K7
Phase_C_HALL_i
R209 100R
C217 100p
GNDD
U205C 74HC7014
5 / 6 Phase_C_HALL

ABN Encoder Input Filtering

Schmitt trigger inputs for taking out noise

+5V
R217 4K7
ENC_A_i
R213 100R
C218 100p
GNDD
U205D 74HC7014
9 / 8 ENC_A

+5V
R218 4K7
ENC_B_i
R214 100R
C219 100p
GNDD
U205E 74HC7014
11 / 10 ENC_B

+5V
R219 4K7
ENC_N_i
R215 100R
C220 100p
GNDD
U205F 74HC7014
13 / 12 ENC_N

Power and Bypass Capacitors

+5V
+3.3V

Rail to rail op-amp necessary for the filter section to work correctly.
Throttle and output buffers run off 5v supply, all others on 3.3v to
prevent ADC damage.

U201E MCP6004 4 / 11 — C201 100n — C202 1u
U202E MCP6004 4 / 11
U203E MCP6004 4 / 11
U204G 74HC7014 14 / 7 VCC / GND
U205G 74HC7014 14 / 7 VCC / GND
C209 100n / C208 100n
C211 100n / C210 100n
C213 1u / C212 1u
C214 10u
GNDD GNDD

+5V +3.3V

5.0v / 3.3v

USB_D+_i — USB_D+
USB_D-_i — USB_D-
CAN_H — CAN_H
CAN_L — CAN_L
Throttle_i — Throttle_i

MotorTemp_i — Motor_Temp_i
TransistorTemp_i — Transistor_Temp_i
A_In1_i — A_in1_i
A_In2_i — A_in2_i
D_In1_i — D_in1_i
D_In2_i — D_in2_i
D_In3_i — D_in3_i
D_In4_i — D_in4_i
A_Out1_i — A_out1_i
A_Out2_i — A_out2_i
D_Out1_i — D_out1_i
D_Out2_i — D_out2_i
Phase_A_HAL_i — Phase_A_HAL_i
Phase_B_HAL_i — Phase_B_HAL_i
Phase_C_HAL_i — Phase_C_HALL_i
ENC_A_i — ENC_A_i
ENC_B_i — ENC_B_i
ENC_N_i — ENC_N_i
D_GND

GNDD

USB_D+ — USB_D+
USB_D- — USB_D-
CAN_Rx — CAN_Rx
CAN_Tx — CAN_Tx
Throttle — Throttle
Motor_Temp — MotorTemp
Transistor_Temp — TransistorTemp
A_in1 — A_In1
A_in2 — A_In2
D_in1 — D_In1
D_in2 — D_In2
D_in3 — D_In3
D_in4 — D_In4
A_out1 — A_Out1
A_out2 — A_Out2
D_out1 — D_Out1
D_out2 — D_Out2
Phase_A_HALL — Phase_A_HAL
Phase_B_HALL — Phase_B_HAL
Phase_C_HALL — Phase_C_HAL
ENC_A — ENC_A
ENC_B — ENC_B
ENC_N — ENC_N

This sheet contains input/output proteciton and conditioning circuitry.
Note that the stm32 USB lines pass through this sheet
without modification.

+3.3V

3.3v
USB_D+   USB_D+
USB_D−   USB_D−

CAN_Rx   CAN_Rx
CAN_Tx   CAN_Tx

Throttle   Throttle
MotorTemp   Motor_Temp
TransistorTemp Transistor_Temp

A_In1   A_In1
A_In2   A_In2
D_In1   D_In1
D_In2   D_In2
D_In3   D_In3
D_In4   D_In4

A_Out1   A_Out1
A_Out2   A_Out2
D_Out1   D_Out1
D_Out2   D_Out2

DGND

GNDD

+3.3V

Reset   7   NRST   PA0   14   Motor_Temp
                                     PA1   15   Transistor_Temp
Boot   60 BOOT0   PA2   16   USART_Tx
                                     PA3   17   USART_Rx
                                     PA4   20   A_Out1
                                     PA5   21   A_Out2
                                     PA6   22   Throttle
                                     PA7   23   A_In1
                                     PA8   41   D_Out1
                                     PA9   42   D_Out2
                                     PA10 43
OSC+   5   PF0   PA11 44   USB_D−
OSC−   6   PF1   PA12 45   USB_D+
                                     PA13 46   JTMS
                                     PA14 49   JTCK
         54 PD2   PA15 50   SPI_SS

         8   PC0   U301   PB0   26   CAN_Status
         9   PC1   STM32F303RETx   PB1   27   Heartbeat
         10 PC2   PB2   28   User_LED
         11 PC3   PB3   55   SWO
A_In2   24 PC4   PB4   56
         25 PC5   PB5   57
D_In1   37 PC6   PB6   58
D_In2   38 PC7   PB7   59
D_In3   39 PC8   PB8   61   CAN_Rx
D_In4   40 PC9   PB9   62   CAN_Tx
SPI_SCK 51 PC10   PB10 29   TMC_4671_En_In
SPI_MISO 52 PC11   PB11 30   TMC4671_Status
SPI_MOSI 53 PC12   PB12 33   TMC4671_SS
User_SW 2   PC13   PB13 34   TMC4671_SCK
         3   PC14   PB14 35   TMC4671_MISO
         4   PC15   PB15 36   TMC4671_MOSI

         18 VSS
         31 VSS
         47 VSS
         63 VSS
         12 VSSA

GNDD

TMC_4671_En_In   TMC4671_EN
TMC4671_Status   TMC4671_Status

TMC4671_MISO   TMC4671_MISO
TMC4671_MOSI   TMC4671_MOSI
TMC4671_SCK   TMC4671_SCK
TMC4671_SS   TMC4671_SS

SPI_MISO   SPI_MISO
SPI_MOSI   SPI_MOSI
SPI_SCK   SPI_SCK
SPI_SS   SPI_SS

User Inputs and Outputs

J302
USART_Tx   2
USART_Rx   3
1
User USART

GNDD
+3.3V

R303
4K7   User_SW
User_SW   SW303

C311
100n

R304
100R

GNDD

CAN_Status   510R   CAN_Status
CAN_Status   R305   D301

Heartbeat   510R   Heartbeat
Heartbeat   R306   D302

User_LED   510R   User_LED
User_LED   R307   D303

GNDD

Reset and Boot switches for programming the microcontroller with the USB
bootloader. SWD connector for in system debugging of the microcontroller.

+3.3V   +3.3V

Boot
SW302
Reset   Reset   Boot   1
Reset   JTCK 2
C303   R301   3
SW301   10K   JTMS 4   J301
100n   Reset 5   SWD
                           SWO   6
GNDD   GNDD   GNDD

Bypass Capacitors, one for each Vdd pin, and a 4.7uf cap for good measure.
Also two bypass capacitors (1uf and 10nf) for the ADC and DAC.

+3.3V   +3.3V

C301 C302 C304 C305 C306   C307 C308
100n 100n 100n 100n 4u7   1u   10n

GNDD   GNDD

Crystal Oscilator with 18pf load capacitor rating.
Assumed stray capacitance of 5pf.
See: https://www.allaboutcircuits.com/technical−articles/
choosing−the−right−oscillator−for−your−microcontroller/

C309
26pf   8Mhz
         Y301   OSC+

C310   R302
26pf   390R   OSC−

GNDD

Samuel Ellicott
Senior Design 2018−2019
Supermileage Motor Controller
Cedarville University

Sheet: /STM32/
File: microcontroller.sch

Title: STM32 Microcontroller

Size: USLetter   Date: 2018−11−17   Rev: 1.0
KiCad E.D.A. kicad (5.0.0−rc2−dev−670−ga3770bf6e)   Id: 3/4

En_In
Status

SPI_CS
SPI_SCK
SPI_MOSI
SPI_MISO

SPI_CS
SPI_SCK
SPI_MOSI
SPI_MISO

HALL_A
HALL_B
HALL_C

HALL_A
HALL_B
HALL_C

ENC_A
ENC_B
ENC_N

ENC_A
ENC_B
ENC_N

DGND

TMC4671 Clock Chip

+3.3V

+3.3V

IQXO-50
X401

C405
100n

GNDD

N/C OUT

V+
GND

CLK

GNDD

GNDD

Voltage references for the current measurement ADC's

+5V

+5V

B_Ref
TP401

A_Ref
TP402

R401
10K

R403
10K

A_Current_Ref
B_Current_Ref

C402
100n

R402
10K

C407
100n

R404
10K

GNDD

GNDD

TMC4671 Debug interfaces

+3.3V

J401
Trinamic_TRMI

RTMI_CS
RTMI_SCK
RTMI_MOSI
RTMI_MISO

RTMI_TRG

J402 USART

USART_Tx
USART_Rx

TMC4671 USART

GNDD

GNDD

Decoupling capacitors

+3.3V

1v8

+5V

C401 | C403 | C404 | C406 | C408 | C409 | C410 | C411
100n | 100n | 100n | 100n | 100n | 100n | 470n | 4u7

C412 | C413 | C414
100n | 100n | 100n

C415 | C416
100n | 4u7

GNDD

GNDD

GNDD

+3.3V

R405
10K

CLK

GNDD

+3.3V

VCCIO1 VCCIO2 VCCIO3 VCCIO4 VCCIO5 VCCIO6

1v8

VCCCORE1 VCCCORE2 VCCCORE3

+5V

5V_ref

2 13 43 52 61 72

15 45 63

23

RST 50
CLK 51
TEST 54
ENI 55
ENO 32
Status 12

En_In
En_Out
Status

TP403 56 DIR
TP404 57 STP
TP405 58 PWMI

TP406 67 REF_Left
TP407 68 REF_Home
TP408 69 REF_Right

SPI_CS 6 SPI_CS
SPI_SCK 7 SPI_SCK
SPI_MOSI 8 SPI_MOSI
SPI_MISO 9 SPI_MISO

USART_Rx 10 UART_RxD
USART_Tx 11 UART_TxD

RTMI_CS 75 GPIO3/AGPI_A_MCD/DBGSPI_CS
RTMI_SCK 76 GPIO4/AGPI_B_MCD/DBGSPI_SCK
RTMI_MOSI 1 GPIO5/AENC_UX_MCD/DBGSPI_MOSI
RTMI_MISO 4 GPIO6/AENC_VN_MCD/DBGSPI_MISO
RTMI_TRG 5 GPIO7/AENC_WY_MCD/DBGSPI_TRG

HALL_A 38 HALL_UX
HALL_B 37 HALL_V
HALL_C 36 HALL_WY
ENC_A 35 ENC_A
ENC_B 34 ENC_B
ENC_N 33 ENC_N
64 ENC_2A
65 ENC_2B
66 ENC_2N

TMC4671
U401

PWM_IDLE_H 59 PWM_Idle_H
PWM_IDLE_L 60 PWM_Idle_L

Brake 31 Brake
PWM_UX1_H 39 PWM_AH
PWM_UX1_L 40 PWM_AL
PWM_VX2_H 41 PWM_BH
PWM_VX2_L 42 PWM_BL
PWM_WY1_H 47 PWM_CH
PWM_WY1_L 48 PWM_CL
PWM_Y2_H 49 PWM_DH
PWM_Y2_L 49 PWM_DL

ADC_I0+ 16 A_Current
ADC_I0- 17 A_Current_Ref
ADC_I1+ 18 B_Current
ADC_I1- 19 B_Current_Ref
ADC_VM 20 Batt_V

AENC_UX+ 25 TP409
AENC_UX- 26 TP410
AENC_VN+ 27 TP411
AENC_VN- 28 TP412
AENC_WY+ 29 TP413
AENC_WY- 30 TP414

AGPI_A 21 Batt_I
AGPI_B 22 TP415
GPIO0/ADC_I0_MCD 70 TP416
GPIO1/ADC_I1_MCD 71 TP417
GPIO2/ADC_VM_MCD 74 TP418

GNDIO6 GNDIO5 GNDIO4 GNDIO3 GNDIO2 GNDIO1

73 62 53 44 14 3

GNDA 24

GNDPAD 0

GNDD

GNDD GNDD

En_Out

PWM_Idle_H
PWM_Idle_L

PWM_AH PWM_Phase_AH
PWM_AL PWM_Phase_AL
PWM_BH PWM_Phase_BH
PWM_BL PWM_Phase_BL
PWM_CH PWM_Phase_CH
PWM_CL PWM_Phase_CL
PWM_DH PWM_Phase_DH
PWM_DL PWM_Phase_DL
Brake Brake_Chopper

**Phase current low pass filters
RC constant set for 159KHz**

A_Current

TP419
A_LTP

100R
R406

Phase_A_Current

C417
10n

GNDD

B_Current

TP420
B_LTP

100R
R407

Phase_B_Current

C418
10n

GNDD

**Battery Voltage and Current
Current RC filter set for 159KHz
Voltage RC filter set for 1.59KHz**

Batt_I

TP422
Batt_I_TP

10K
R409

Batt_Current

C420
10n

GNDD

Batt_V

TP421
Batt_V_TP

110K
R410

VBatt

C419
10n

R408
10K

GNDD

Title: **TMC4671**

Size: USLetter | Date: 2018-11-28 | **Rev: 1.0**
KiCad E.D.A. kicad (5.0.0-rc2-dev-670-ga3770bf6e) | Id: 4/4