VFD Motor Control

Notes:

-Documentation example: what: why?, where?

-Conops: Research/Project planning; research done by 2nd week, project planning done by 9/15; template, past examples; problem motivation, needs statement, needs analysis; why we want to solve this problem, it needs to be done, why does it need to be done

-Block diagram: use to assign parts; Label box with hardware or software or online program

-Testing: environment and ethical factors; exceeds scope, does not include snow, ocean, etc. so it is guaranteed to be broken; safety standards, ieee standards, bluetooth, usb

-Budget: $100/1 person \* 4 people = $400 before April, <400 needs TA approval, >400 needs professor, does not reflect on grade

-MCU: probably need; check MCU presentation; order 25% more I/O pins than expected; No BGA; C/C++; use integrated debugger

-VFD motor controller: variable frequency drive aka changes the frequency and voltage of motor power supply aka changes the speed and torque/rpm of motor; allows for smooth start up/cool down; converts voltage twice; HV connects to microprocessor via optoelectronics b/c microprocessor hates high voltage

-AC/DC with diodes -> Cleans DC with capacitor -> DC/AC with transistors as switches

-<https://www.youtube.com/watch?v=g7jFGOn6xfU>

-Rectifier -> DC Bus -> Inverter

-<https://www.youtube.com/watch?v=UWsy-O-0XfM>

-Rectifier: diodes in parallel as 1 way bridge for current; diodes open/close in sequence

-DC bus: series of capacitors/resistors in parallel; cleans/smooths; capacitors store/release current

-Inverter: 6 insulated gate bipolar transistors (IGBTs) open/close in pairs; pulses of power or pulse width modulation; pulses in pos/neg at different intervals to go DC to AC; short pulses equal higher frequency

-rectifier bridge converter -> DC link -> inverter

-<https://en.wikipedia.org/wiki/Variable-frequency_drive>

-microprocessor governs operation: basic programming for display; uses variable and function parameters to provide control, protect and monitor the VFD, moto, and driven equipment

-rectifier bridge converter: circuit break/fuses, isolation contactor, emc filter, line reactor, passive filter

-DC link: braking chopper, braking resistor

-Inverter: output reactor, sine wave filter, dV/dt filter

Rectifier:

-transformer, if I need to step up or step down voltage; has math

-<http://www.vfds.org/variable-frequency-drive-rectifier-245010.html>

-rectifier diodes: has math

-<https://en.wikipedia.org/wiki/Rectifier>

-need diode voltage rating, need current rating, need voltage drop calculations, need to know switching speed

-choose between a controlled (Thyristor) or uncontrolled? Uncontrolled?

-<https://cr4.globalspec.com/thread/150888/Use-of-Thyristor-in-VFD#:~:text=Re%3A%20Use%20of%20Thyrister%20in%20VFD,-%231&text=To%20get%20variable%20frequency%20out,a%20Silicon%20Controlled%20Rectifier%20%2D%20SCR>.

-<https://www.youtube.com/watch?v=yEPe7RDtkgo>

-needs to handle 120 LN input, 208 LL input, 295 DC output

DC Link:

-VLL = 208 V

VLN = VLL / 31/2 = 208 / 31/2 = 120.089 V = 120 V

a. VDC = VLL \* 21/2 = 208 \* 21/2 = 294.156 V = 294 V

b. VDC = (VLLpeak \* 3) / pi = (VLL \* 21/2 \* 3) / pi = (208 \* 21/2 \* 3) / pi = 281 V

PLoad = 0.25 HP = 186.425 W

a. ILoad = 2 A

b. ILoad = Pmotor / (31/2 \* VLL \* PF) = 186.425 / (31/2 \* 208 \* 1) = 0.517 A

fpwm = 20 \* 103 Hz

t = T = 1 / fPWM = 1 / (20 \* 103) = 0.05 \* 10-3 s

Vripple = 2% \* VDC = 0.02 \* 294.156 V = 5.883 V

ILoad = C \* dVripple / dt => C = 2 \* 0.05 \* 10-3 / 5.883 = 16.998 µF = 17 µF

Iripple = 20% \* ILoad = 0.2 \* 2 = 0.4 A

VDC = L \* dIripple / dt => L = VDC \* t / Iripple = 294.156 \* 0.05 \* 10-3 / 0.4 = 36.770 mH = 37 mH

-simulation notes and schematic examples

-<https://hua-sing.com/enews/Inverter-DC-Link-Capacitor-Selection-125.html>

<https://up.codes/viewer/texas/nfpa-70-2023/chapter/4/equipment-for-general-use#460>

-capacitor ratings:

-current: 2 \* 135% = 2.7 A, NEC 2023 460.8(A)

-voltage: 295 \* 1.5 = 450 V

- Ripple Current range:

-inductor ratings:

-current:

-voltage:

-Power control:

-pins:

-pins 2, 4, 6: bootstrap capacitors connection from 1, 3, 5; 1uF, 25V

-pins 7, 8, 9, 10, 11, 12: from optoelectronics

-pins 13, 16: 13 needs 12 V, 16 into ground

PCB: get schematic capture; get netlist; place/route; check manufacturing rules; get CAM Files (Gerber & NC Drill)

-Schematic capture: block diagram; parts (digitkey (5 days) or mouser (1 day)); design schematic; check datasheet

-netlist: push schematic first

-place/route: check presentation for vendor; maybe don’t ruse auto-router; use 45\*, not 90\*

Soldering:

-flux, solderer next to pad, solder to solderer, melt onto pad, flux remover

-clean with soap, water, toothbrush

-hot dry

Introduciton Presentation:

-execution plan:

-pcb 8-10 days for board to arrive; extra time might be needed for parts or pcb order b/c of china holiday

-check if we lusher/zach has parts we need; ex: nanos

Final Presentation

-Title page: Final Project Presentation, Team 70: VFD Motor Control, names

-Likes demos: assembled boards, show graphs, firmware GUI handheld device, firmware pwm signals video

-make videos gifs so they work

-express what I have done, what I need to do before demo, what I will present at demo, what goals I have for 404

-validation plan: flesh out, no fails only pass or untested

-include subsystem block diagram or schematic

Validation/Debugging:

-Rectifier/power filter: not working, input 3 phase 5V, output 7.1V dc, need to use 3 waveform generators, one for each phase at 0\*, -120\*, 120\*

-15V/ISO\_15V Converter: not working, input 15V dc, output 15V dc, figure out how to test without breaking isolation, U1 not measuring 15V input, check solder at C7 pin 2 for full connection to pad, U1 not measuring ground at pin 1 or 3, check solder at C8 pin 1 for full connection to pad

-3.3V/ISO\_5V Converter: not working, input 3.3V dc, output 5V dc, figure out how to test without breaking isolation, check if pin layout is backwards, use breadboard for backup, U2 not measuring 3.3V input at pin 2, check solder at C21 pin 2 for full connection to pad, U2 not measuring ground at pin 1, check solder at C21 pin 1 for full connection to pad

-check power supply validation announcement

Demo:

-explain subsystem

-simulation: have ready

-schematic have ready to explain

-validation: have completed

-pcb fails is ok, explain why for partial credit

-Lusher or group of TAs grading demo

Project Update Presentation:

-validation plan: split into multiple slides for readability

-video: needs to be a gif

-subsystem progress:

-introduction project (8.78 hours = 9 hours):

-attempt 1, 10/1: 4:10am-4:48am (48min), 11:08am-2:58pm (230min)

-attempt 2, 10/14: 1:39am-2:15am (36min), 3:57am-7:30am (213min)

-order parts (1.70 hours = 1.5 hours):

-order 1, 10/3: 3:27am-4:13am (46min)

-order 2, 10/19: 10:48am-11:42am (56min)

-rectifier schematic (6.25 hours = 6.5 hours):

-rectifier part selection, 10/17: 2:30am-4:12am (102min)

-4 pin connector, 10/19: 9:15am-10:48am (93min)

-rectifier model, 4 pin connector, 10/20: 2:00pm-5:00pm (180min)

-dc link schematic (2.8 hours = 3 hours):

-calculations, 10/19: 11:42am-2:30pm (168min)

-power control schematic (2.83 hours = 3 hours):

-power control model, 10/4: 12:54pm-1:39pm (45min)

-6 pin connector, 10/15: 11:46am-1:21pm (95min)

-updates, 10/21: 5:40am-6:10am (30min)

-mcu power supply schematic (1.82 hours = 2 hours):

-mcu power supply, 10/21: 7:31am-8:31am (60min)

-mcu power supply, 10/21: 6:10am-6:59am (49min)

-project update presentation (3.13 hours = 3 hours):

-10/19: 2:30pm-3:23pm (57min)

-10/21: 5:00am-5:40am (40min), 6:59am-7:31am (32min), 8:31am-9:30am (59min)

-boards ordered by 10/28 deadline

Final presentation

-subsystem progress:

-schematic, 10/22-10/28 (12.57 hours = 12.5 hours):

-6 pin connector, 10/22: 1:22am-1:50am (28min)

-6 pin connector, 10/22: 11:10am-12:50pm (100min)

-3 pin connector, 10/22: 12:50pm-2:00pm (70min)

-10/26: 4:06pm-5:12pm (66min)

-10/27: 1:46am-5:35am (229min)

-bootstrap capacitors, 10/28: 3:28am-5:11am (102min)

-Lusher schematic & office hours, 10/28: 1:14pm-3:53pm (159min)

-pcb layout, 10/22-10/28 (1.65 hours = 1.5 hours):

-10/27: 5:35am-6:08am (33min)

-10/27: 4:24pm-5:30pm (66min)

-schematic, 10/29-11/4 (15.85hours = 16 hours):

-10/29: 11:10am-2:00pm (170min)

-11/1: 3:19pm-4:02pm, 5:18pm-6:45pm, 11:17pm-12:00am (173min)

-11/2: 12:00am-2:36min, 6pm-6:25pm, 8pm-9:03pm (244min)

-11/3: 4:30pm-6pm, 10:27pm-11:15pm (138min)

-11/4: 1:33am-4:10am, 6:09am-6:42am, 12:00pm-12:35pm (226min)

-pcb layout, 10/29-11/4 (6.43 hours = 6.5 hours):

-layout, 11/4: 6:42am-9:30am, 2:21pm-5:30pm, 8:47pm-9:16pm (386min)

-pcb layout, 11/5-11/11 (7.35 hours = 7.5 hours)

-routing/tracing, 11/5: 1:00am-3:06am, 11:15am-3:25pm (376min)

-pcb order, 11/5: 3:25pm-4:30pm (65min)

-order parts, 11/5-11/11 (6.25 hours = 6.5 hours)

-order 2, 11/8: 3:07am-3:59am, 5:42am-7:15am (145min)

-order 2, 11/11: 3:00pm-5:30pm; 7:00pm-8:20pm (230min)

-soldering, 11/12-11/18 (10.05 hours = 8.5 hours)

-practice, 11/12: 12:29pm-2:15pm (106min)

-11/14: 5:30pm-9:00pm (210min)

-11/17: 4:09pm-5:30pm, 6:05pm-7:19pm, 8:18pm-9:00pm(197min)

-11/18: (90min)

-order parts, 11/12-11/18 (4.67 hours = 4.5 hours)

-order 2, 11/12: 4:19am-6:56am, 11:15am-12:29pm (231min)

-order 2, 11/13: 4:20pm-5:09pm (49min)

-validation/debugging, 11/12-11/18 (1.58 hours = 1.5 hours)

-rectifier, power filter, 11/17: 5:30pm-6:05pm (35min)

-15V/ISO\_15V Converter, 3.3V/ISO\_5V Converter, 11/17: 7:18pm-8:18pm (60min)

-final presentation, 11/12-11/18 (2.2 hours = 2 hours)

-11/18: 5:38am-7:50am (132min)

-soldering, 11/19-11/25 (7.13 hours = 7 hours)

-11/19: 3:10pm-7:08pm (238min)

-11/20: 3:31-5:11pm (100min)

-11/21: 8:50am-10:20am (90min)

-validation/debugging, 11/19-11/25 (18.8 hours = 19 hours)

-11/21: 10:20am-11:00am, 1:45pm-3:45pm, 7:09pm-9:10pm (281min)

-11/22: 9:11am-12:45pm (214min)

-11/24: 6:54pm-9:00pm (126min)

-11/25: 9:53am-6:20pm (507min)

- validation/debugging, 11/26-12/2 ()

-11/26: 2:55am-4:22am, 5:39am-6:22am, 8:40am-

Technical Merit upgrades:

-series inductors

-transformer

-dc link: snubber circuit (resistor/capacitor in series, bleeder resistor (resistor/capacitor in parallel), pre-charge resistor

-relay

-capacitors in parallel

Wire Chart:

-Black: in phase a, out phase a

-Red: in phase b, out phase b

-Blue: in phase c, out phase c

-Yellow: in 15v, out iso15v, pwm1, pwm5, vin1

-Green: in 3.3v, out iso5v, pwm2, pwm6, vin2

-Yellow/black: pwm3, pwm7, vin3

-Green/black: pwm4

-White: in phase pgnd, out iso15/5 pgnd, out phase pgnd, pwm pgnd, vin pgnd

-White/black: in 15/3.3 gnd

Questions:

-How do I connect the rectifier to 3-phase power? Do I need to add some sort of input to the schematic and pcb layouts? Do I need to order a component (wire) to connect the outlet to the pcb?

Math Questions:

What is the min VDC? Get from mcu datasheet

How do I calculate the VDC?

IDC = Pload / VDC = ? /

Diode (current) = 1.5-2 time the IDC (how do i know it is 1.5-2 times, neee?, NEC?)

Pd = Vf \* If = 0.7V \* IDC

120/208

VLN = 120 V

VLL = 208 V

Vpeak = VLN \* 21/2 = 120 \* 21/2 = 169.706 V

Vdiode >= 2 \* Vpeak = 3 \* 169.706 = 509.118 = 600 V (what is the clearance, 2-3 times Vpeak, where?, IEEE? NEC?)

Idiode > Iload = 2 A (what is the clearance, where?, Idiode is given?, IEEE? NEC?)

Pload = 0.25 HP = 186.425 W

Iload = Pload / Vload = 186.425 / Vload =

Vload = (need motor data sheet, ask lusher)

What is the continuous current rating? Need max current

How do I get max current? Need motor data sheet

ILoad = 2 A

f = 60 Hz  
VDC = (3 \* 31/2 / pi) \* Vpeak = (3 \* 31/2 / pi) \* 169.706 = 280.691 V (wrong equation, need to fix, )  
Vripple = 2% \* VDC = 0.02 \* 280.691 = 5.613 V

fripple = 2 \* f = 2 \* 60 = 120 Hz

C = ILoad / (fripple \* Vripple) = 2 / (120 \* 5.613) = 0.00296929 F = 2969 µF

VDC = 280.691 V

fripple = 120 Hz

Iripple = 30% \* ILoad = 0.3 \* 2 = 0.6 A

L = VDC / (fripple \* Iripple) = 280.691 / (120 \* 0.6) = 3.899 H

2N7002-TP: find part, mosfet

solder pcb

debug pcb

size wires

need to simulate circuit: make sure ripple is in range

upload all documents to github

update block diagram

update schematic and pcb with new 47 pF Cap

update schematic and pcb with new 47 uF Cap

update pcb with correct fuse clip distance

update 3.3/iso5 pin 3 gnd

update daily check in

25V, 60V Wonhyeok Jang

lusher office hours: M 1-4pm

recitifer: 5 VAC to 6.1 VDC

dc link: 6.1 VDC to 6.1 VDC filtered on oscilloscope

power control: pwm signals and 6.1 VDC to waveform of adjusting voltage

15v to iso15v: 15v to 15v

3.3 to iso5v: 3.3v to 5v

15V/iso15V: full validation

3.3V/iso15V: test on bread board

power control Vin1 discrepancy

rectifier + dc link: get larger than 10V