07/17/2024

\*This day’s notes are going to be all my collective progression so far to this day. I roughly started around 07/08/2024. But as the true engineer that I am, I kept mental notes and did not document my thoughts until this day\*

* Display Driver
  + MAX7219
  + Cheaper
  + If I run into problems, I feel like it would be better to learn about the debugging issues associated with MAX7219 (but would have already been solved with MAX7221)
  + Uses common cathode displays, which theoretically are more power saving. In my eyes, there is a static power consumption when constantly running a source. There is also leakage current through diodes since semiconductors are not ideal.
* Microcontroller
  + STM32L452RE
  + Low power: wanted to power with a battery and hopefully last a long time so I can flex to my non-engineering friends that I can make something
  + Low pin count: this MCU has one of the lower PIN counts of the STM32 series
  + No high-speed requirement: application only requires a low clock speed for display driver
  + Memory requirements: This MCU has 512KB of flash memory which I think would be a good starting point for my potentially bad MCU programming. Gotta start somewhere
* External Battery
  + Initially wanted a coin cell battery
    - Wanted the small form factor, but the typical maximum current rating is around 5mA constant current, which I would need much more already just from display
    - These batteries typically produce 3V, which means I need to up-convert which also means less current after the conversion. Cannot go this route
  + The answer: 9V battery.
    - Although it has a bigger form factor, which is not the biggest priority in this project, it would have the current requirements I would need for the project
* Power Supplies
  + With a 9V battery, I would need to down-convert for both the MCU and the display driver.
  + LMR51610YFDBVR
    - Using a regulator over a controller since I don’t need huge current requirements
    - There were effectively 3 parameters to choose for this product line: switching frequency, max current output, and modulation operation
    - 400kHz vs 1MHz
      * 1MHz so I can choose smaller external component values and reduced output ripple
    - 600mA vs 1A
      * I chose 1A:
        + MAX7219 has a maximum sink current of 500mA
        + Maximum Vdd current is 100mA
        + Choosing 600mA, I might be clamping myself at maximum ratings. Although it is unlikely that I would be using maximum ratings, I will play it safe.
      * I planned on ordering a few of these and making a bunch of down converter boards for future projects
    - PFM vs PWFM
      * PWFM: generally, the MCU would need a constant and clean power source.
      * In an ideal world, I would use PWFM for the MCU and PFM for the display driver to save every bit of power for my device, but given that this is more about learning about MCU programming than it is about squeezing for battery life, I just ordered 10 devices and didn’t look back
  + I need at least 2 power supplies. One for a 3.3V supply and one for a 5V supply. Powering the MCU and the display driver respectively.

07/18/2024

Note: Working on wiring the display driver with the 8 7-segment displays.

* The SPDT switches I got from Digikey don’t fit the basic breadboard wires, so I used some SPST switches I had from before. Same concept, I just have to hold the button to produce a 1
* I wanted to also emphasize on saving energy even through static power losses, so I wanted to configure the pins in the MCU to be pull-down
  + The internal pull-down resistors are weak at nominally 40kOhm
  + In good practice, I will be using my own pull-down resistors at 10kOhm
* Looks like there is an output clock pin on the STM32 on the output pin labelled MCO. Going to attempt to get 10 MHz out for MAX7219
* Testing displays
  + Displays have a max current of 25mA, so I tested the brightness at 20mA. The typical forward voltage drop is 2V.
    - (5V-2V/R)=20mA 🡪 R=150Ohm
      * This felt like I was scorching my eyeballs
    - (5V-2V/R)=10mA 🡪 R=300Ohm
      * This felt better for my eyeballs
      * Plus the MAX2719 has a table and the lowest their default values go is 10mA
  + According to the table as mentioned above I would need 63.7kOhm for a forward voltage drop of 2V and a desired current of 10mAA table with numbers and symbols

    Description automatically generated
  + I don’t have 63.7kOhm as a default resistor value, so I had to use with what I was working with. I was able to create 63.76kOhm, which is good enough to test out the entire circuit  
    A graph of a graph

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07/19/2024

* Setting output voltage of LMR51610YFDBVR with feedback voltage divider network
  + Goal is to set output voltages for both 5V for MAX7219 and 3.3V for digital logic
    - Equation to set output voltage is RFBT=((Vout-Vref)/Vref)\*RFBB
      * Vref=0.8V
    - Datasheet recommends a maximum voltage input at FB to be 5.5V. This means that the voltage drop across RFBB is at most 5.5V
  + Second goal is to set common resistor values for easy component purchasing
    - Recommended value of RFBT is between 10kOhm to 100kOhm.
    - After some trial and error, I was able to come up with RFBT=66.5kOhm and RFBB=12.7kOhm

07/25/2024

* Back from vacation. Went through the datasheet for LMR51610YFDBVR more and realized there is a table that has typical values for the voltages I am looking for. A table with numbers and symbols

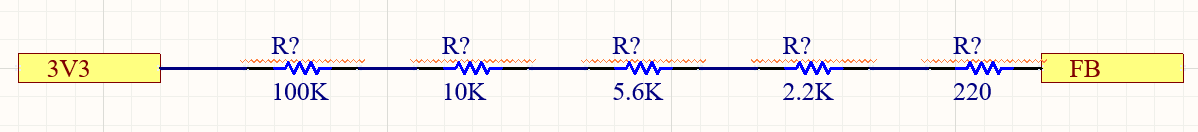
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* Working with values that I have for inductors, I made an equivalent inductance of 8.3uH  
  A diagram of a diagram

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* Also don’t have 69.8 exactly. So, have to make do. Came up with 69.83kOhms  
  
* I was able to output 3.7V with my current setup. However, I noticed that when I would turn off the 9V supply then turn it back on, the output voltage would be 8.8V. I realized that after removing and replacing the inductors, the output voltage would go back to 3.7V. This leads me to believe that the inductors are not properly discharging at turn off.  
  A diagram of a circuit

  Description automatically generated
  + There are multiple reasons why the voltage is not exactly 3.3V.
    - Improper “layout” since I am using a breakout board instead of TI’s recommended layout
    - Resistors are 5% tolerant and they are really pushing that 5% tolerance level which will greatly affect the FB pin noise sensitivity
    - Having to use multiple inductors for that equivalent inductance will create lots of noise and most likely affects the discharge of the stored energy at turn off. I assume the internal soft start is not functioning properly.
      * After measuring the output voltage on a multimeter, I was watching the voltage drop from 8.8V to 3.7V. I am a firm believer that it is because there is just so much energy stored in my inductors at startup, and it takes a long time for the IC to normalize to the programmed output voltage.
    - I wish I could try an asynchronous design with a diode, but I do not have any in-hand for this design.
  + After testing with similar values, I will be following the table from the datasheet to output 3.3V   
    A close-up of a circuit board

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07/30/2024

* Just thinking about more design problems, just making myself a better designer for the next time
  + The GPIO output max of the microcontroller is 0.3+Vddio, basically 3.6V. But the minimum voltage for Vih for the display driver is 3.8V. I will need to use a voltage level translator. I will be using TXU0304PWR for my level translations.
  + Also, to lower board space, I will be using a SMPS to down convert from 9V to 5V, then using an LDO to convert 5V to 3.3V for the microcontroller. A simple 300mA LDO would work well since the total sum currents of all Vdd pins is 140mA.
    - I do plan on wanting to power the board with just USB and not the 9V battery and vice versa. So, I’m thinking of having to use a simple Schottky diode that will match my current restraints to prevent USB power going into the output of the SMPS
* Let’s build the SMPS to output 5V
  + Only difference from the 3.3V version is the RFBT needs to be 118kOhms. I can make 118.02kOhms
  + With this configuration, I was able to get 5.07V on the output. It seems that there is a stability issue at lower voltages. The datasheet did mention that there needed to be a level of precision to drop to lower voltages.
* Let’s start working on the MAX7219
  + I need to set ISET. I said I was going to use the 63.7kOhms. I was able to make 63.78kOhms. A graph with numbers and lines

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07/31/2024

* I learn more every day. Most of the pins are 5V tolerant. I just need to program the pin to be in open-drain mode instead of push-pull. I will use a 100Ohm resistor for pull up to keep up with the 10 MHz clock for the MAX7219