Breadboard Power Subsystem

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Chapter 1

Introduction

1.1 Design Problem Statement

Design and construct a stepper motor power circuit that can interface with a microcontroller for logic input and meet specific power output requirements for the motor.

1.2 Context Diagram

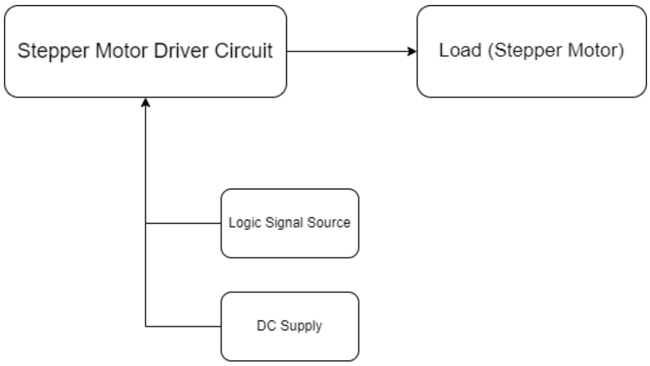

Figure 1.1: Context Diagram

1.3 High Level Requirements Diagram

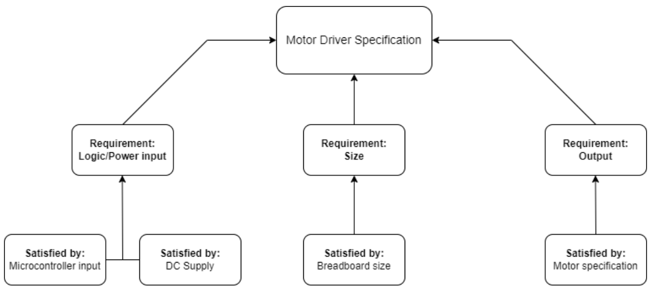

Figure 1.2: High Level Requirements

1.4 Project Specification and Requirements

1.4.1 Specifications

1. High impedance logic (switching) signal output
2. Capable of using 3v3 logic input signal
3. Draw maximum 1mA at input
4. Capable of sustaining 1.5A at 12V on output
5. Fit on a single breadboard
6. Consist of less than 20 components

1.4.2 Requirements

1. Circuit switches on at greater than 2.4V and off at less than 0.3V
2. Current draw maximum 1mA on input stage
3. Circuit operates at 12V
4. Voltage across load is at least 11.5V at 1.5mA
5. Switching speed less than 1us

1.5 Expected Operation

From the specifications and requirements for this project, a relatively simple switching circuit using transistors as the main component seems the best suited to the task. These circuits can easily interface with 3v3 logic from microcontrollers if biased properly and most commonly available transistors can achieve very fast switching speeds. The only issue I foresee could be the requirement for 11.5V at 1.5A at the output as power draw and heat could be too high for certain components. As a knock on effect, using transistors with higher power ratings can have an effect on the switching speed.

Chapter 2

Subsystem Design

For this switching circuit, following extensive research, a high side switch configuration seemed to be the best suited to the specifications. A high side switch was chosen due to the fact that it is not desirable to inadvertently power the load (a motor in this case) when it is shorted to ground as it would be if a low side switch was used.

High side switches can be made using a combination of two transistors (one NPN and one PNP) and resistors to set base currents to desirable levels.

2.1 Component Calculations

2.1.1 Transistors

The PNP transistor will need to output 1.5A at 11.5V with a 12V supply. This necessitates the use of a power transistor such as the TIP32. On the other hand, the NPN transistor will simply need to be driven into saturation to act as a switch. The 2N2222A transistor will suffice for these requirements (see below for calculations)

TIP32 PNP BJT

1. Maximum Vce: 40V
2. Maximum Ib: 1.0A
3. Maximum Ic: 3.0A
4. Vce sat: 0.5V
5. Vbe: 0.7V

From these maximum ratings, sustaining 11.5V at 1.5A at the output will be well within the capabilities of the TIP32. In order to maintain 1.5A at 12V, assuming a DC current gain (from datasheet) of 25, the base current will need to be:

$$Ib = \frac{Ic}{\beta dc}$$

$$\frac{1.5}{25} = 0.06A = 60mA$$

2N2222A NPN BJT

1. Maximum Vce: 30V
2. Maximum Ic: 600mA
3. Vce sat: 0.3V
4. Vbe: 0.7V

In order to drive the 2N2222A into saturation, considering the lowest DC current gain at an Ic of 0.1mA, the PN2222A needs a base current of at least 0.002mA at 2.4V to saturate and turn on.

2.1.2 Resistors

Using these current values and knowing the values for Vce sat and Vbe for both transistors, we can calculate the resistor values for the following circuit. The base resistance into the NPN transistor can be calculated as:

$$Rb1 = \frac{Vb}{Ib} = \frac{2.4 - 0.7}{0.002} = 850$$

Knowing that the voltage across the base resistor for the PNP transistor will be 11.5V (Vcc-Vce(sat)) and the current needs to be 0.60mA, we can calculate the resistance as:

$$Rb2 = \frac{11.5}{0.0006} = 19166 = 19k$$

the closest available values are: Rb1 = 820 ohm Rb2 = 18k ohm This leaves us with the following circuit:

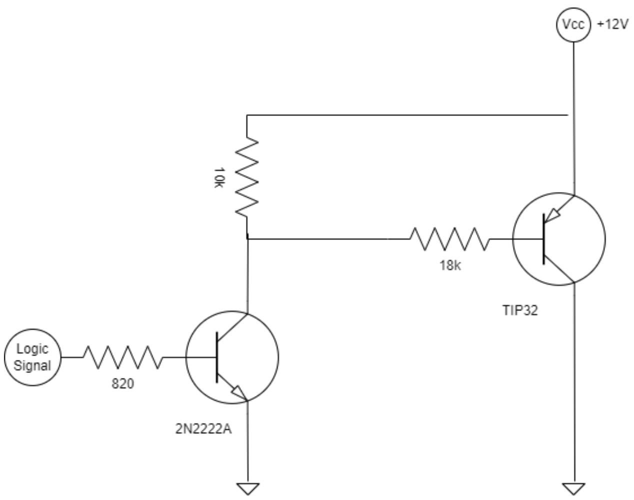

Figure 2.1: High side switch circuit

Chapter 3

Conclusions

3.1 Testing Requirements

As mentioned in the introduction, the system needed to meet certain specifications and pass certain tests. We can see here that the circuit proposed is both less than 20 components and would be small enough to fit on a single breadboard.

3.2 Testing and Results

In terms of meeting the switching requirements, the circuit was probed at both the input to the NPN transistor and at the emitter of the PNP transistor (where the load would be connected). Using an input of a square wave with a minimum of 0V and a maximum of 3V and a period of 1us, the following table of results was seen:

Input Voltage (V)	Output Voltage (V)	Output Current (A)
0	0	0
2.4	11.2	1.3
0	0	0

Table 3.1: Input output results of switching test

As we can see from this table, the circuit switched at the required levels, and due to the period of the input being 1us, the switching speed requirement was also met. Unfortunately, the output voltage and current were not at the required values however close they may have been. This is most likely due to the specific components used and their tolerances. These values can be fine tuned in due course to ensure correct output for the motor circuit.

Additionally the input current (through Rb1) was measured at less than 1mA which satisfies the second to last requirement.

Finally, the circuit operated at 12V and therefore met the last requirement.