University of Illinois

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Friend Finder Armband

Design Review

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Team #30

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1. Introduction

1.1 Motivation: Many times GPS devices can not be used to locate a person in a big crowd. They are not accurate enough to tell you exactly where a person is within close distances, and sometimes the signal is unreliable. The friend finder armband aims to fill this void in the market by creating an intuitive tool to easily find others which works where GPS does not. Our product would be useful in a myriad of situations including concerts, malls, and any other events where large gatherings of people make getting separated easy.

1.2 Objectives: Our goal is to develop a compact armband that will allow the users to easily locate each other in any situation. The armbands will use a system of antennas to locate each other. There will be increasing vibration with increasing proximity. Moreover, the armbands will have LED's to point the user in the right direction.

Features:

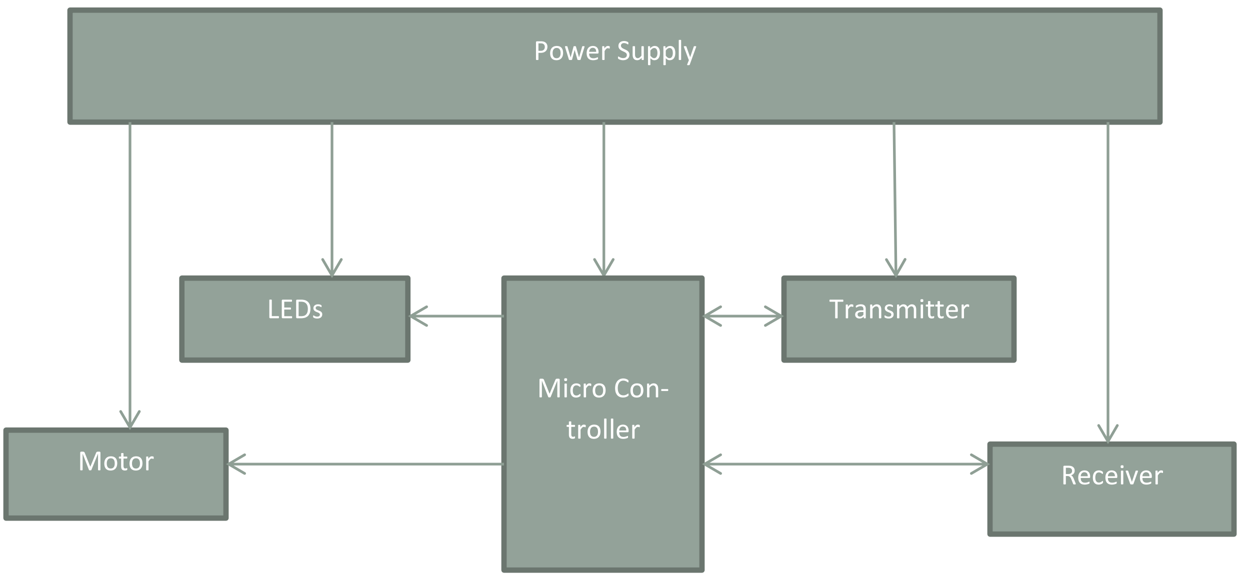
- Sends and receives position wirelessly.
- LED display to indicate direction of other armband.
- Vibrates more intensely with increasing proximity.

Benefits:

- Easily locate friends in a large crowd
- Works when GPS does not
- User friendly interface
- Robust design to be used in almost any situation

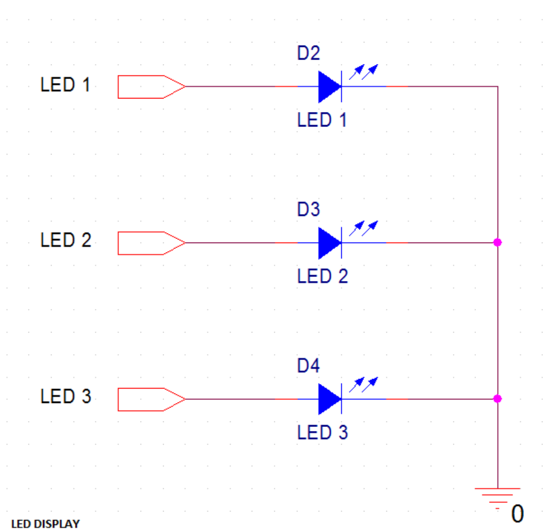
2. Design

2.1 Block Diagram:

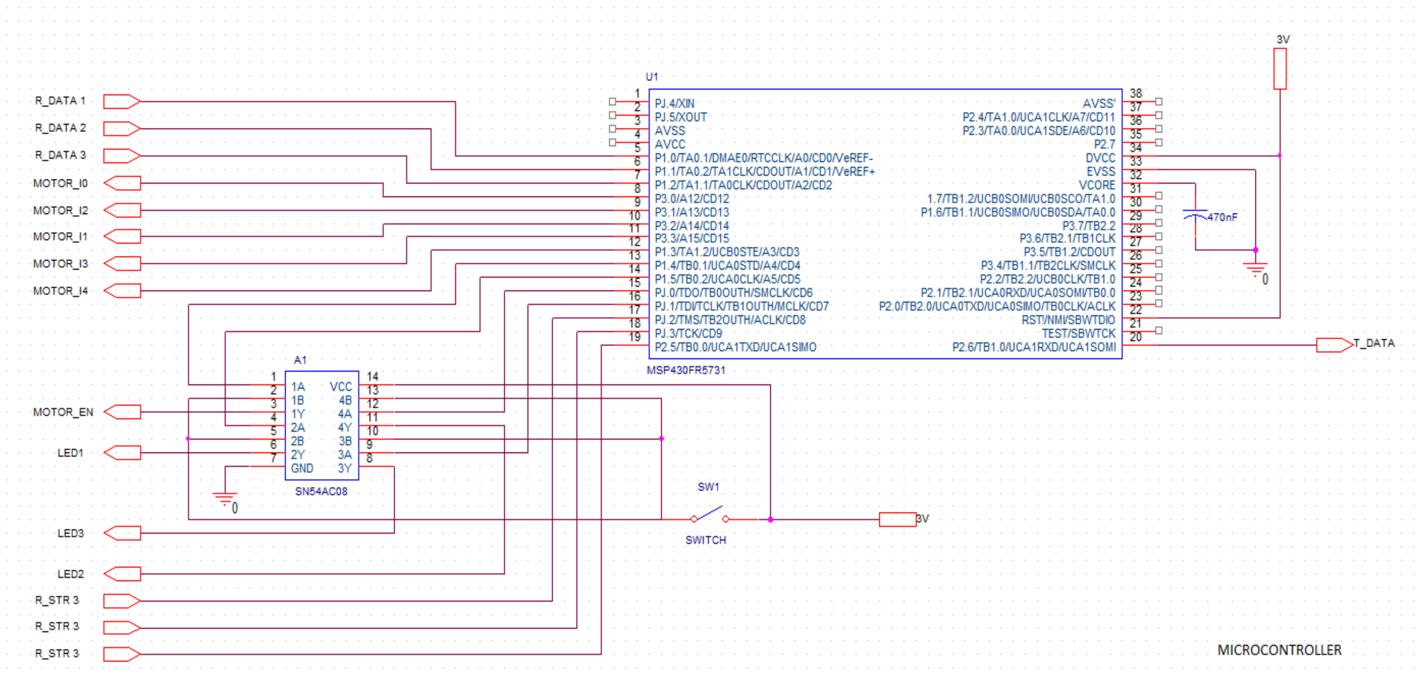


2.2 Schematics

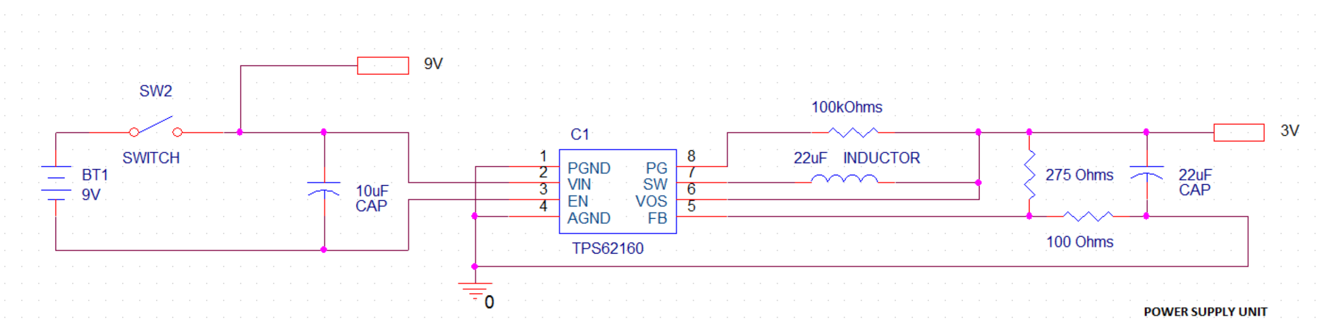
LED Display



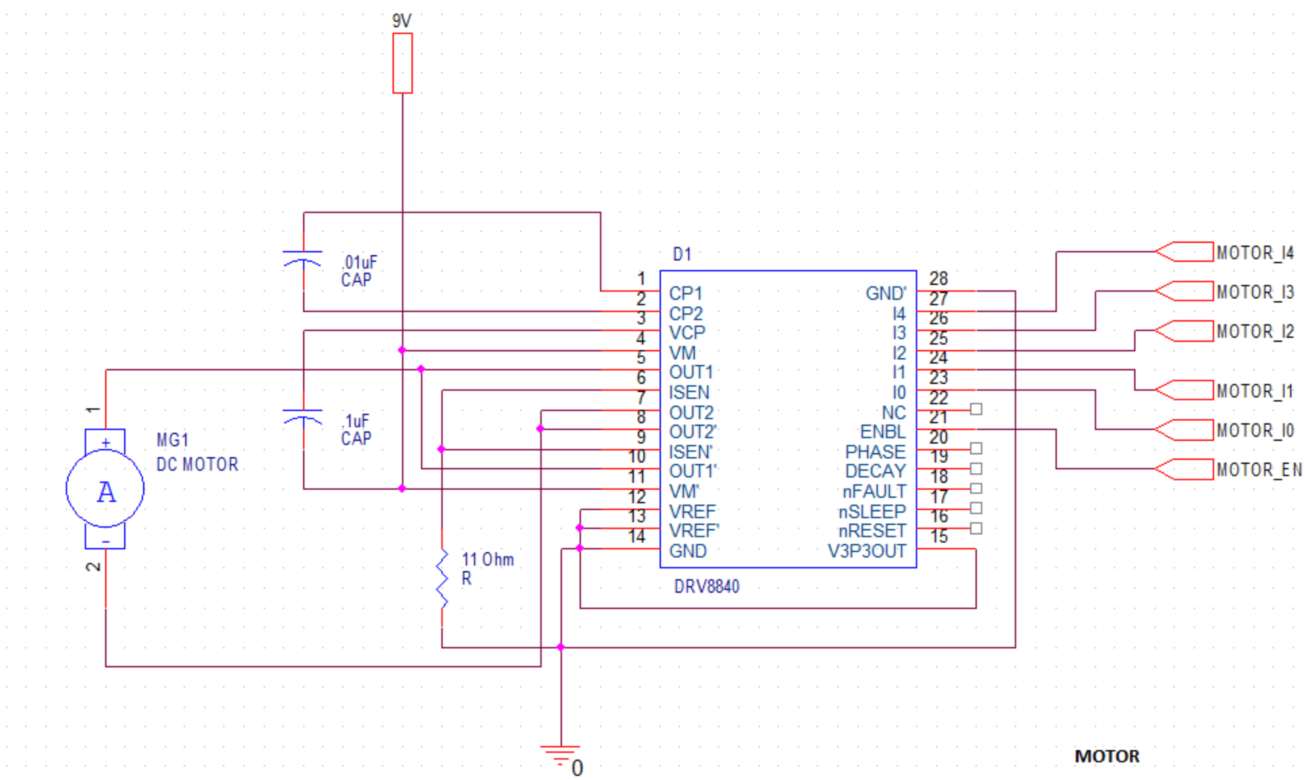
Microcontroller



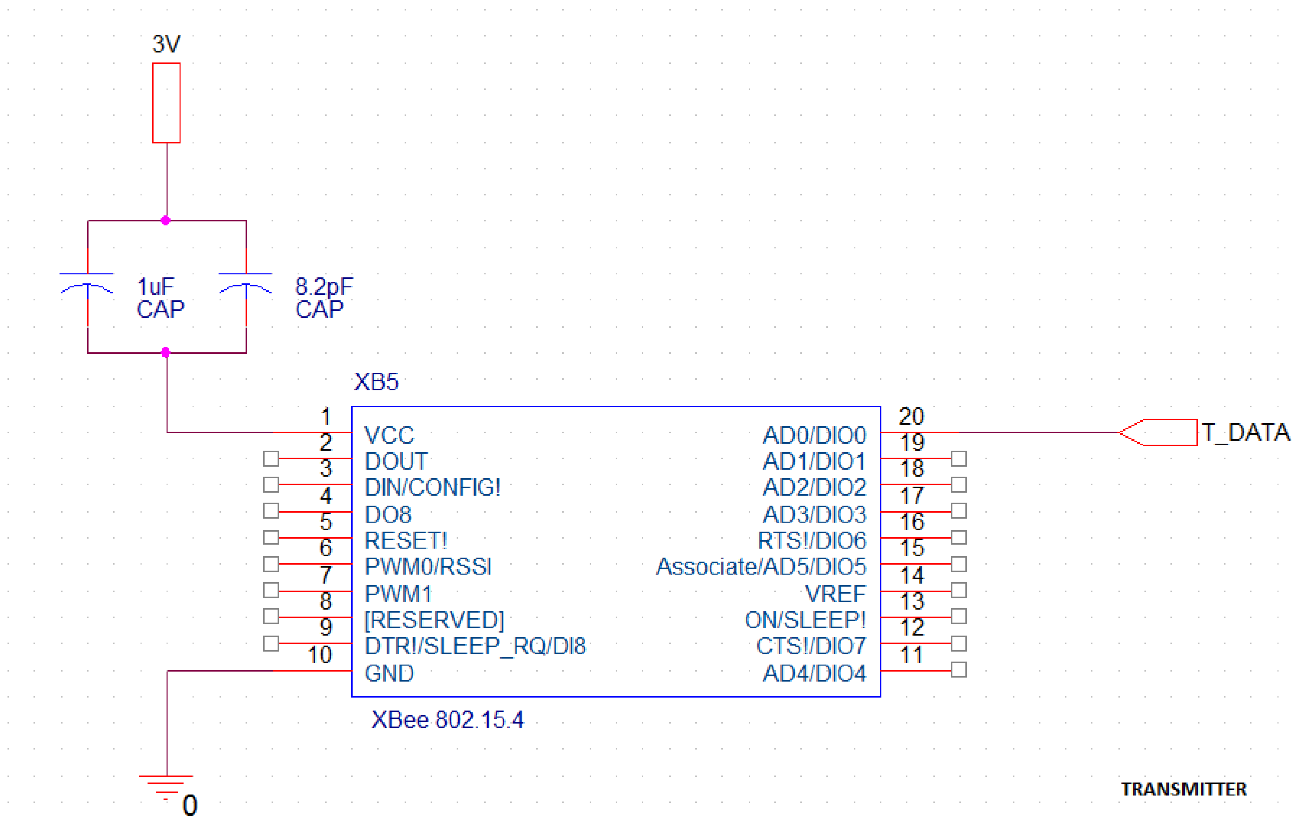
Power Supply



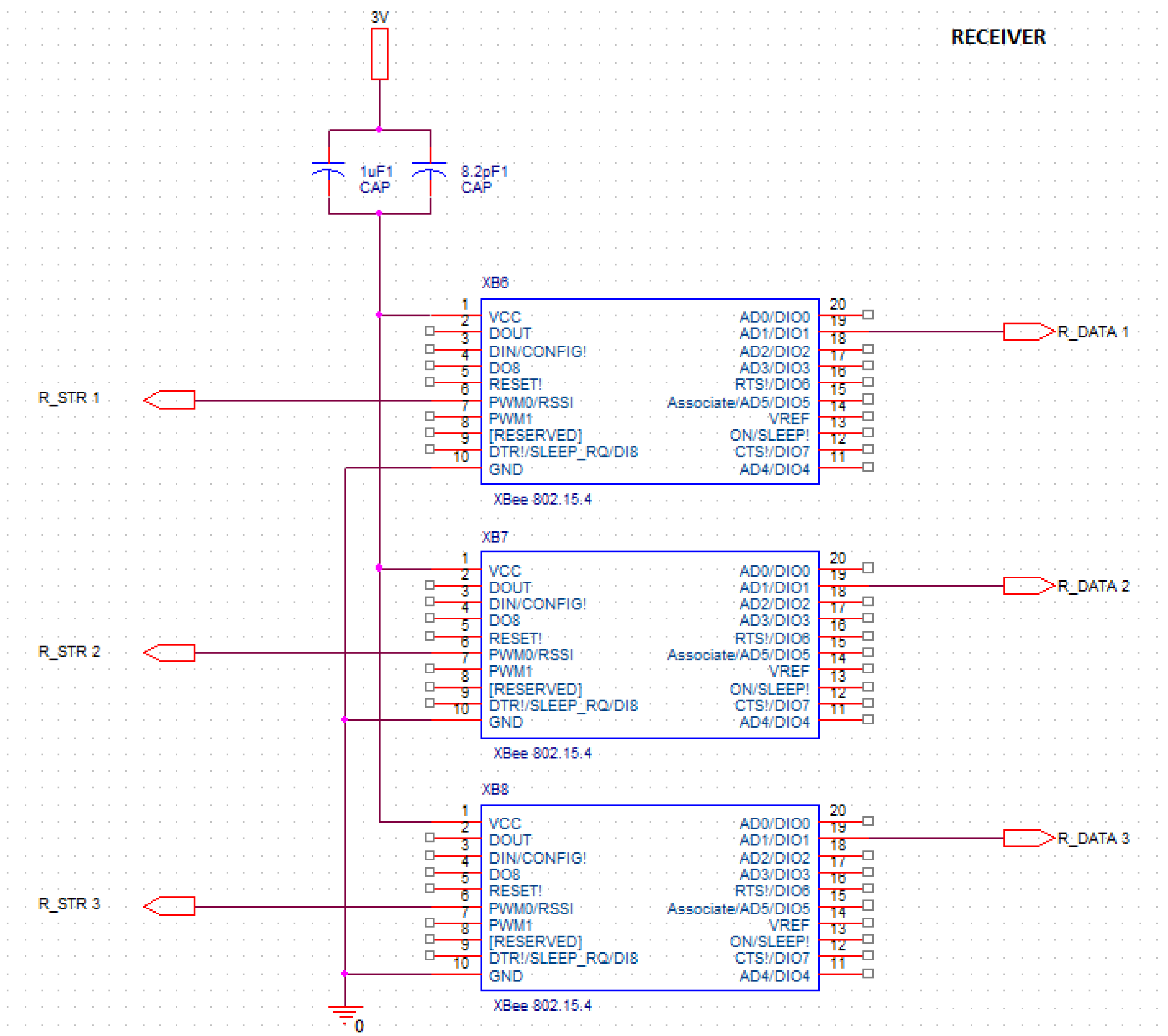
Motor


9V
.01uF
CAP
.1uF
CAP
MG1
DC MOTOR
A
11 Ohm
R
D1
CP1
CP2
VCP
VM
OUT1
ISEN
OUT2
OUT2'
ISEN'
OUT1'
VM'
VREF
VREF'
GND
GND'
I4
I3
I2
I1
I0
NC
ENBL
PHASE
DECAY
nFAULT
nSLEEP
nRESET
V3P3OUT
DRV8840
MOTOR_I4
MOTOR_I3
MOTOR_I2
MOTOR_I1
MOTOR_I0
MOTOR_EN
0
MOTOR

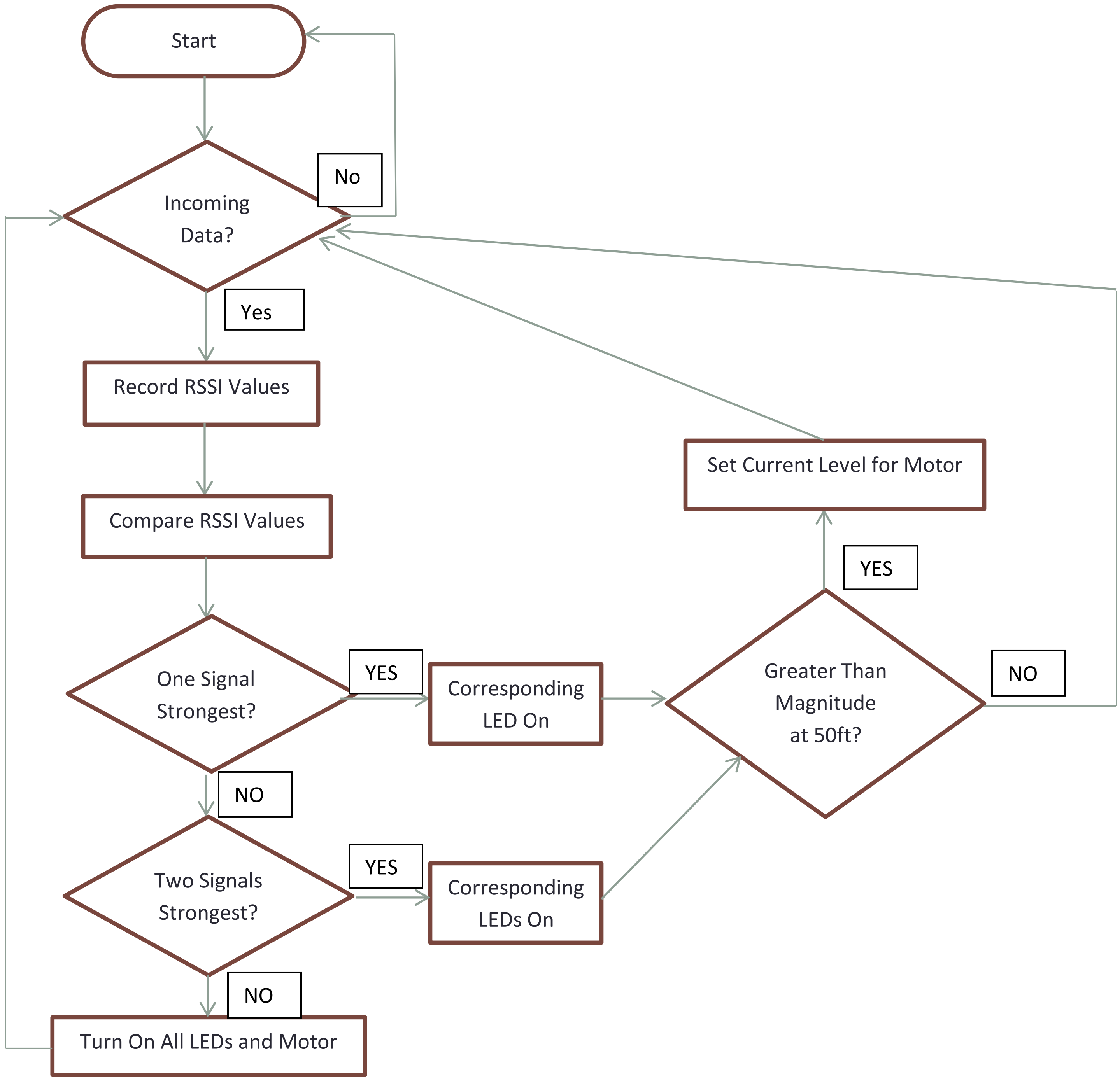
Transmitter



Receiver


RECEIVER
3V
1uF1
CAP
8.2pF1
CAP
XB6
VCC
DOUT
DIN/CONFIG!
DO8
RESET!
PWM0/RSSI
PWM1
[RESERVED]
DTR!/SLEEP_RQ/DI8
GND
AD0/DIO0
AD1/DIO1
AD2/DIO2
AD3/DIO3
RTS!/DIO6
Associate/AD5/DIO5
VREF
ON/SLEEP!
CTS!/DIO7
AD4/DIO4
XBee 802.15.4
R_STR 1
R_DATA 1
XB7
XBee 802.15.4
R_STR 2
R_DATA 2
XB8
XBee 802.15.4
R_STR 3
R_DATA 3
0

2.3 Microcontroller Flowchart



2.4 Block Descriptions:

Power Supply: The main power will be from a 9V DC battery. There is also a DC/DC converter IC to step the voltage down to 3V. The power supply gives 3V power to the motor, microcontroller, transmitter, and receiver. The power supply sends 9V to the motor driver.

LEDs: This module contains three LEDs that indicate the direction of the paired armband. The LEDs each receive a signal from the microcontroller telling them when to turn on. The LEDs get power from the microcontroller. There is also a switch that is ANDed with the signal from the microcontroller, giving the user the ability to turn off the user interface.

Motor: The motor module contains the motor driver and the motor. The motor driver receives an enable command from the microcontroller indicating when vibration is required. This enable is also ANDed with a switch giving the user the ability to turn off the user interface. The motor driver also receives 5 bits from the microcontroller to control the current level given to the motor; this regulates the intensity of the motor vibration. The motor driver gives the required current to the motor. As the proximity increases the microcontroller will tell the motor driver to increase the current into the motor. The motor gets 3V from the power supply.

Microcontroller: This is the main brains of our design. The microcontroller sends data to the transmitter to send. It receives incoming data from the receiver and the RSSI (received signal strength) information. The incoming data from the receiver is line passed and uses the digital in/out ports, not requiring A/D conversion. By comparing the strength of the received signals (from the RSSI values) it will control the LEDs to indicate position. Each LED corresponds to the direction of each antenna respectively. It will use the magnitude of the strongest signal to control the motor driver, telling it to make the motor vibrate more intensely with stronger reception. The LED and motor enables are ANDed with a switch giving the user the ability to turn off the user interface. The microcontroller gets 3V from the power supply.

Transmitter: This module will transmit a signal over a single antenna indicating the presence of the friend finder armband. It receives data from the microcontroller to transmit. The transmitter gets 3V from the power supply.

Receiver: This module will use three antennas and receivers to receive the signal transmitted from the other armband. They each output the incoming data (sent from the transmitter) and the RSSI (received signal strength) to the microcontroller. The receiver gets 3V from the power supply.

2.5 Calculations

Received Signal Strength

$\mathrm{Pr} = \frac{Pt*Gr*Gt*\lambda^2}{(4\pi)^2 d^n}$ - Friis Equation. [1]

Where Pr is power received, Pt is power transmitted, Gr and Gt the antenna gains, d is the distance, and n is the loss parameter. From [1], n was found to be about 1.7981 for indoor environments. The Xbee-PRO transceiver transmits at a frequency of 2.4 Ghz, which corresponds to a λ=.125m. Gr and Gt for the Xbee-PRO is 1.412 which was calculated from the Xbee-PRO data sheet which gave gain in dBi. [2]

Using Friis Equation and the specifications of the Xbee-Pro transceiver, we can calculate the difference in RSSI between signals received at each of the 3 triangulation antennas. In these calculations we assumed an antenna spacing of 7cm, or .07m. The RSSI signal is represented by 8 bits and has a range from -36 dBm to -100 dBm. [3] This means that we can discern changes in RSSI as small as .25 dBm.

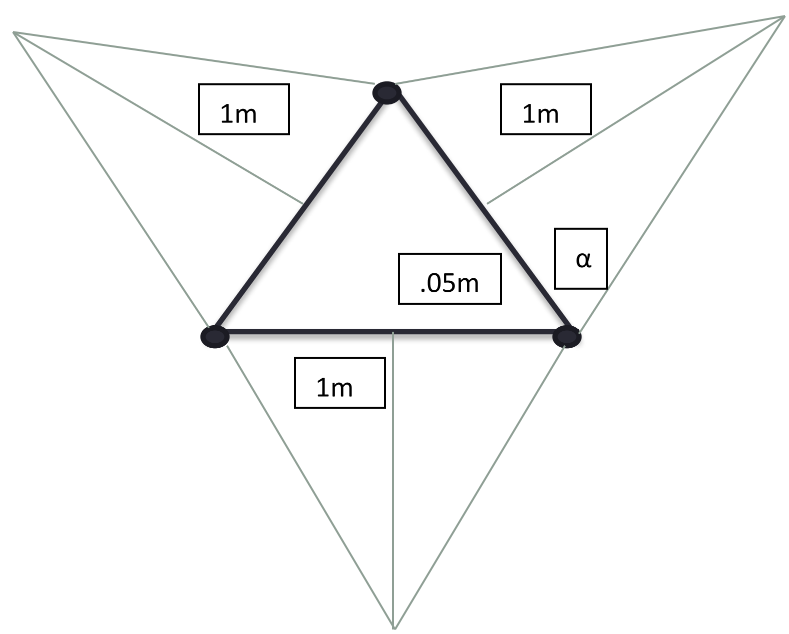
For Pt of 10 dBm:

At d=1m, Pr= -27.04 dBm. This is not a discernible change because the RSSI output will default to -36 since this number is below the rating.

At d=3.3m (10ft), Pr=-36.4dBm. This is when we can start to tell changes in proximity (hence vibrations increase up to this point).

At d=30m, Pr = -53.6 dBm. At d=30.07m, Pr= -53.63 dBm which is not a discernible change. To resolve this, we plan on using RF shielding to create a more directional antenna, so only signals incoming from a specific direction will be detected, thereby giving a more accurate location.

The geometry of our design is shown below:



Solving for α with the requirement that we can detect radiation from any direction 1m away, we get that α=87 degrees. Knowing that each antenna is equally spaced at 10cm, we can find that the angle subtended by our shield should be equal to 360-60-87-87=126 degrees. Any angle larger then this will give us complete coverage past 1 meter.

Battery Life

The battery life was calculated using specifications from the datasheets [4]-[10]. The Amps drawn from the system that use 3V are:

- XBee-PRO transmitter: 215mA
- XBee-PRO receiver: 55mA*3
- LEDs: 30mA*3
- Motor: 53mA
- Microcontroller: 2mA

This totals to 525mA, which corresponds to 1575mW of power. All these components go through the DC/DC converter with an effieciency of 85%. Therefore the actual power drawn from the battery is 1853mW. The motor driver draws draws 192mW. So the total load is 2045mW, which means this is a 227mA load. From the datasheet for the battery the lifetime is 750mAh for 200mA discharge. This gives a lifetime of 6750mWh. Therefore the friend finder armband should last approximately 3.3 hours. By having two batterys in parallel the lifetime should double.

3. Requirements and Verification

3.1 Performance Requirements

- Indicate location via LEDs from 3ft to 200ft outdoors
- Indicate location via LEDS from 3ft to 100ft indoors
- Indicate location via LEDS from 3ft to 200ft outdoors
- Accuracy of directionality of 60 +/- 30 degrees
- Indicate close proximity via vibration from 10ft to 50ft
- Armband lasts at least 5 hours

3.2 Testing Procedures:

The friend finder armband consists of 6 modules which all contribute to the overall function of our design. At the highest level, the friend finder armband must be able to transmit its location, detect the direction and strength of the other armbands transmission, and notify the user via vibration and LEDs.

Requirement	Verification
Microcontroller	
1. Microcontroller detects differences between incoming signals and sends signals to LEDs. a. Microcontroller gets RSSI signals from all three antennas. b. Microcontroller compares stored signals to calculate which are greatest and sends correct signals to LEDs.	1. The circuit will be connected to three different signal generators, and the Motor_En, LED 1, LED 2, and LED 3 signals will be connected to an oscilloscope. The incoming signals from the signal generators should be compared, and the LED corresponding to the strongest signal or signals should be high. a. We will have microcontroller output signals it is receiving from signal gen-

	erator to other output pins. These will be read on an oscilloscope. If the signal is above 2.5V when high and lower than .5V when low the test has passed. b. Correct LED signal is above 2.5V based on highest input from signal generator.
2. Microcontroller correctly activates and controls magnitude of vibration a. Microcontroller finds strongest signal and stores magnitude. b. Microcontroller compares magnitude of stored RSSI signal with that of stored reference signal from 50 ft. c. Microcontroller sends appropriate 5-bit current control to motor.	2. The microcontroller will be connected to three signal generators and the pins I0-I4 will be measured on an oscilloscope. a. Have microcontroller output the magnitude of the strongest signal to an unused I/O pin read on oscilloscope. If the binary valueis the same as that of the signal generator then the test has passed. b. Output stored reference signal (value will be gotten from testing) and ensure it is the same. Output difference between it and incoming strongest signal. If the difference matches what we calculate the test has passed. c. Output correct current control bits through I0-I4. For every ~3% change in magnitude we will increment the current.
Transceiver	
3. Accuracy of directionality of 60 +/- 30 a. Antenna's receive signals only within 180 degrees	3. One receiver will be rotated, while the transmitter will remain in place. The output signal strength will be measured on an oscilloscope. a. Output signal is at least 20dB higher in the 180 degrees in front of the antenna.
4. Transmitter sends signal a. Transmitter able to receive serial data from microcontroller b. Transmitter sends serial data Omni directionally	4. Function Generator will be connected to the data in pin on the transmitter and the data out pin on the receiver will be hooked up to an oscilloscope to check for correct transmission. The receiver will be moved in all direc-

	tions. a. Oscilloscope has same binary values on receiver as generated. b. Oscilloscope reads a signal greater than 2.5V in all directions.
5. Receiver receives signal up to 100ft indoors and 200ft outdoors. a. Receiver gets incoming serial data up to 100ft indoors. b. Receivers get incoming serial data up to 200ft outdoors.	5. Function generator will be used to send a signal from the transmitter. The receiving antenna will be placed at the corresponding distance for each test. Oscilloscope will be connected to the receiver to read the incoming signal. a. Oscilloscope shows same binary values at 100ft indoors. b. Oscilloscope shows same binary values at 200ft outdoors.
User Interface	
6. Motor vibrates more or less intensely a. Motor begins vibrating when enable signal is high b. Motor vibrates more intensity with larger current control signal	6. Motor enable and current control signals will be connected to an outside power supply and ground to give logic signals to the motor. An oscilloscope will be used to read the output current from the motor driver. a. When motor enable is greater than 2.5V, motor will vibrate. b. As the current control bits are incremented the current is at the correct percentage of 60mA according to table 3 of the motor diver datasheet.
7. LEDs illuminate when active.	7. LEDs will be connected to an outside power supply and resistive network. When 3V (20mA) is supplied to LEDs they will light up.
Power Supply	
8. Power supply gives correct voltages at outputs.	9. Power supply will be hooked up to an oscilloscope. Above 8.5V will be read at the supply to motor. Above 2.5V will be read at other supply output.

Entire Project	
9. Armband lasts at least 5 hours	8. Armbands will be left with all the LEDs on and the motor vibrating for 5 hours. After five hours armbands will be checked.

3.3 Tolerance Analysis

The transceiver is the key component in this device since it is the one used to detect the other armband. An important part of the friend finder armband will be the ability to transmit despite arm orientation. This way if you are trying to find your friend you can locate them despite what they are doing. We will test that the receiver can locate the transmitter at a variety of orientations. We require that our tolerance be +/- 30 degrees when the antennas are perpendicular to each other. The reason for this is that radiation from antennas oscillates in one axis, and cannot be received in a orthogonal axis. This is illustrated in the figures shown below:

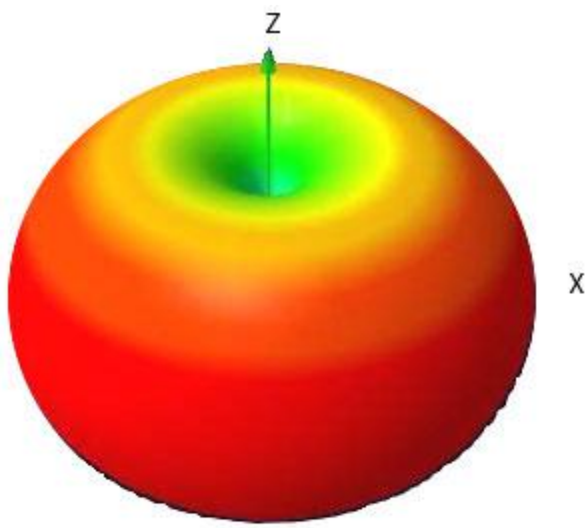


Figure 1. Radiation pattern from omni-directional antenna [11]

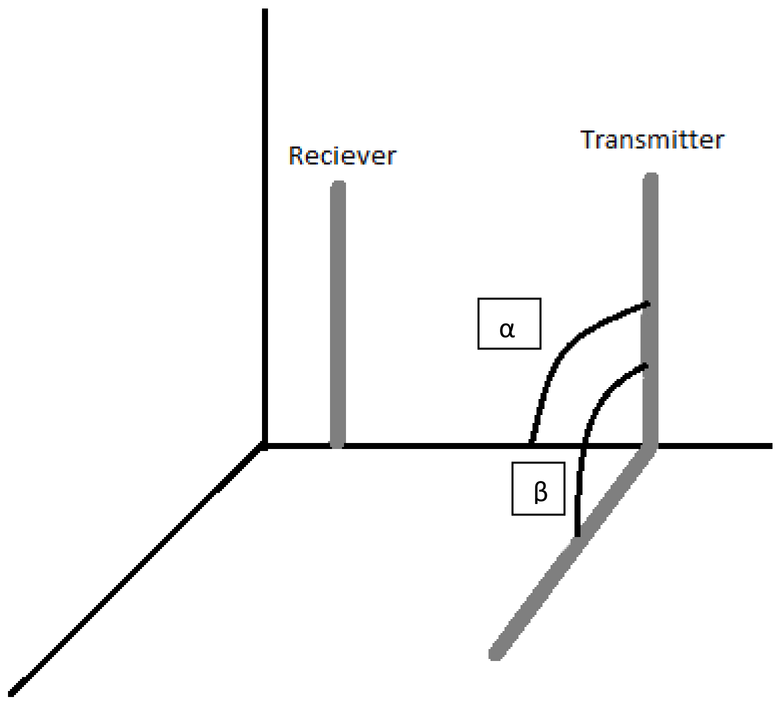


Figure 2. Defining rotation angles

Here, rotation in alpha causes the null to point towards the transmitter, while rotation in beta causes the oscillation of the receiver to be orthogonal to that of the transmitter.

The friend finder armband is designed to work when armbands are in the same room. But we would like to test the tolerance of our system when walls and other objects impede our transmission. We will find the tolerance for the number of walls we can propagate through while still getting accurate measurements.

4. Cost and Schedule

4.1 Cost Analysis

Parts

Part	**Quantity**	**Price**	**Total Cost**
TI MSP430FR5731	2	$1.95	$3.90
Xbee-Pro 802.15.4	8	$38.00	$304.00

TI DRV8840	2	$6.92	$13.84
Pico Vibe 12mm Vibration Motor – 3.4mm type	2	$6.68	$13.36
LED-117 Ultra Bright Blue	6	$.82	$4.92
Energizer LA522	4	$7.00	$28.00
PB-94 DPDT Push Button Switch	4	$1.37	$5.48
TI TPS62160	2	$1.71	$3.42
TI SN54AC08	2	$2.20	$4.40
Capacitors	9	$1.40	$12.60
Resistors	4	$0.20	$0.80

Total Parts Cost: $394.72

Labor

Name	**Rate**	**Hours**	**Total**	**Total * 2.5**
Tim Capota	$40/hr	240	$9,600	$24,000
Dave Drake	$40/hr	240	$9,600	$24,000

Total Labor Cost: $48,000

Total Cost: $48,394.72

4.2 Schedule

Date	Task	Group Member(s)
6-Feb	Finish Proposal Research Microcontroller/Motor Research Transmitter/Receiver	All Dave Tim
13-Feb	Sign Up for Design Review	All

	Design RF Design Microcontroller Design PSU	Tim Dave Tim
20-Feb	Design Review	All
27-Feb	Order RF/Microcontroller Order PSU/Misc. parts Order LEDs/Motor	Tim Dave Dave
5-Mar	Build PSU Build RF system	Dave Tim
12-Mar	Build LED/Motor Program Microcontroller	Tim Dave
19-Mar	Spring Break	
26-Mar	Prepare for Mock-up Presentation Build armband 1 Build armband 2	All Dave Tim
2-Apr	Mock-up Presentation Test RF system Test LED/Motor	All Tim Dave
9-Apr	Tolerance Analysis Debugging	Dave Tim
16-Apr	Preparation for Demo/Presentation	All
23-Apr	Demo/Presentation	All
30-Apr	Demo/Presentation/Checkout	All

5. Ethical Considerations

Safety is an important consideration when taking on any electrical engineering project. The IEEE code of ethics #1 states: “to accept responsibility in making decisions consistent with the safety, health and welfare of the public, and to disclose promptly factors that might endanger the public or the environment;” As with any electronic device, shock is always a safety concern. Therefore, we will ensure that all connections posing any threat are shielded from the user and power levels are less than those which could cause serious injury.

6. References

[1] E. Goldoni et al, “Experimental Analysis of RSSE-based Indoor Localization with IEEE 802.15.4,” in *2010 European Wireless Conference*. [Online]. 2010, pp. 71-77. Available: http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=05483396&tag=1

[2] Xbee/Xbee-PRO RF Modules Product Manual v1.Ex– 802.15.4. Digi International Inc. [Online]. Available: http://ftp1.digi.com/support/documentation/90000982_F.pdf

[3] D. Gascón and M. Yarza. (2008 Nov.) Indoor location using 802.15.4 – ZigBee. [Online]. Available: http://www.sensor-networks.org/index.php?page=0827027001

[4] LA522 Datasheet. Energizer. [Online]. Available: http://data.energizer.com/PDFs/LA522_EU.pdf

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[7] TPS62160 Datasheet. Texas Instruments. [Online]. Available: http://www.ti.com/lit/ds/slvsam2/slvsam2.pdf

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[9] TI SN54AC08 Datasheet. Texas Instruments. [Online]. Available: http://www.ti.com/lit/ds/scas536d/scas536d.pdf

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