The Medspencer

Group 6: Matthew Hoover, Sakeenah Khan,
Gustavo Morales Burbano, Ivan Alvarez

Sponsored by Dr. Fredesvinda Jacobs-Alvarez
MD, head physician of Esperanza Behavioral Health and Services

MOTIVATION

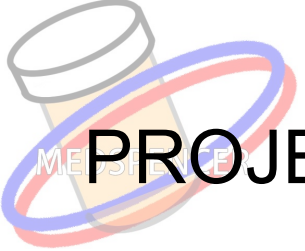
- **Medication nonadherence** limits the effectiveness of health care services and prescribed medications
- **~50% of patients** with chronic illnesses don't take medications as prescribed[1]
- Implications include **decreased quality of life**, poorly managed symptoms, and even death[2]
- Costs the health care system **over $300 billion a year** due to additional doctor visits, emergency department visits, and hospitalizations[2]

[1] Sabaté, Eduardo, editor. Adherence to Long-Term Therapies: Evidence for Action. World Health Organization, 2003
[2] Zullig, Leah L. "Engaging Patients to Optimize Medication Adherence." NEJM Catalyst, NEJM Group, May 2017

MAIN IDEA

- **Main goal:** To increase medication adherence in patients that have complicated medication regimes with multiple prescription medications and schedules.

- **Our solution:** The Medspencer will sort and schedule doses and notify patients to take their medicine. It will also report to the caretaker and physician on the patient's adherence.



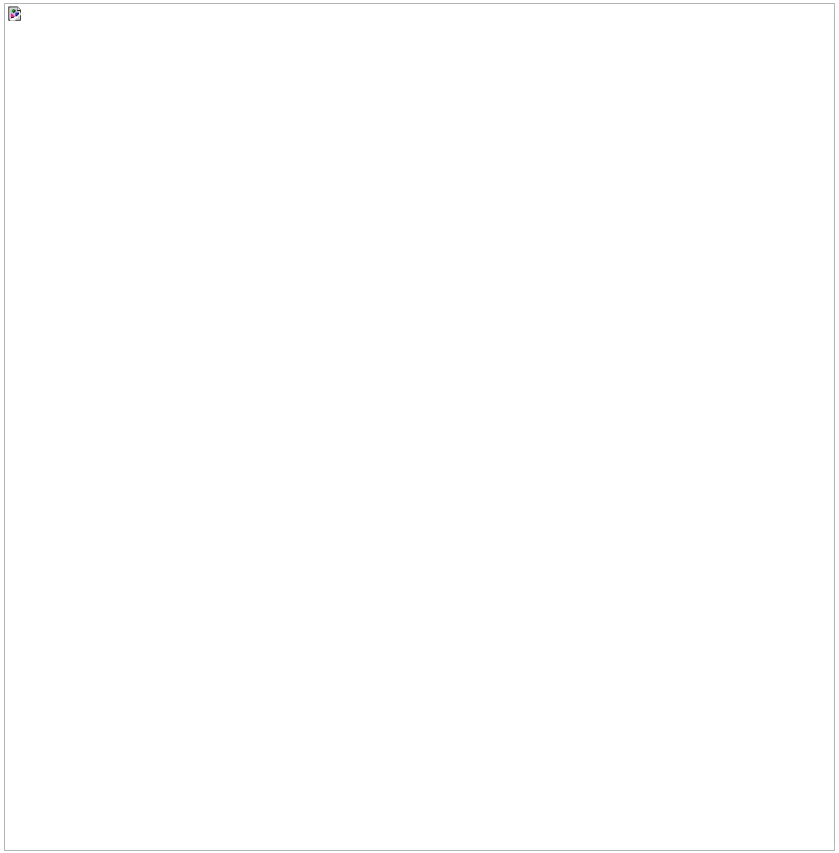
PROJECT OVERVIEW AND FEATURES

- **Touchscreen**-based user interface
- Caretaker manages **prescriptions** and **schedules**
- Patient identification via **fingerprint** reader
- **Speaker** alerts patient at scheduled dosage time
- Medicine is dispensed to patient using **motors**

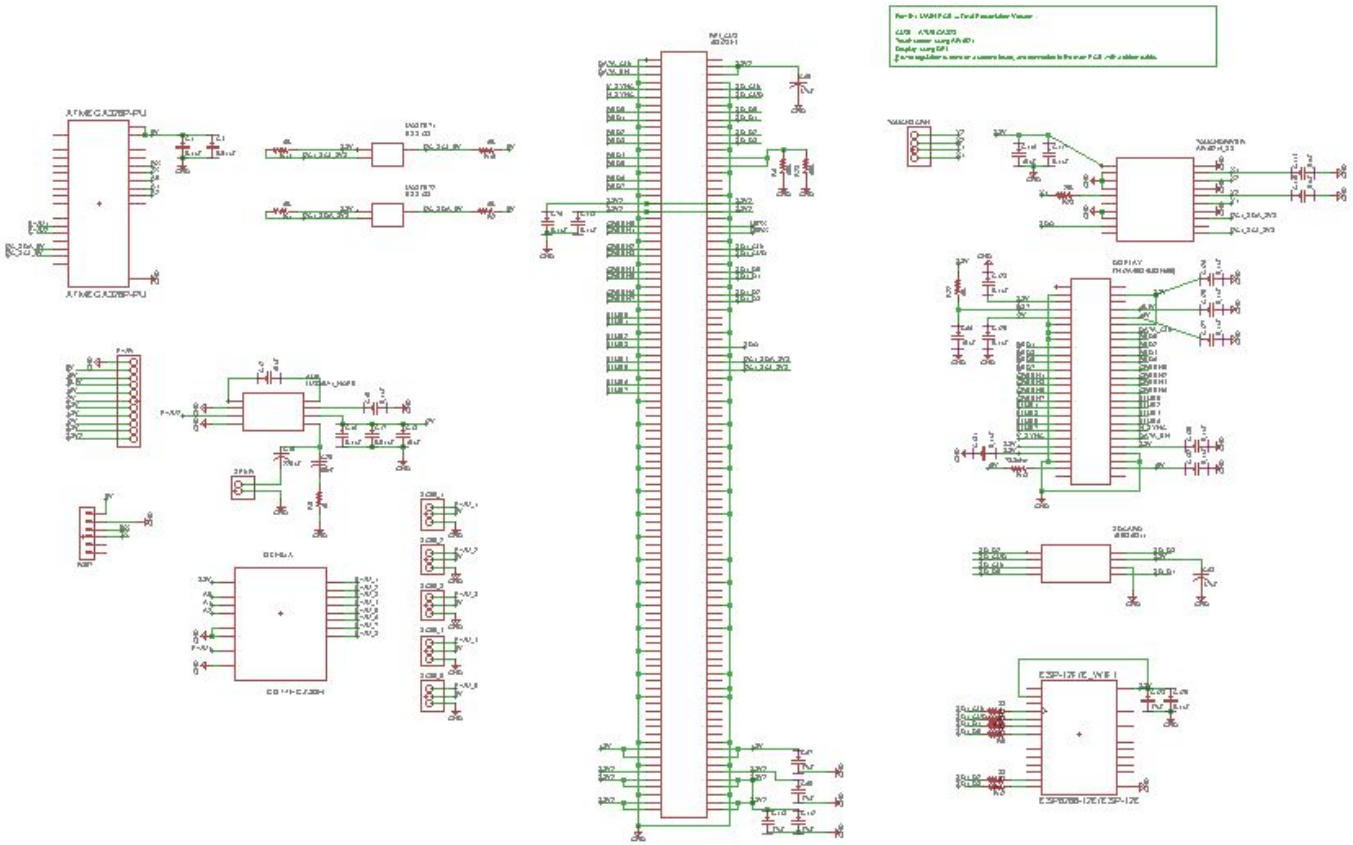
SPECIFICATIONS

- Software
  - Speed: 1.2GHz
  - Memory: SD Card (8GB)
  - Communication protocols: I2C, UART, PWM signal
  - Graphic user interface
- Hardware
  - PCB size: 2 PCBs (80mmx100mm)
  - Up to 5 servo motor for dispensing
  - 7” LCD Display
  - Resistive touchscreen
  - Fingerprint scanner
  - 4Ω 2W Speaker
- Power
  - 20 VDC (120 VAC domestic power)
  - 1.6 A MAX requirement

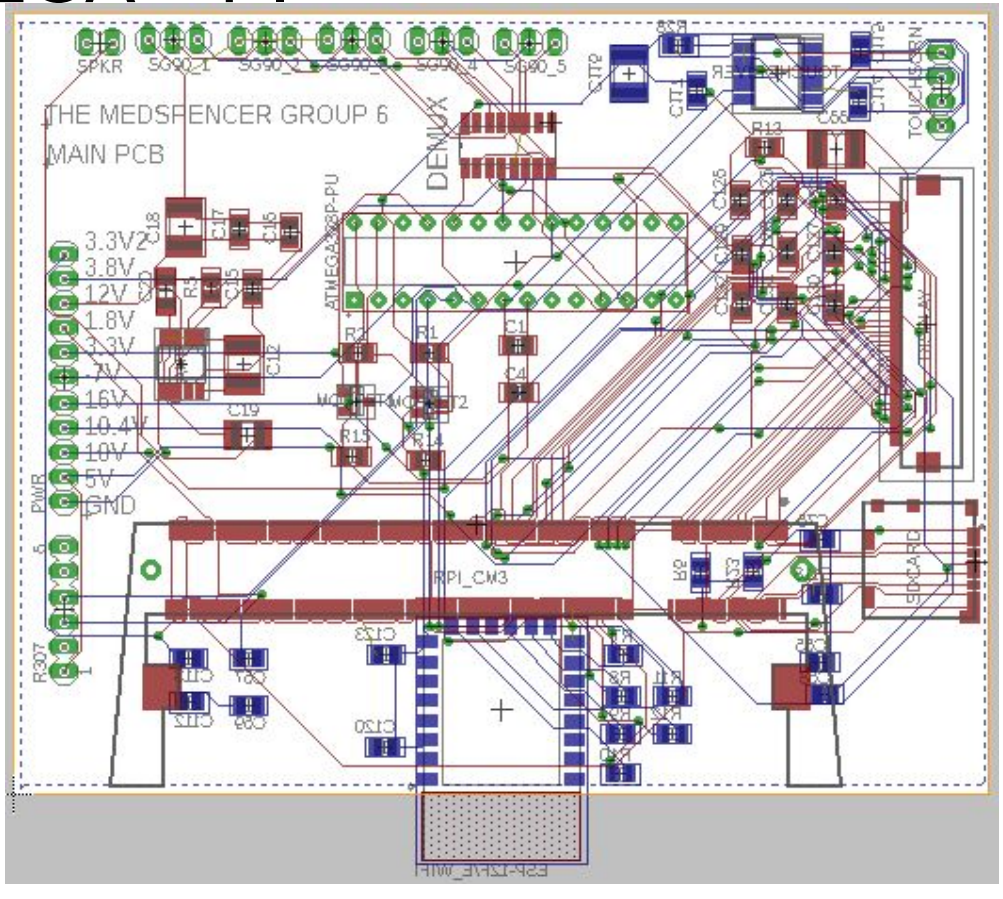
HARDWARE DIAGRAM



SCHEMATICS: ATMEGA + PI



PCB: ATMEGA + PI

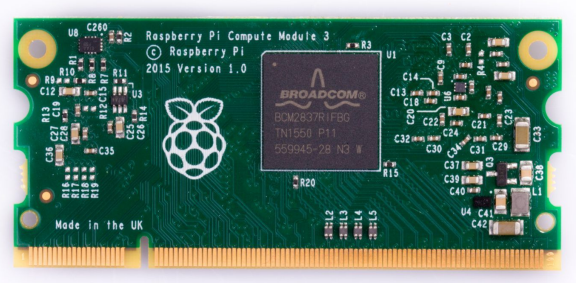


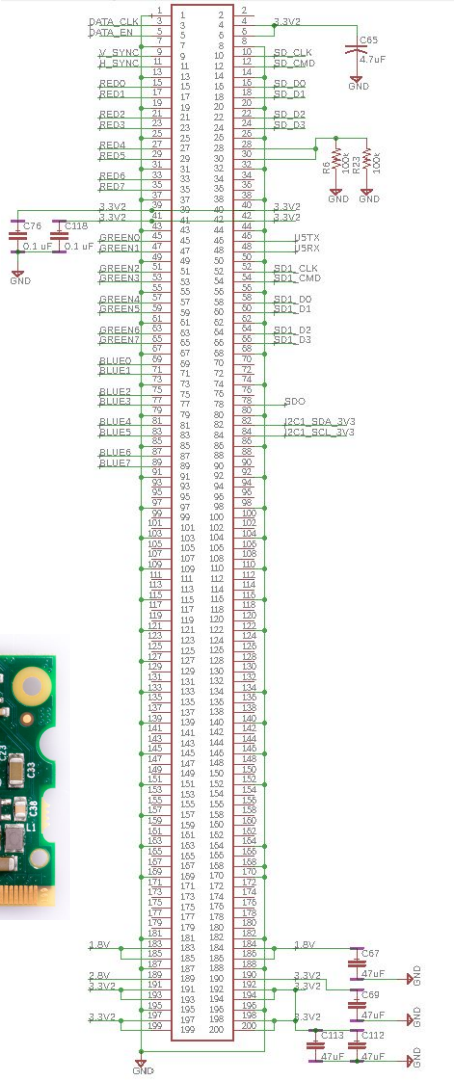
Processor Comparison

	PIC32MZ DA	Pi CM3L	ATMEGA328P
COST	$20.63	$25.00	$2.15
PROGRAM MEMORY	2M bytes	SD card (8GB)	32K bytes
DATA MEMORY	640K bytes	1G byte	2K bytes
I/O PIN	176	200	23
CLOCK RATE	200MHz	1.2GHz	20MHz
POWER	1.8V and 3.3V	1.8V and 3.3V	5V

Raspberry Pi Compute Module 3 Lite

- Clock rate: 1.2GHz
- Operating voltage: 3.3V
- 54 GPIO pins
- Two I2C communication buses
- Display Parallel Interface
- Two SDIO interfaces
- Linux kernel support

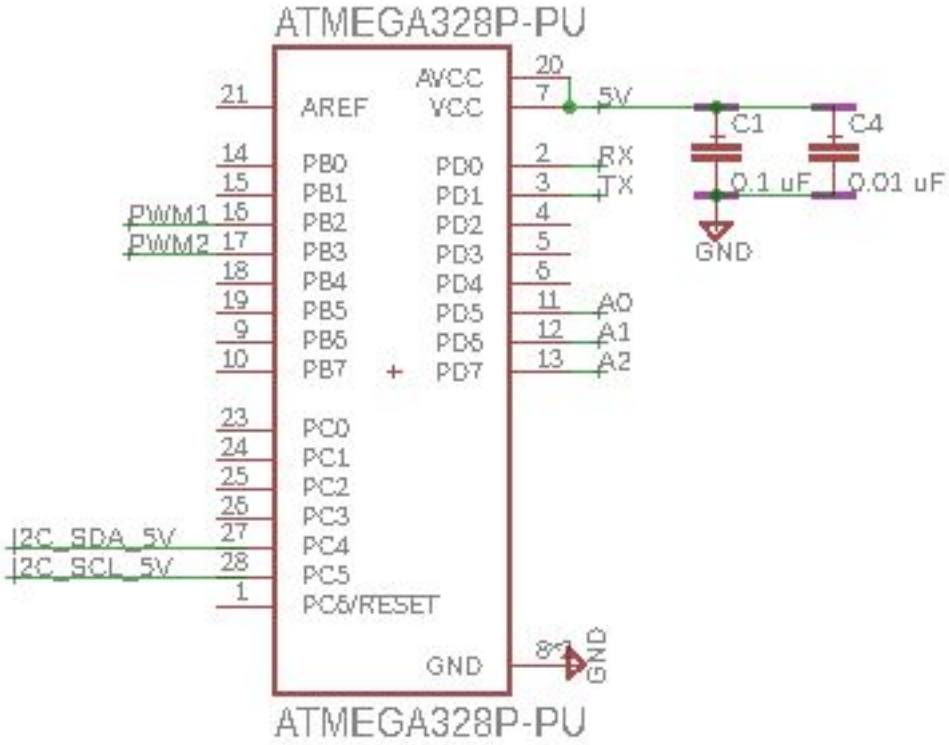




Raspberry Pi compute Module 3 lite (CM3L); “Compute Module Datasheet”, Raspberry Pi, October 2016.

ATMEGA328P-PU

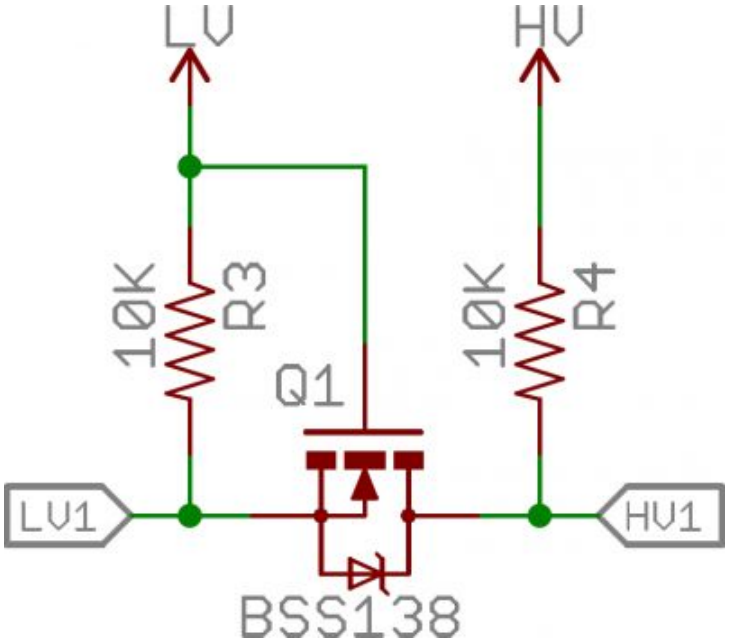
- Clock Rate 20MHz
- 32KBytes of in-system self-programmable flash program memory
- One I2C communication bus
- 23 programmable I/O lines
- Operating voltage: 1.8 - 5.5V
- Current consumption: 0.2mA



8-bit AVR Microcontrollers; ATmega328/P Datasheet.” Atmel Corporation, November 2016.

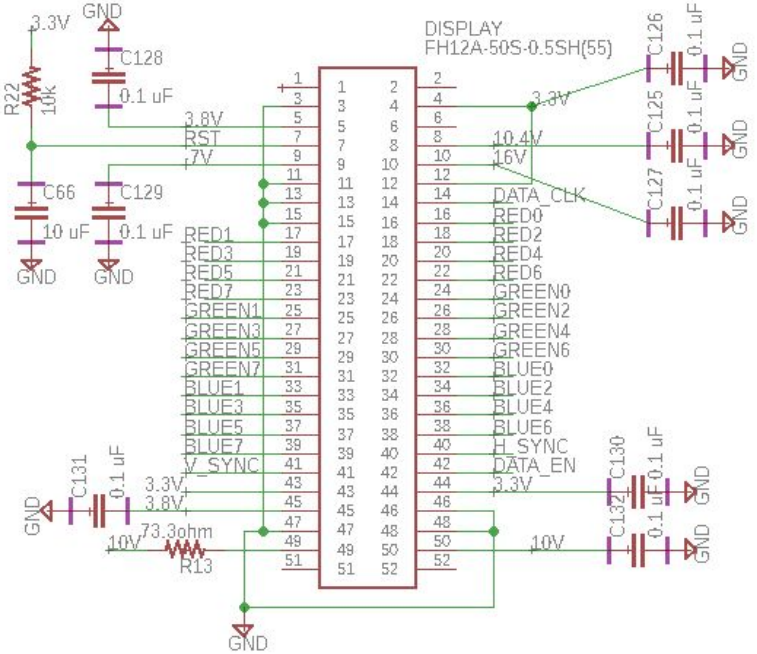
Pi CM3L → ATMEGA328 Communication

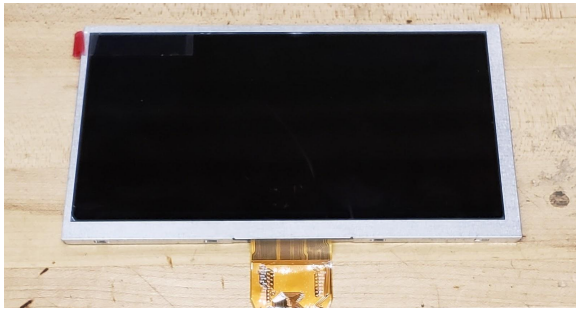
- Bidirectional voltage level shifter required for I2C communication between the Pi CM3L (3.3V) and ATMEGA328 (5V)
- Requires MOSFETs with low threshold voltage, lower than 3.3V
- I2C communication requires pull-up resistors
- Circuit repeated twice, to shift logic level for SCL and SDA lines



LCD Display

- Innolux AT070TN90 LCD Display
  - WVGA resolution (800x480)
  - 24-bit color
  - Communication interface:
    - Design choice: DPI (Display Parallel Interface)
    - Alternative option: HDMI

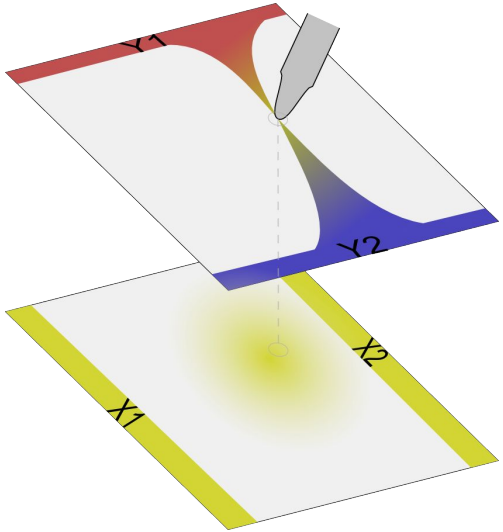


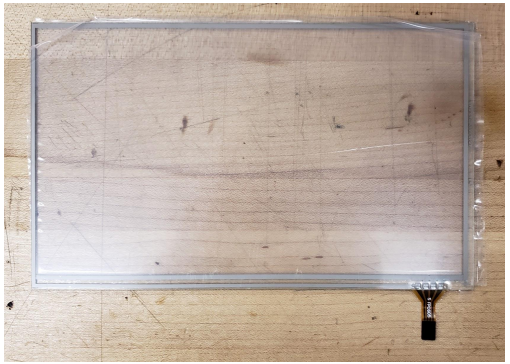


"LCD Module Specification" (Model Name: AT070TN92 V.1; Remark: Touch Screen Panel). Innolux Display Corporation, Feb. 2009.

Resistive Touch Panel

- Resistive Touch Panel
  - 3 layers: top conductive layer with two electrodes (Y1 and Y2), a space layer in the middle, bottom conductive layer with two electrodes (X1 and X2)
  - When touched, the top and bottom layers press together, resulting in a voltage gradient
  - Measure the voltage gradient to calculate touch coordinates
  - Communication interface: ADC

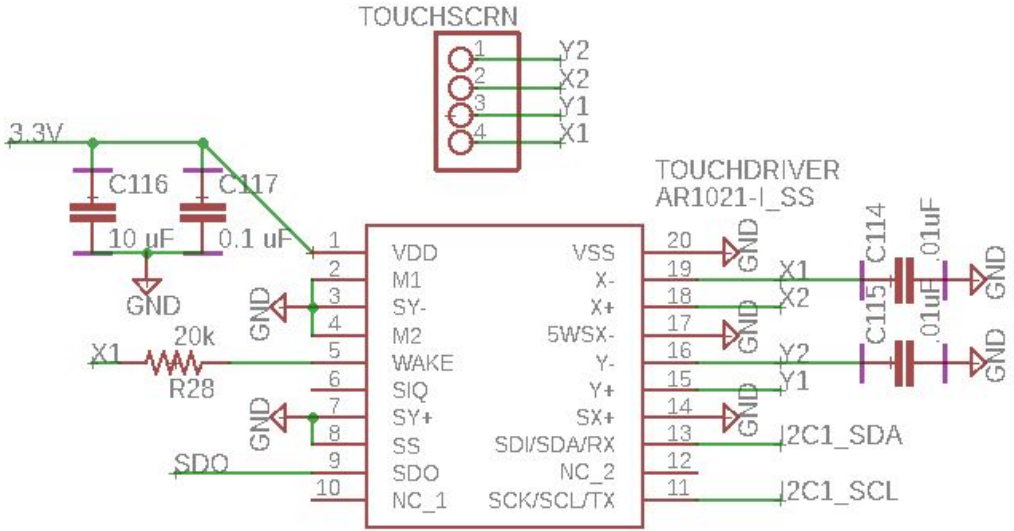




“LCD Module Specification” (Model Name: AT070TN92 V.1; Remark: Touch Screen Panel). Innolux Display Corporation, Feb. 2009.

Resistive Touch Screen Controller

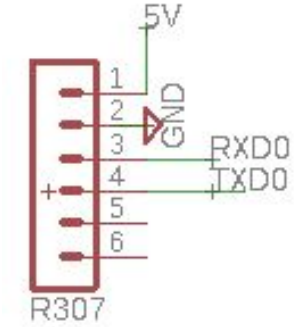
- Design choice: AR1021 Resistive Touch Screen Controller
  - Processes touch data and delivers calibrated touch coordinates to MCU
  - Communication protocol: I2C
  - Power input: 2.5-5V, 125µA (max)
- Alternative choice: USB to Pi
- Alternative choice: PIC32
  - Utilize ADC modules on PIC32
  - Supply power to, measure, and calibrate the touch panel directly using the PIC32 microcontroller

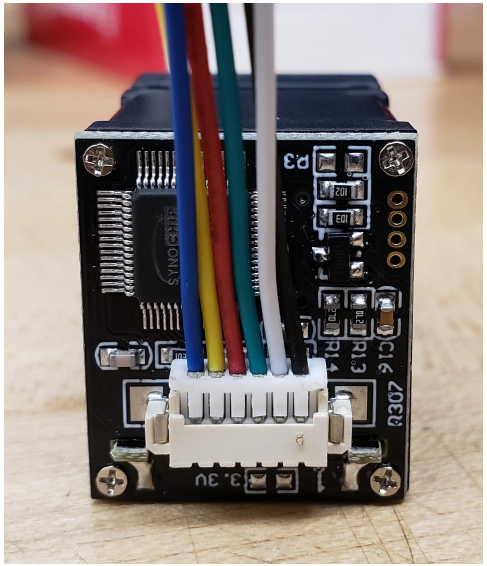


"AR1000 Series Resistive Touch Screen Controller." Microchip, 2016.

Fingerprint Scanner

- R307 Fingerprint Identification Module by Hangzhou GROW
  - Optical sensor scans fingerprint and creates digital model
  - Communication protocol: UART
  - Power input: 4.2-6V, 50mA (typ)
  - Matching mode: 1:1 and 1:N
  - Storage capacity: 1000 fingerprints



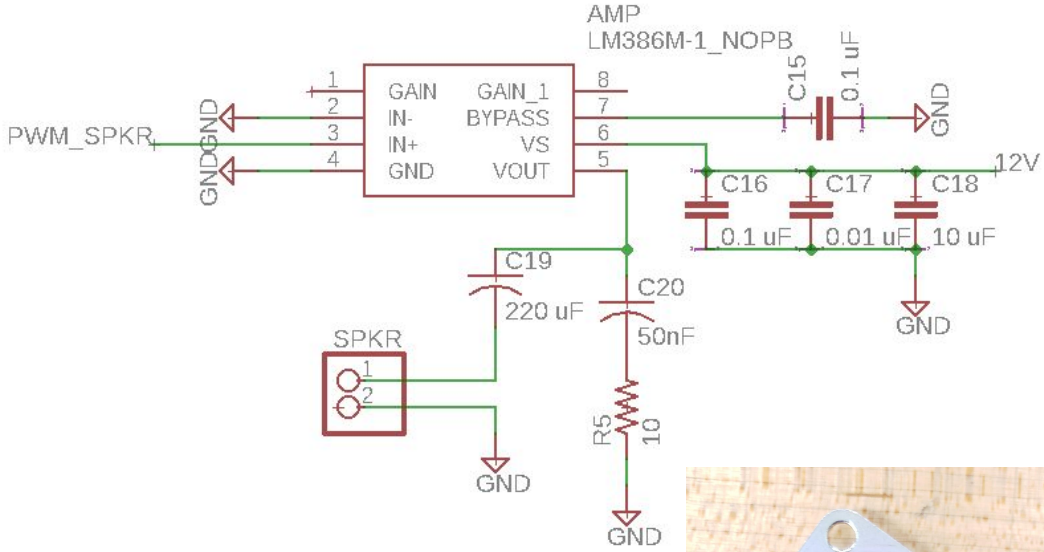


"R307 Fingerprint Module User Manual." Hangzhou Grow Technology Co., Ltd., Feb. 2011.

Speaker

- CMS-40504N-L152 Speaker by CUI, Inc.
  - Signal input: PWM
  - Power input: 2W
  - Impedence: 4Ω
  - Resonant frequency: 500Hz

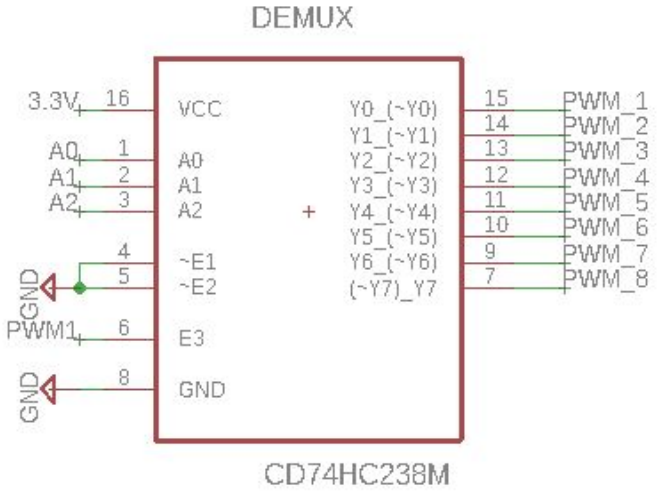
- LM386M-1 Audio Power Amplifier
  - Signal input: PWM for speaker
  - Power input: 15V (max), 4-8mA
  - Gain: 20-200

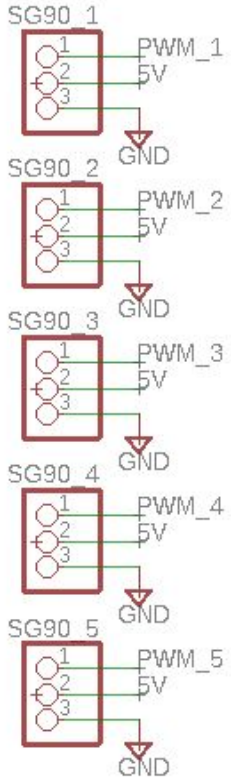


“Model: CMS-40504N-L152; Description: Speaker.” CUI, Inc., June 2016.
“LM386 Low Voltage Audio Power Amplifier.” Texas Instruments, May 2017.

Dispensing Mechanism

- SG90 Servo Motors
  - A motor dispenses from each individual medicine vial
  - Signal input: PWM
  - Power input: 3.5-6V, 220mA
- CD74HC238M Demultiplexer
  - Selects which SG90 to rotate
  - Signal inputs: PWM signal for SG90, 3 address bits
  - Power input: 2-6V, 50mA (max)





"Servo Motor SG90 Datasheet." Tower Pro.
"High Speed CMOS Logic 3- to 8-Line Decoder/Demultiplexer." Texas Instruments, Aug. 2004.

Power Requirements

COMPONENT	V_{SUPP} (V)	I_{SUPP} (mA)
DC Power Supply	20	3.25 A
Microcontroller ATMEGA328P-PU	5	4
Raspberry Pi CM3L	3.3 1.8	250 250
Bidirectional Logic Level Converter	5 3.3	16
LCD Display AT070TN90	3.3 10.4 10.0 16.0 -7.0 3.8	10 50 135 1 1 10

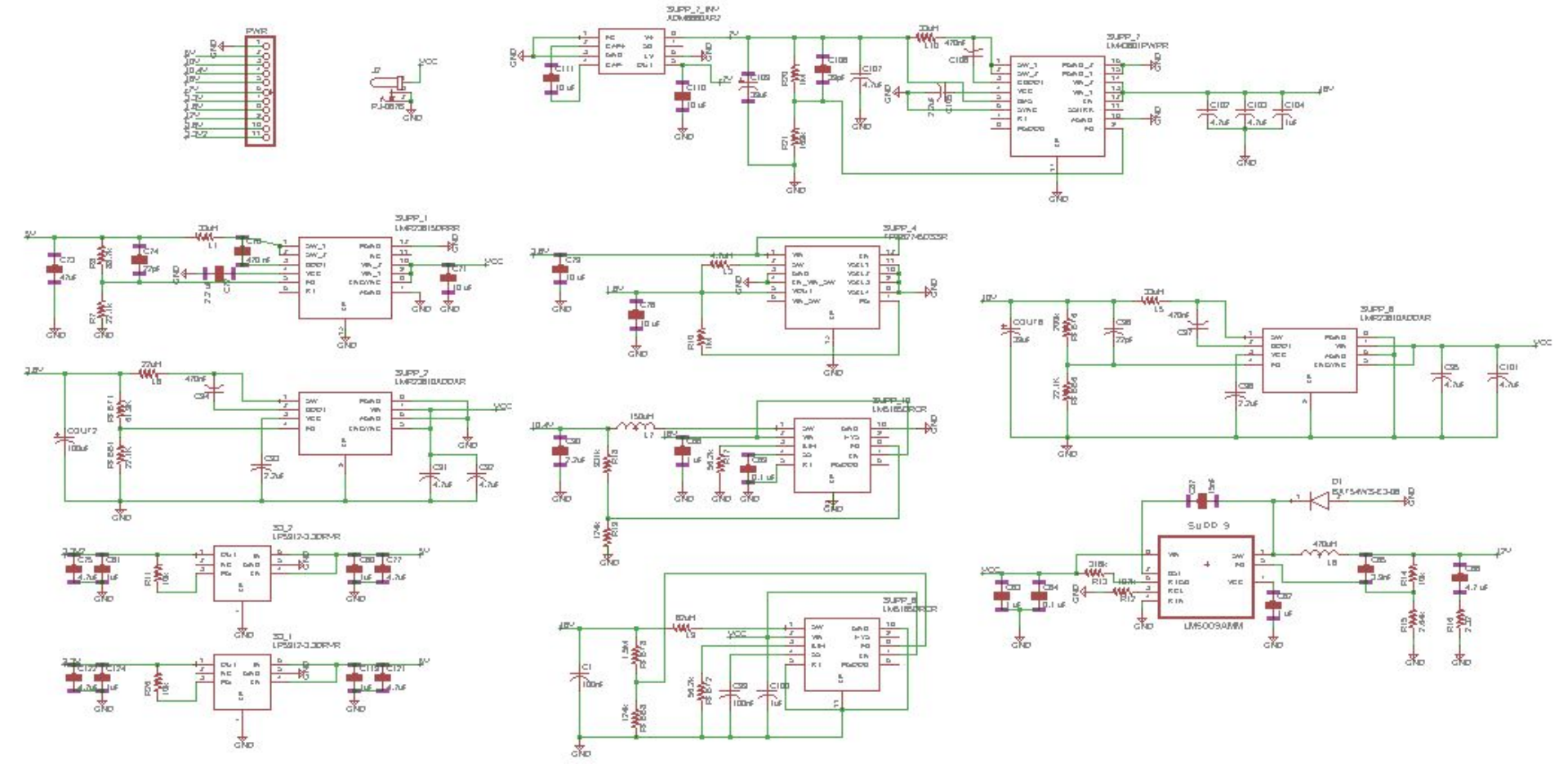
Power Requirements (continued)

COMPONENT	V_{SUPP} (V)	I_{SUPP} (mA)
Resistive Touch Screen Controller AR1021	3.3	0.125
SD Card Reader 104031-0811	3.3	500
Demultiplexer CD74HC238M	3.3	50
SG90 Servo motor	5	220
Fingerprint Scanner R307	5	50
Audio Amplifier LM386	12	4

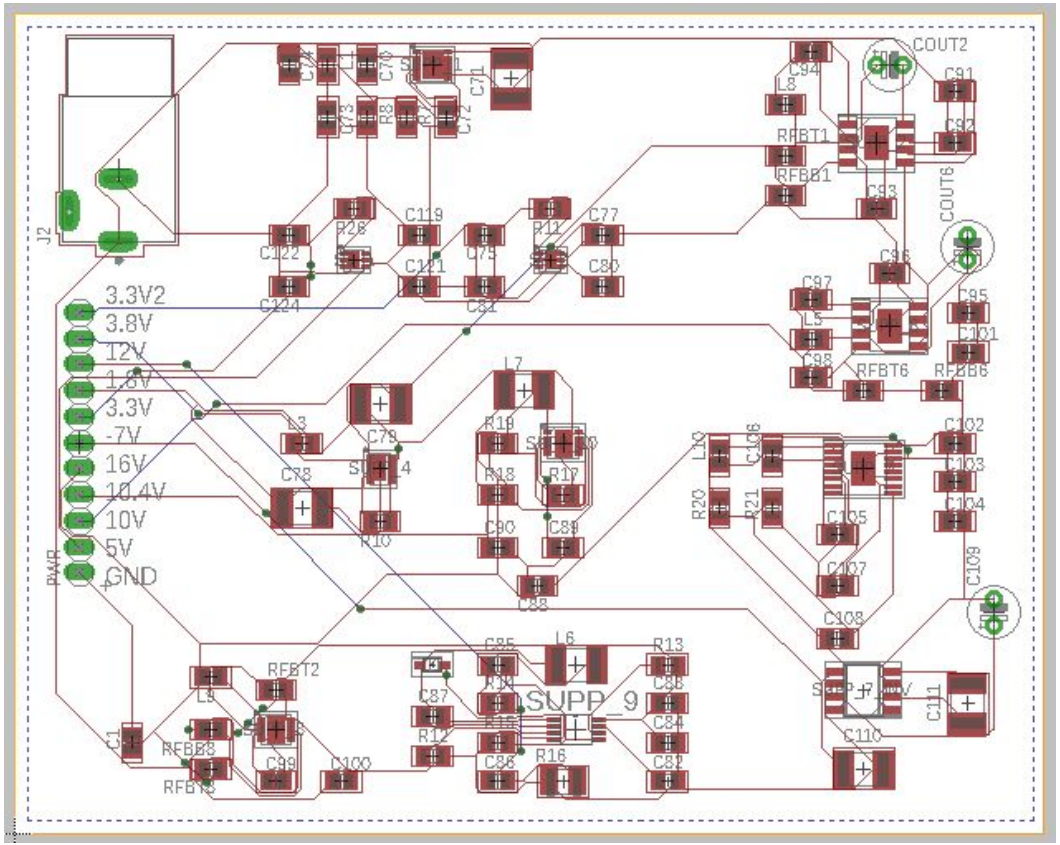
Voltage Regulation Devices

DEVICE	$V_{IN, MAX}$ (V)	V_{OUT} (V)	$I_{OUT, MAX}$ (A)
LP5912-3.3 LDO	6.5	3.3	0.5
LMR23615 regulator	36	5	1.5
LMR23610 regulator	36	3.8, 10	1
TPS62745 regulator	10	1.8	0.3
LM43601 regulator	36	7	1
ADM8660 inverter	7	-7	0.1
LM5165 regulator	65	16, 10.4	0.15
LM5009 regulator	95	12	0.15

Voltage Regulation Schematics

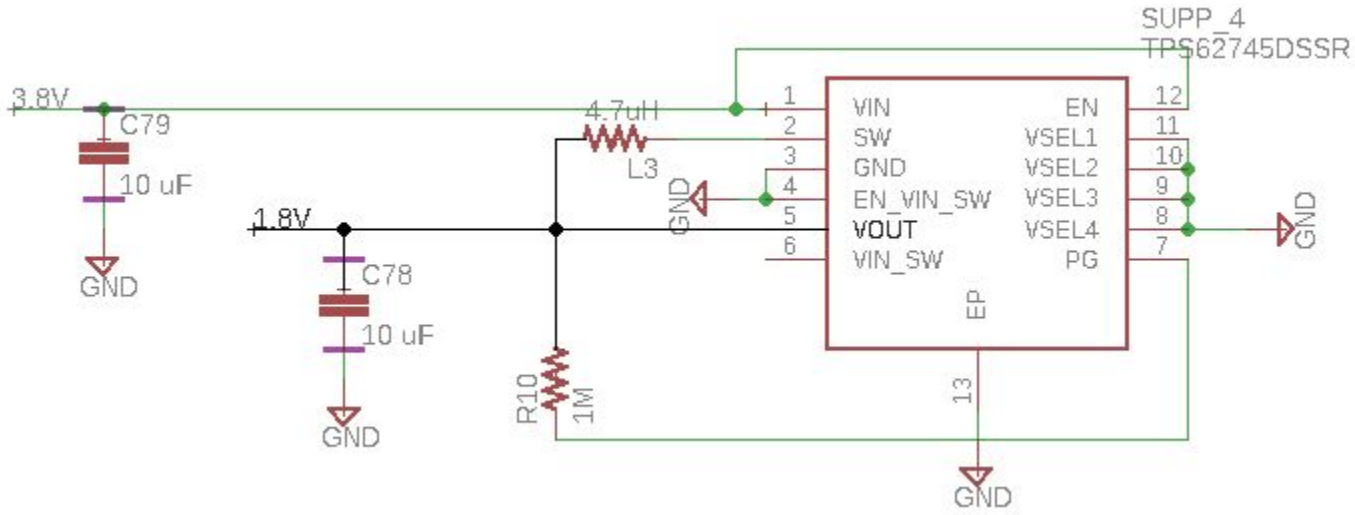


Voltage Regulation PCB



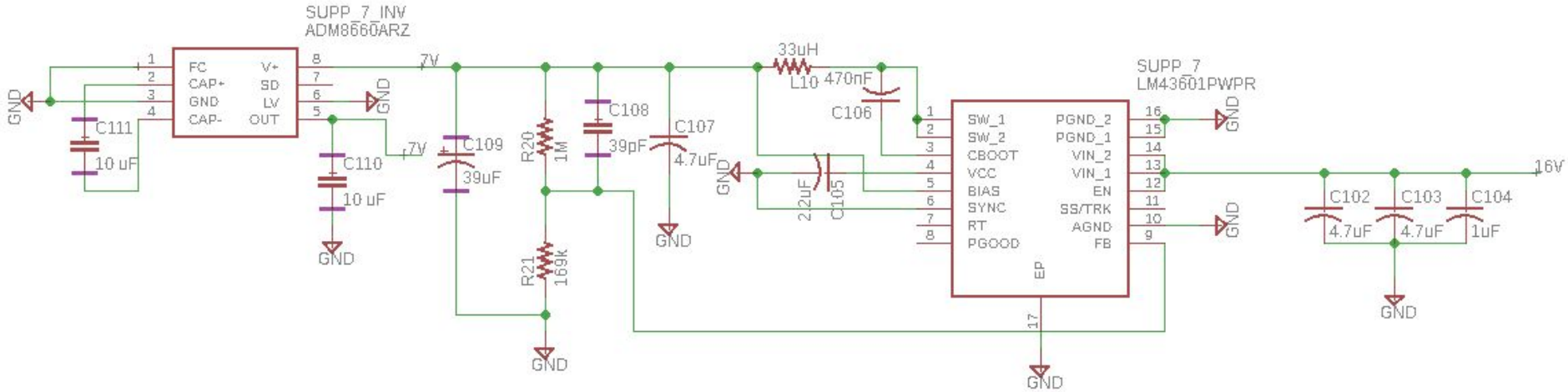
TPS62745 Step down converter

- Pi requires 1.8V power supply
- Programmable output through output voltage selection pins



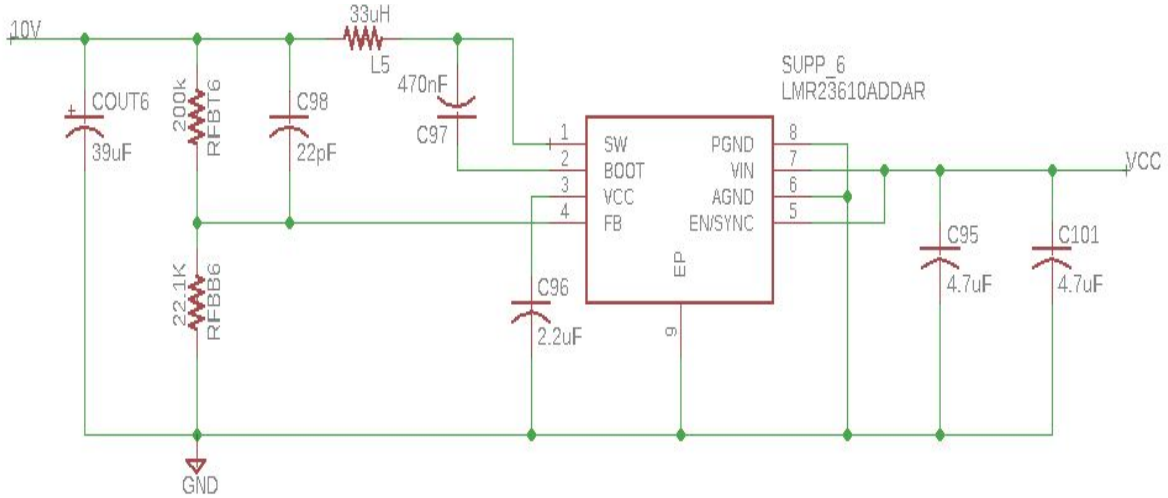
Power Supply: -7V

- LCD display requires V_{GL}= -7V (gate off voltage)
- LM43601 step-down voltage converter regulates +7V
- ADM8660 inverts input supply voltage
- $R_{FBB} = V_{FB}R_{FBT}/(V_{OUT}-V_{FB})$, R_{FBT}=1MΩ, V_{FB}=1.016V, R_{FBB}=169k



LMR23610 simple switcher

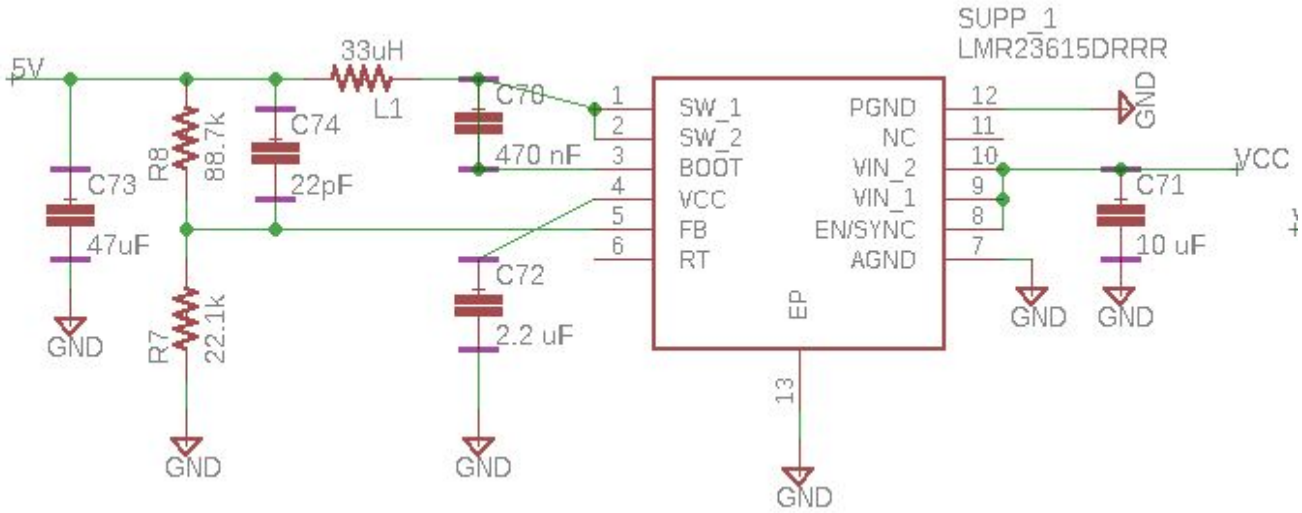
- LCD display requires 3.8V and 10V power levels
- $R_{FBT} = (V_{OUT}-V_{ref})\, R_{FBB} / V_{ref}$, V_{ref}=1V, R_{FBB}=22.1kΩ



Output Voltage	R_{FBT}
3.8V	61.9k
10V	200k

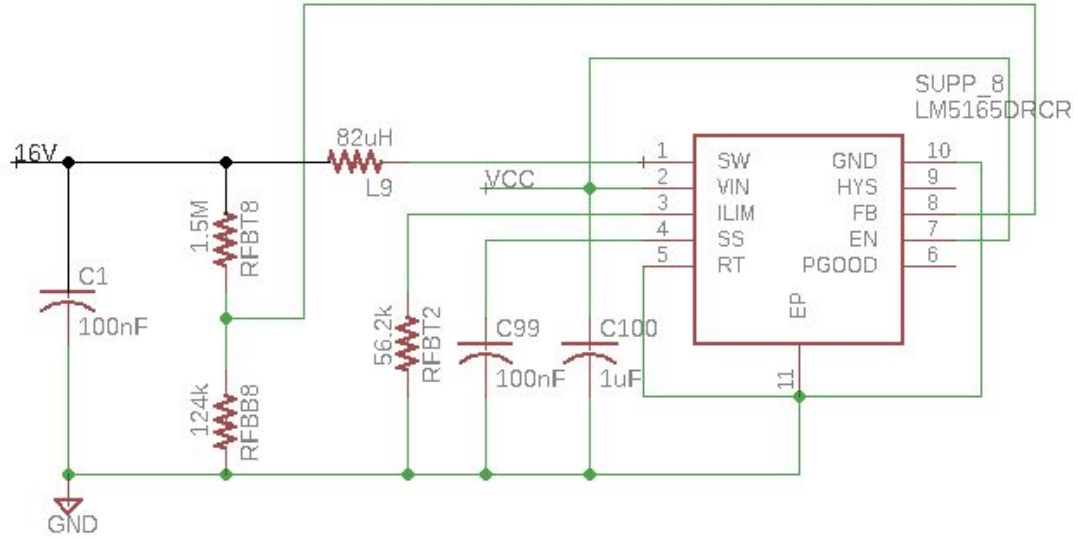
LMR23615DRRR Synchronous step-down converter

- 5V power supply required for ATMEGA328P and peripherals
- $R_{FBT} = (V_{OUT}-V_{ref})\, R_{FBB} / V_{ref}$



LM5165 Synchronous Buck Converter

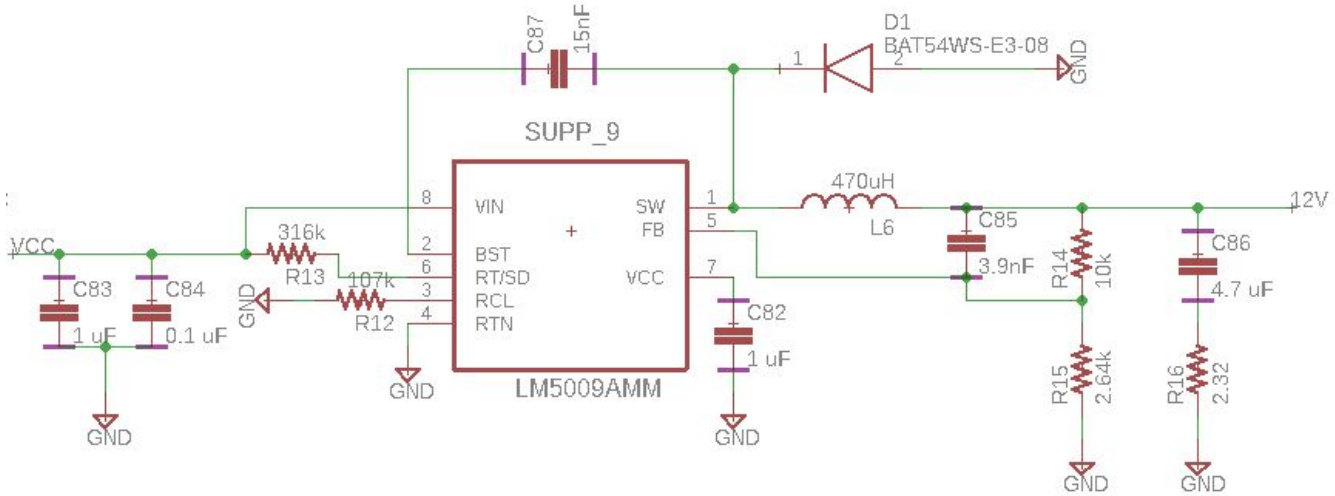
- LCD display requires input voltages of 16V and 10.4V
- $R_{FB2}=V_{FB}R_{FB1}/(V_{OUT}-V_{FB})$



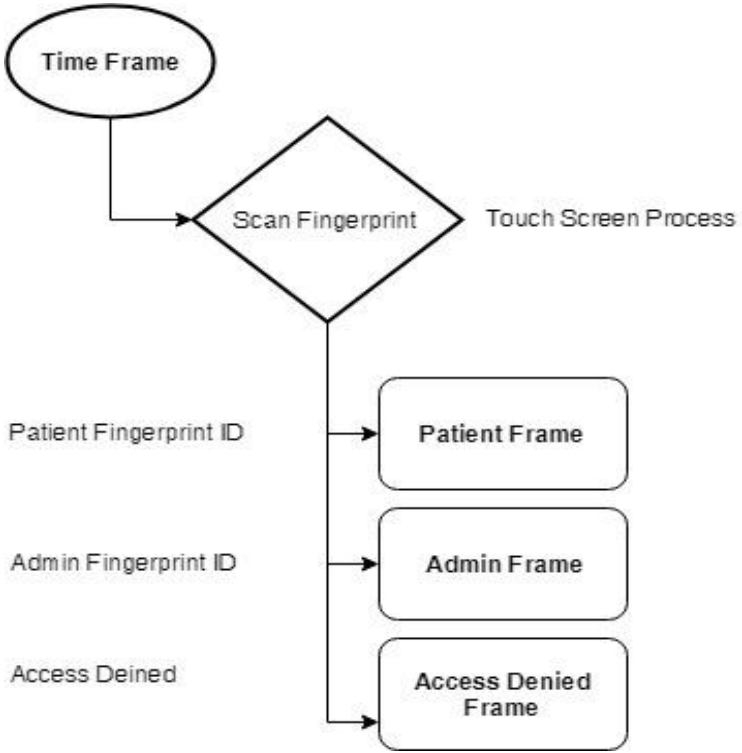
Output voltage	R_{FB2}
16V	1.5M
10.4V	931k

LM5009AMM step-down switching regulator

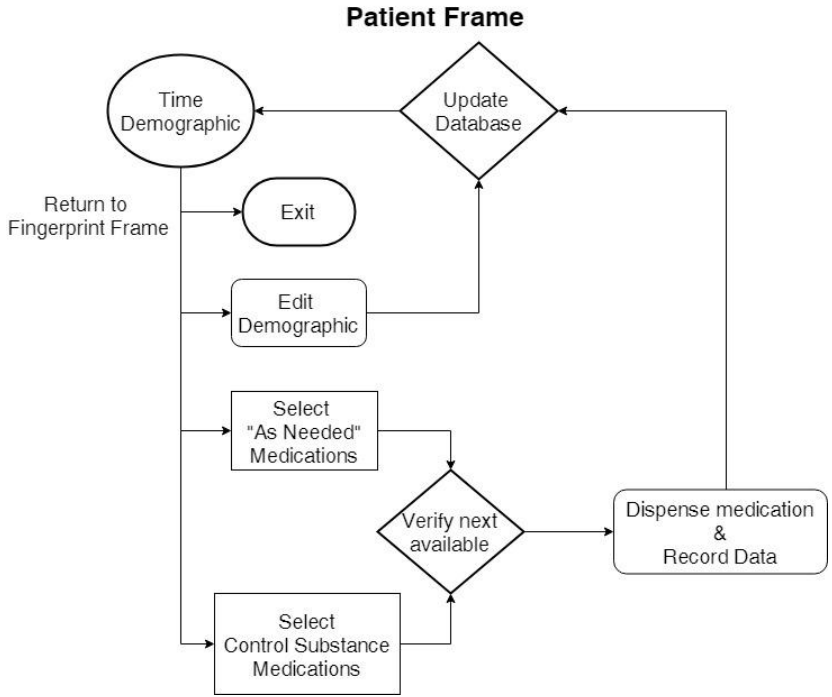
- Speaker amplifier requires 12V supply
- $V_{OUT}=V_{FB}*(R_1+R_2) / R_2$

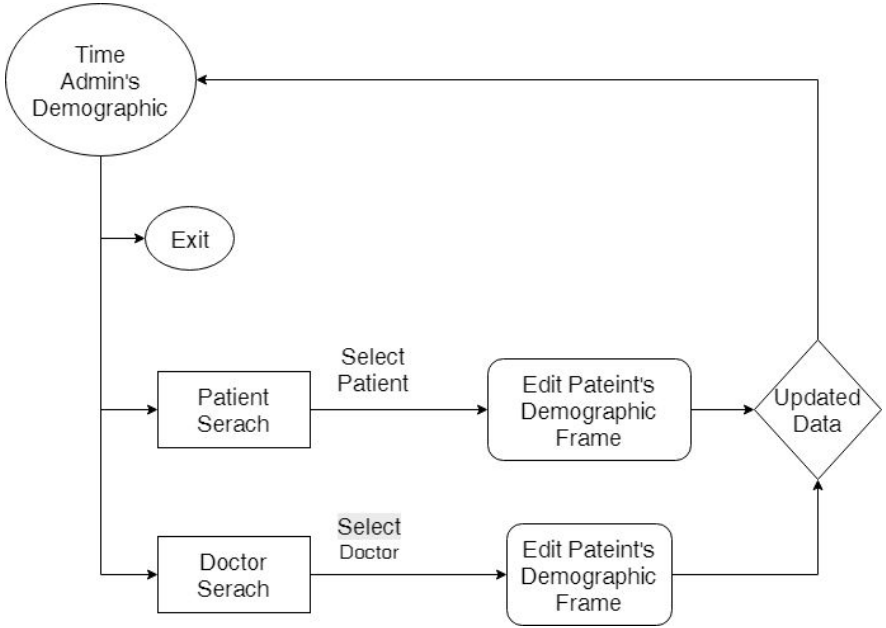


CM3L Software Diagram

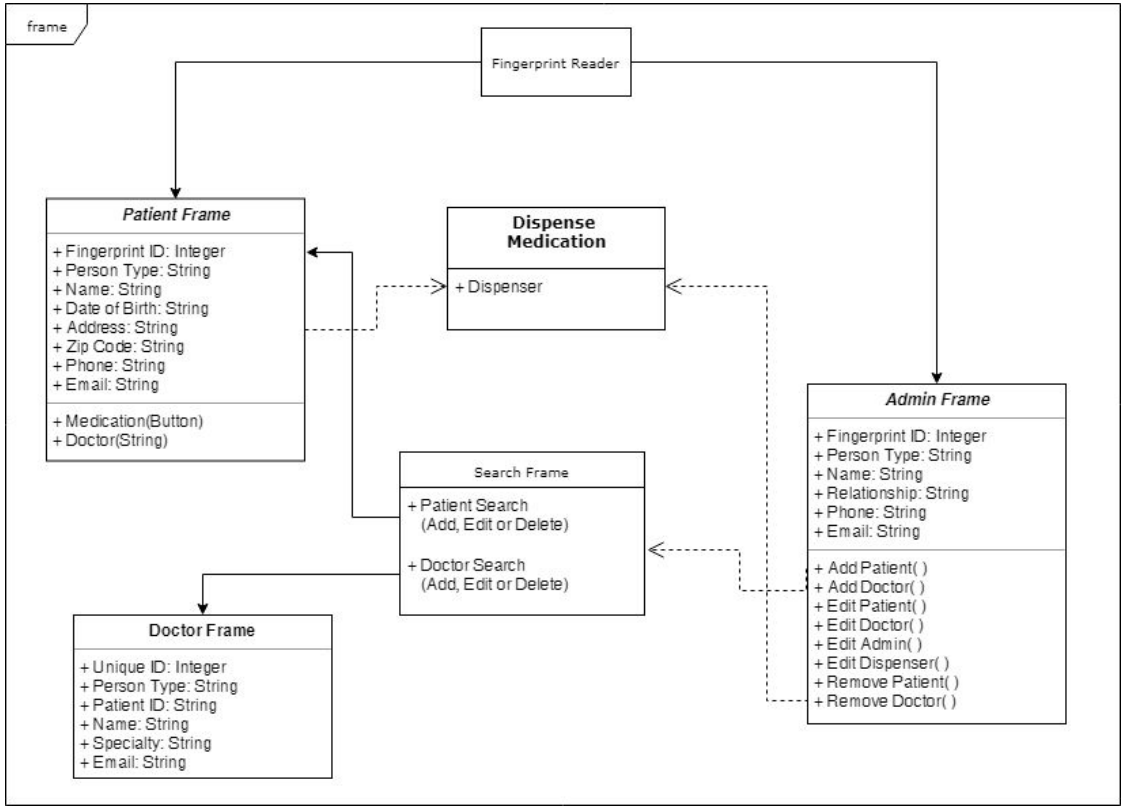


Patient and Administrator Framework

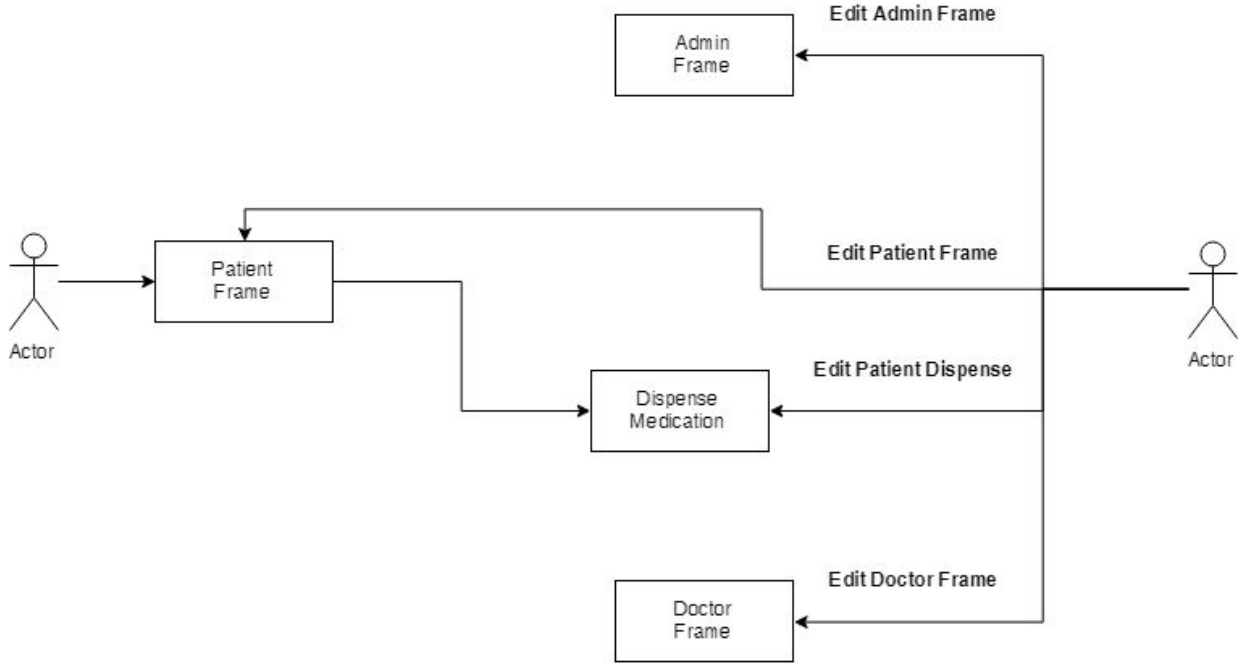




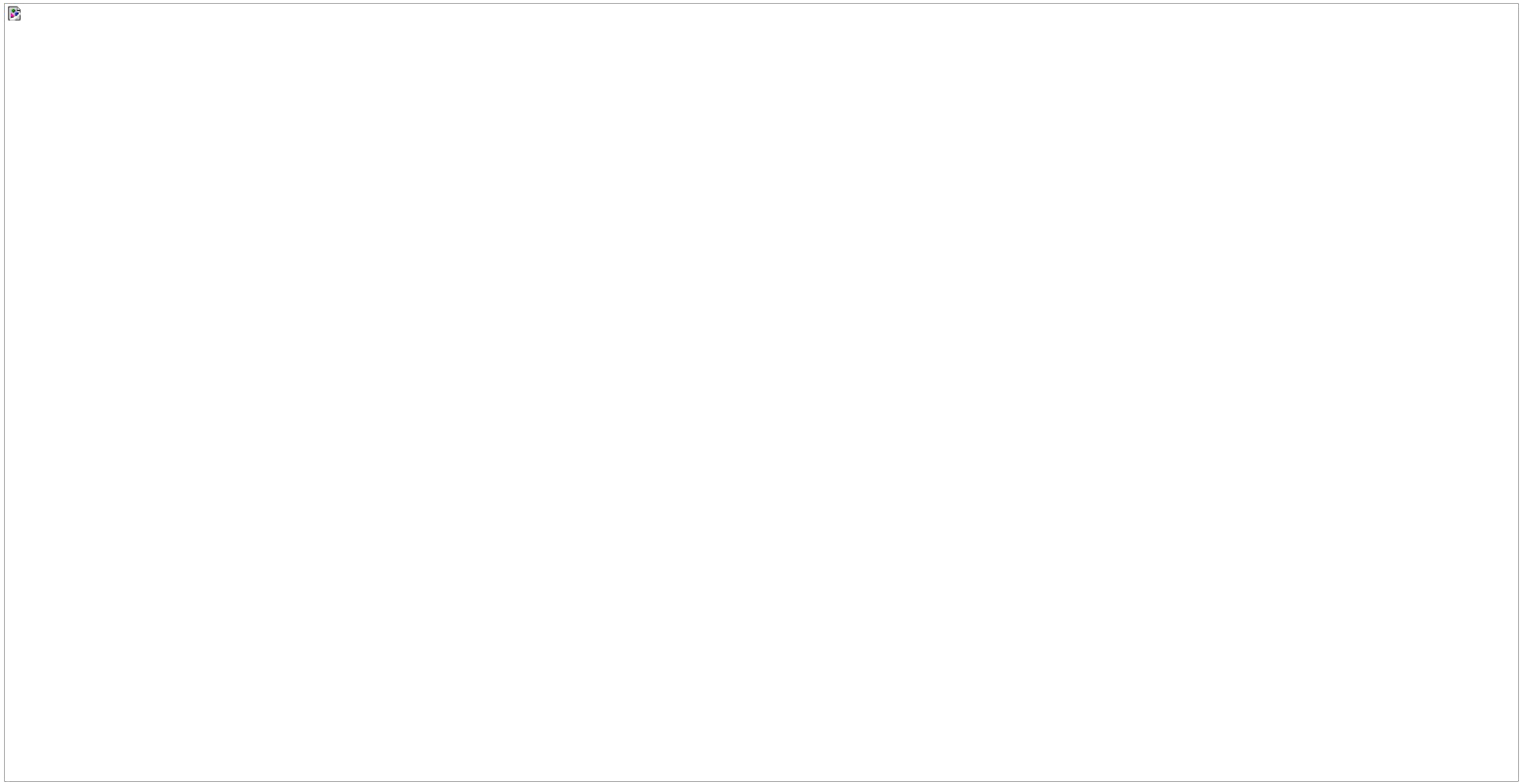
Class Diagram



User Case Diagram



ATMega328P Software



ATMega328P Commands

Command Frame

I2C Address	Command	Parameter
0x18	1 byte	1 byte

Command	Parameter	Return Value
Scan Fingerprint <0x01>		Fingerprint ID <1-127>
Register Fingerprint <0x02>	Fingerprint ID <1-127>	Fingerprint ID <1-127>
Dispense <0x03>	Cylinder number <1-5>	
Play Alarm <0x04>		

WORK DISTRIBUTION

	Power Regulation	Controller Circuitry	Peripheral Circuitry	Embedded Development	Communication Interfacing	Python Development
Gustavo	**P**		**P**	S		
Ivan					S	**P**
Matthew		S		**P**	**P**	
Sakeenah	**P**	**P**	**P**			

BUDGET: TOTAL = $440.92

COMPONENT	COST	DISTRIBUTOR
Display AT070TN90	$20.00	Alibaba
Microcontroller ATMEGA328P-PU	$2.15	Mouser
Raspberry Pi CM3 Lite	$25	ALLIED/Element14
CM3L Conector	$20	ALLIED
Servo Motors SG90 x5	$8.85	Amazon
Touchscreen	$14.99	Alibaba
Fingerprint Reader R307	$9.90	AliExpress (HZGROW)
ESP-12F	$3.05	Banggood
Capacitors	$25.05	Mouser

BUDGET: TOTAL = $455.92 (221.95 R&D)

Diodes	$0.80	Mouser
Voltage regulators	$30.42	Mouser
PCBs	$40.00	JLCPCB
Speaker	$2.06	Mouser
SD card slot	$1.75	Mouser
Amplifier LM386	$0.88	Mouser
Demultiplexer CD74HC238M	$0.65	Mouser
DC power jack PJ-067B	$2.50	Mouser
50p TTL interface connector	$3.19	Mouser
BSS138 MOSFETs x2	$0.54	Mouser
RPI CM3L Dev Kit (R&D)	$200	Element14

CHALLENGES

1. PIC32 graphics framework non-functional
2. I2C communication
3. Numerous power supplies for LCD display
4. LCD backlight drew too much current

QUESTIONS?