

The Memrowave



- Designing the microwave of the future
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- Joseph Serritella (EE)
- Winston Todd (CpE)

Project Goals and Requirements

- The Goal of the project was to analyze the possible design solutions to create
 - Automated Microwave
 - Using Barcode scanning
 - WiFi connectivity
- Design a microwave that has
 - An automatic timer and 10 power levels
 - Local and online database
 - Touch screen interfacing

Microwave specifications

- Developing a system that
 - Scans barcodes within an average of 5 seconds
 - Minimum storage capability for 1000 products
 - Cycle through 10 power levels
 - Power DC components with a maximum of 2 Amps
 - Utilize 2.4 GHz Wi-Fi connections

Hardware Requirements

| Requirement | Constraint |
|------------------------------|----------------------|
| Resolution LCD | 480X272 |
| Camera Frame Rate | 24 Frames per second |
| LCD screen size | 4.3" |
| GPIO pins on microcontroller | 4 pins |
| Communication | I2C |
| Storage size | 512MB |
| Max power consumption | 1070W |

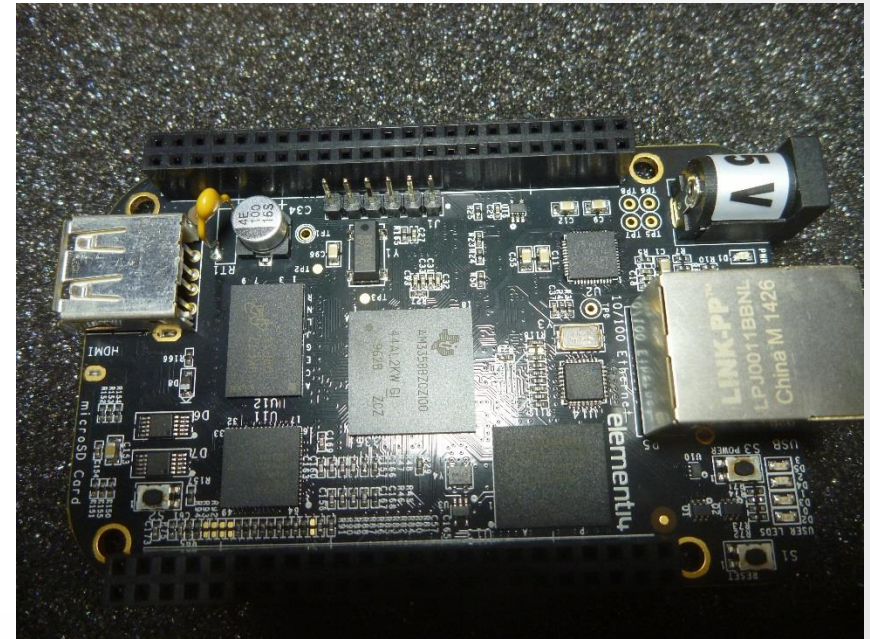
Hardware Selections

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Selecting components to interface with
microwave's subsystems

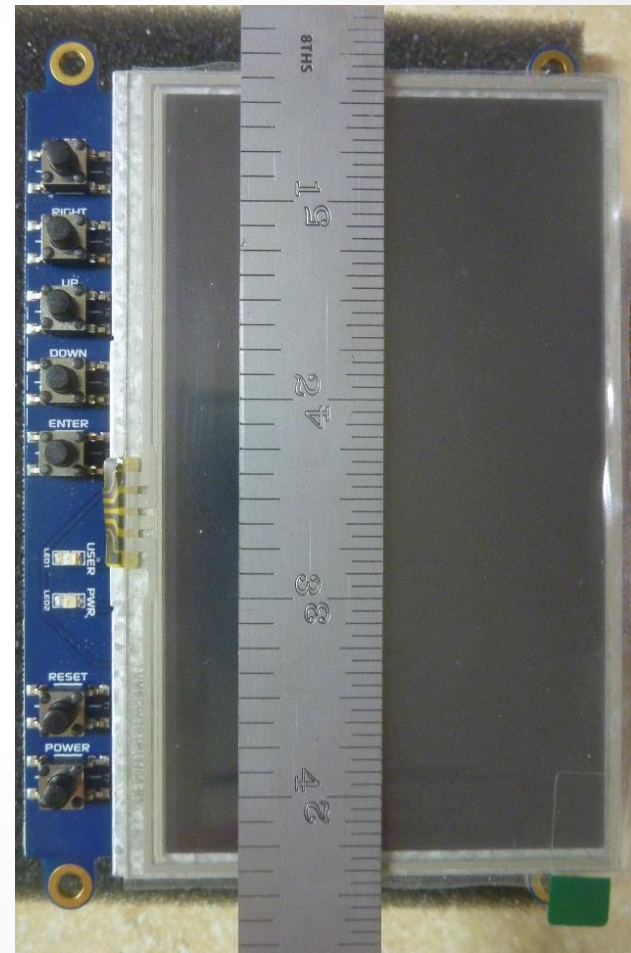
User Interface/Control

- element14 Beaglebone Black Rev C
- AM3358 Sitara ARM Cortex-A8
- 1 GHz
- 512MB DRAM
- Android 4.2.2 Jelly Bean
- Linux Kernel 3.2
- 5V, 460mA
- GPIO, I²C



LCD Touchscreen

- 4D Systems 4DCAPE-43T
- 4.3" TFT LCD
- 480x272 resolution (portrait)
- Resistive touch
- Powered with 5V directly from BBB headers
- Dimensions: 4.74x3.15"



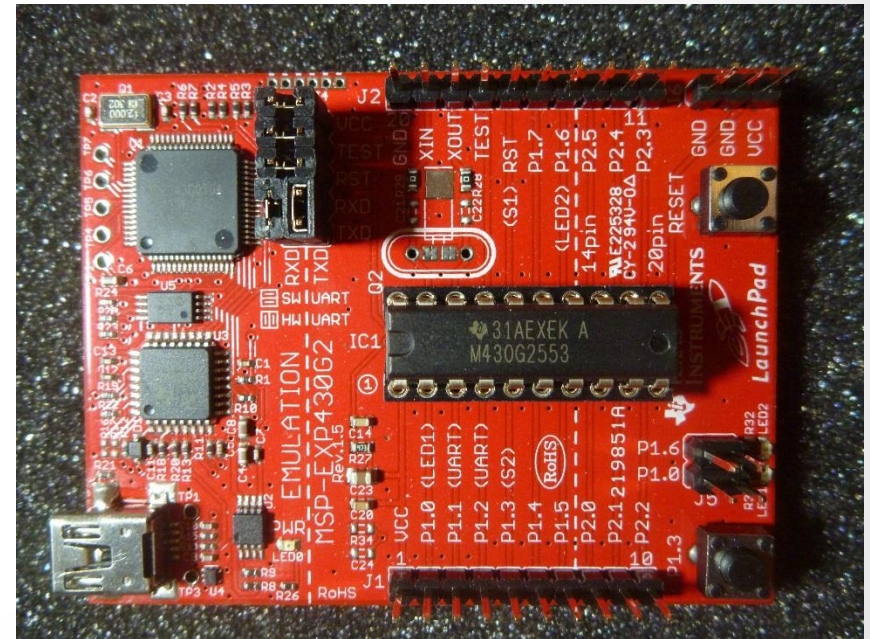
USB Camera/Wifi

- Logitech HD C270
- Video capture up to 1280 x 720 pixels
- Photo up to 3.0 megapixels
- Logic Supply UWN200
- MediaTek MT7601 (Ralink 7601) controller
- 2.4GHz, 802.11b/g/n
- 4" antenna



Microwave Control

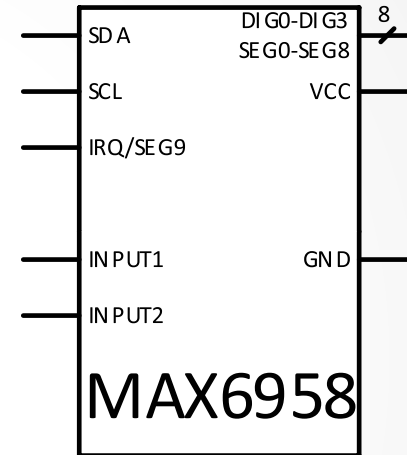
- Texas Instruments MSP430G2553 microcontroller
- 16MHz
- 16KB flash
- 1.8 - 3.6V, 330 μ A/MHz
- 20-pin plastic dual in-line package (PDIP)
- GPIO, I²C



7-Segment LED Display

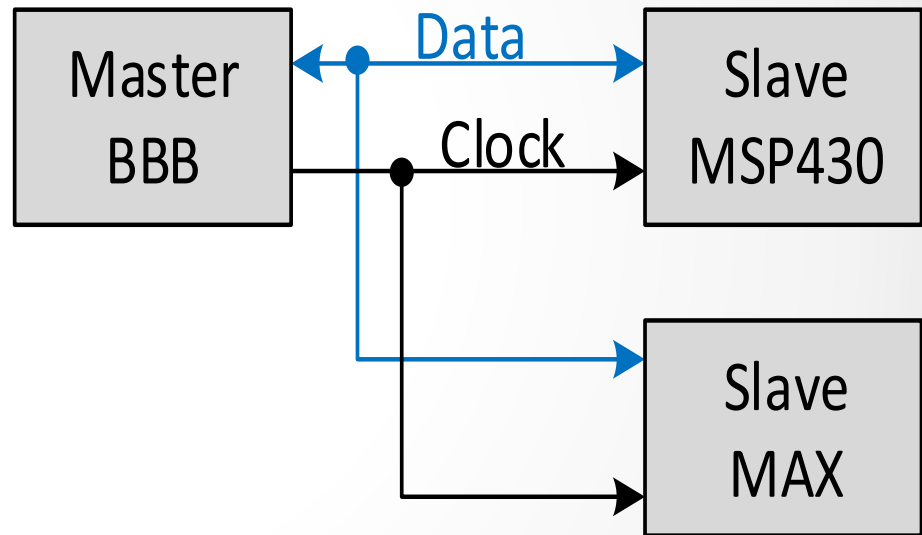
- Maxim Integrated MAX6958
- LED display controller
- 16-pin PDIP
- 3V to 5.5V
- I²C

- Lite-On LTD-4708JR (x2)
- 2-digit, 7-segment LED modules
- 0.4-inch digit height

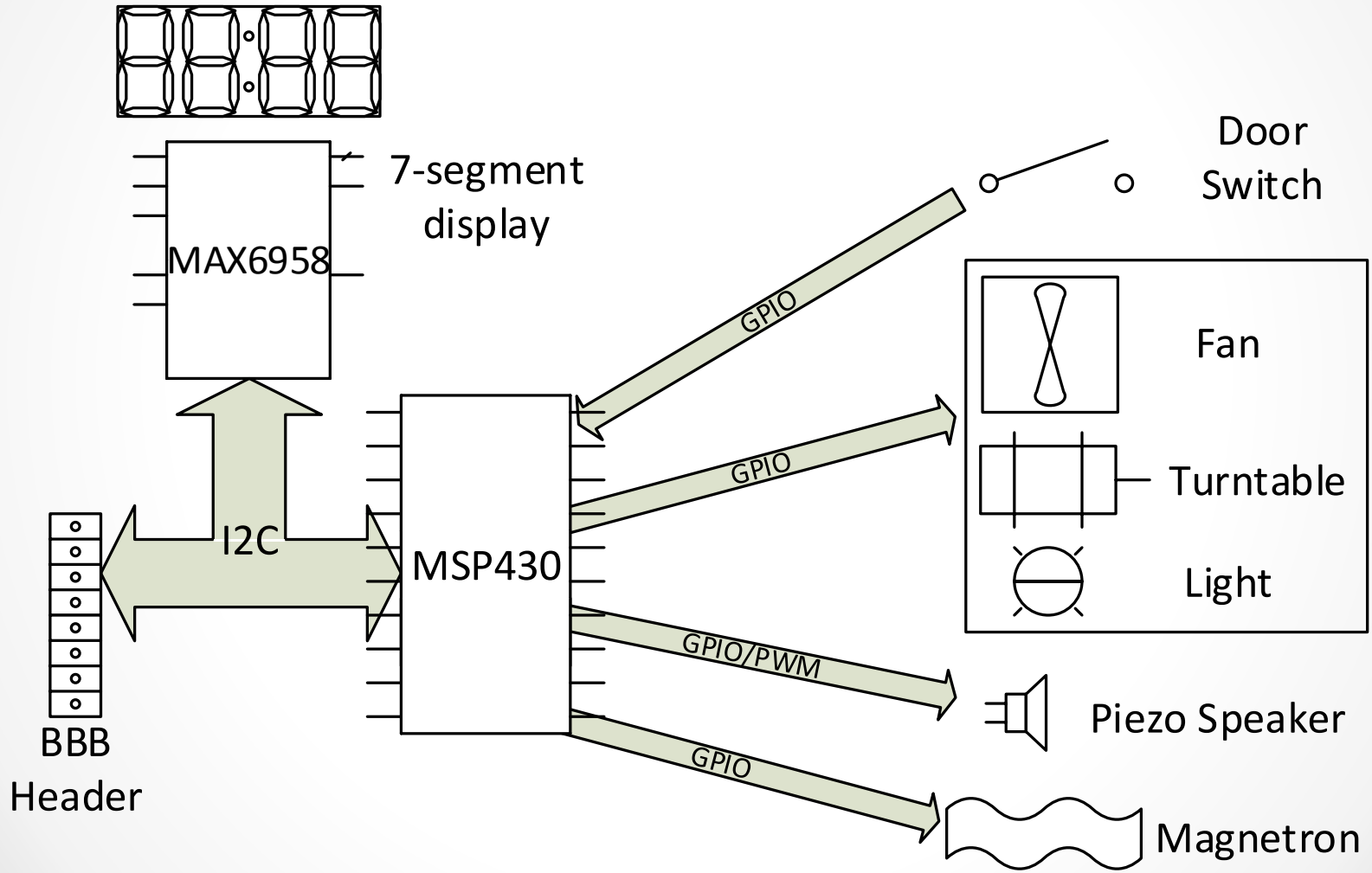


Inter-Integrated Circuit (I²C)

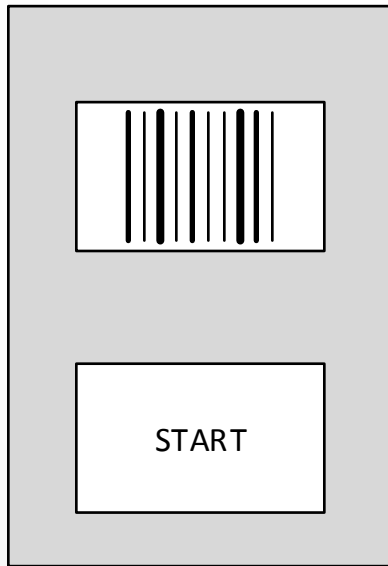
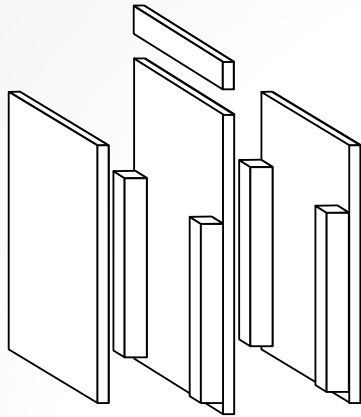
- Computer bus
- Serial communication
- Half duplex
- Multi-master
- Up to 1008 nodes (10-bit addressing)
- Single-ended signal
- 0.1-5.0 Mbit/s



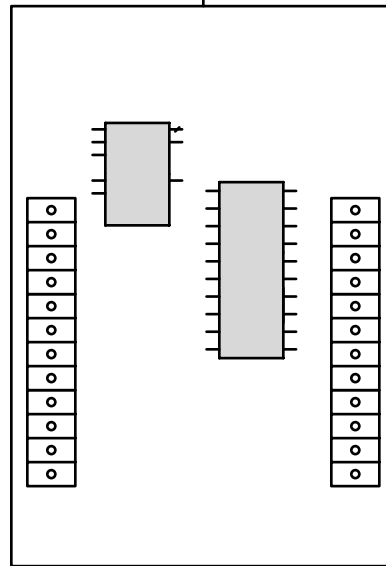
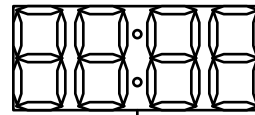
Microwave Control



Boards



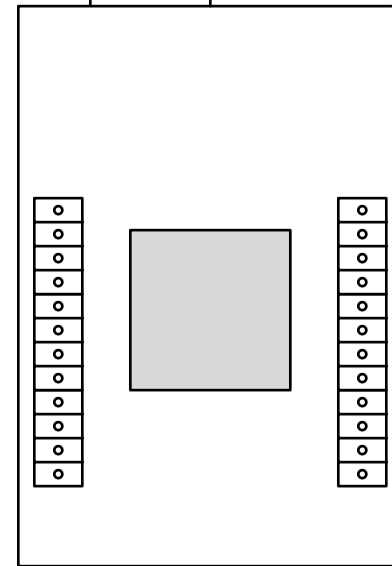
LCD



PCB

WiFi

Camera



BBB

MSP430G2553

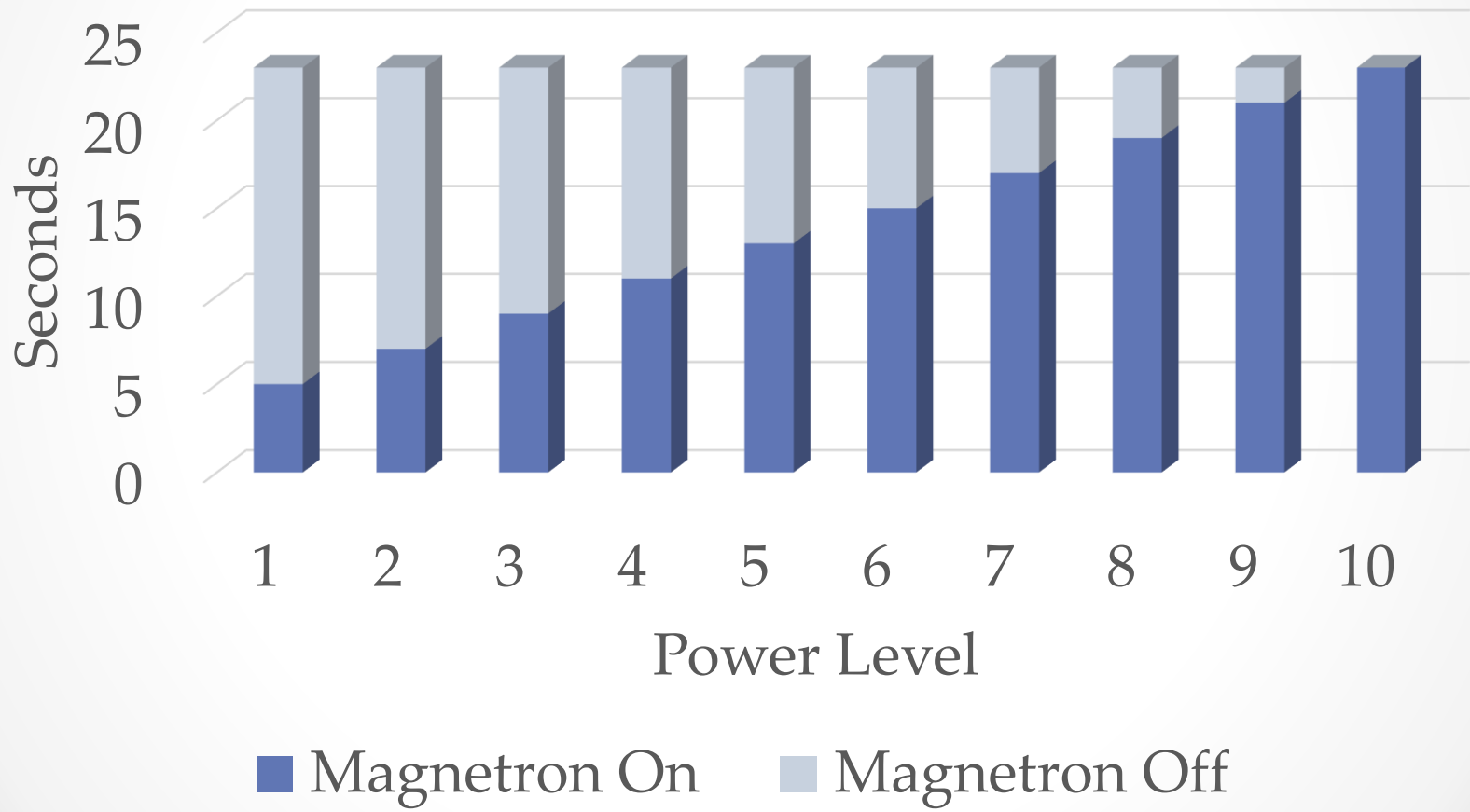
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Control of Memrowave cook systems

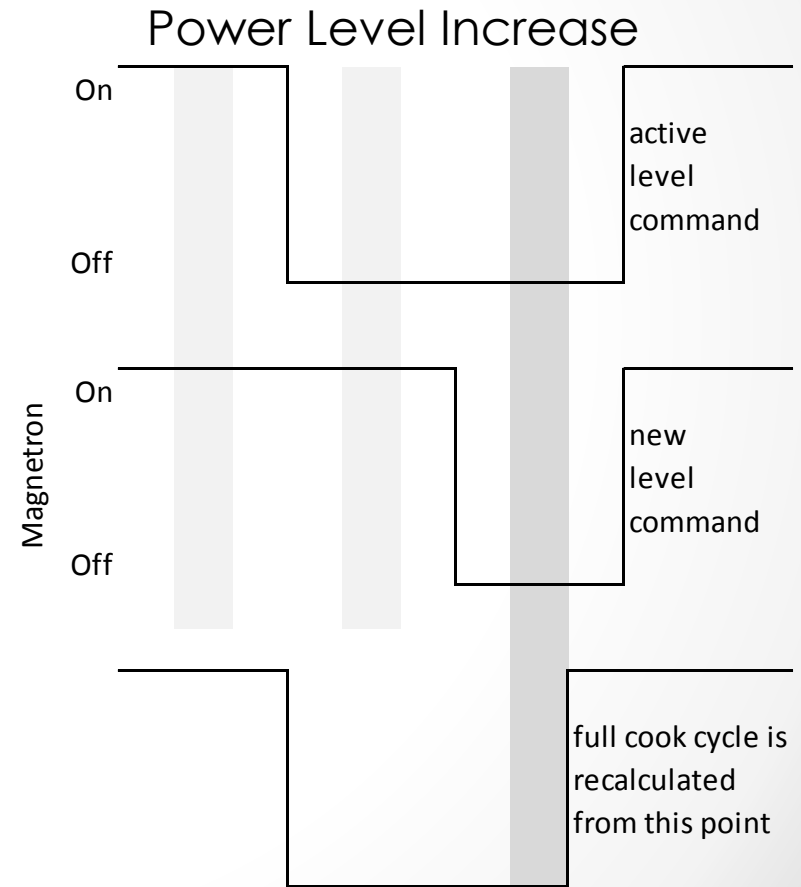
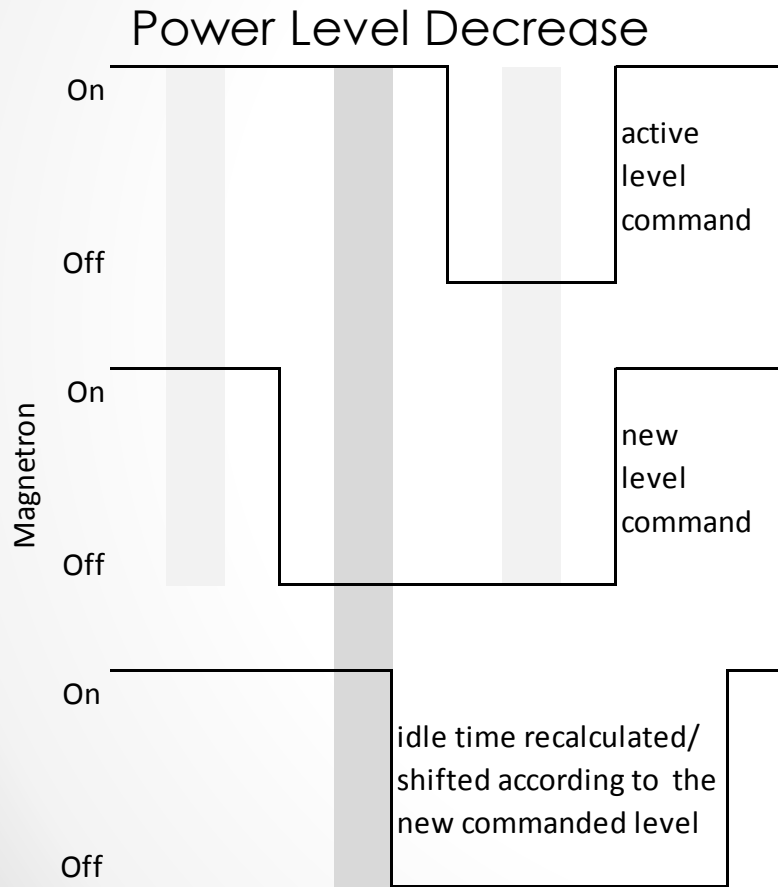
MSP430G2553

- User safety
 - Operate only at commanded power level
 - Stop operation when door is opened
 - Stop cooking within a maximum of 1 second if Beaglebone Black is unresponsive
- Operation
 - 5 sec minimum magnetron on-time
 - Minimum magnetron off-time for power transitions
 - < 100ms command execution response time
 - Actual response time achieved: < 15ms

Cooking Cycle



Power Level Transition



Web Database

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Internet accessible products database

Web Database

- A web database of products was implemented so users will not have to manually enter product information
- Product settings can be cached to the Memrowave's local database
- MongoDB was used for the database
- Node.js + Express for the web server
- REST API will deliver JSON-formatted data


Web Database Schema

```
product( {  
  name: String,  
  description: String,  
  upc: { type: String, index: true },  
  image_url: String,  
  steps: [ ( {  
    step_number: Number,  
    instructions: String,  
    cook_time: Number,  
    power_level: Number,  
    pause_before_step: Boolean  
  } ) ]  
} )
```

Web Database

HTML Output

server-memrowave.rhcloud.com/product/552f496c41523ba62f4c82eb



Description Individual snack bag.

UPC 023896529202

Step1

- Instructions**
MIGROWAVE AND LISTEN! Stop microwave when popping begins to slow down (about 2 seconds between pops).
- Cook Time**
120 seconds
- Power Level**
10
- Pause Before Step**
true

JSON-formatted Data

server-memrowave.rhcloud.c

```
{"name":"Pop-Secret Movie Theater Butter Popcorn (1.75oz)","description":"Individual snack bag.","upc":"023896529202","_id":"552f496c41523ba62f4c82eb","__v":0,"steps":[{"step_number":1,"instructions":"MIGROWAVE AND LISTEN! Stop microwave when popping begins to slow down (about 2 seconds between pops).","cook_time":120,"power_level":10,"pause_before_step":true,"_id":"552f496c41523ba62f4c82ec"}]}
```

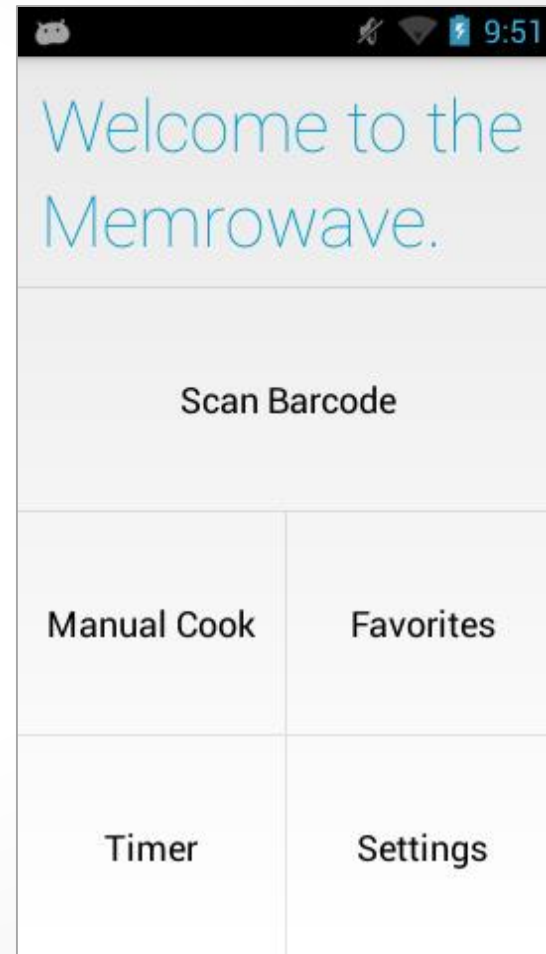
Application Software

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User interface and control of Memrowave systems

Home Screen

- Main entry point
- Five options
 - Scan a barcode
 - Manual Operation
 - Favorites
 - Timer
 - Settings



Barcode Scanner

- Using the Zbar library to decode barcodes
- Align barcode on the screen automatically scan and decode
- Beep confirmation of scan success
- Scan result used to search for matching products



Product Database

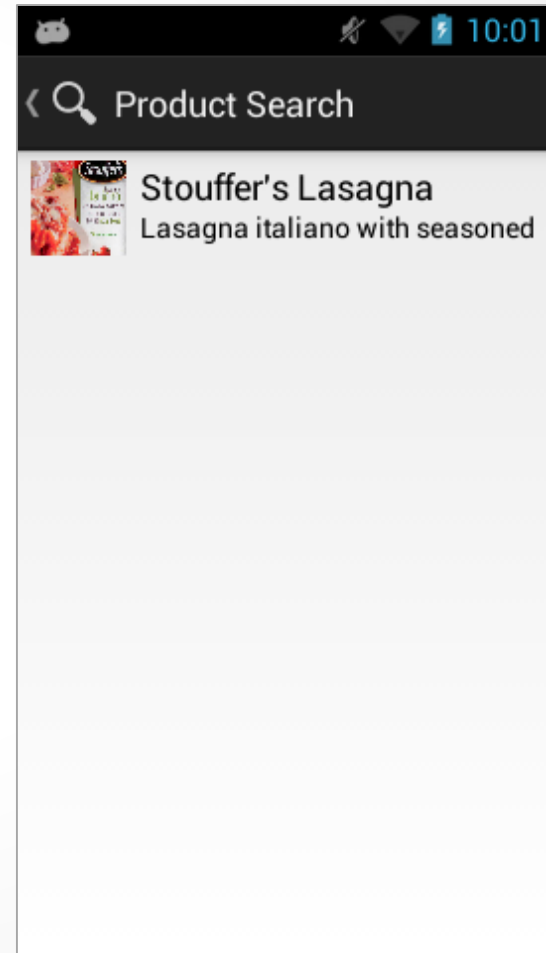
- A local SQLite3 database is used to store product information, including:
 - Product name
 - Product description
 - Location of product image
 - Cooking steps, with
 - Step instructions
 - Power level
 - Cook time

| Product |
|----------------|
| id |
| name |
| description |
| upc |
| image_location |

| Step |
|--------------|
| id |
| product_id |
| instructions |
| cook_time |
| power_level |

Product Search

- Lists all products with matching barcode
- Search locations:
 - Local database
 - Web database
- Selecting a product will bring up the Product Description screen, allowing the user to cook the product



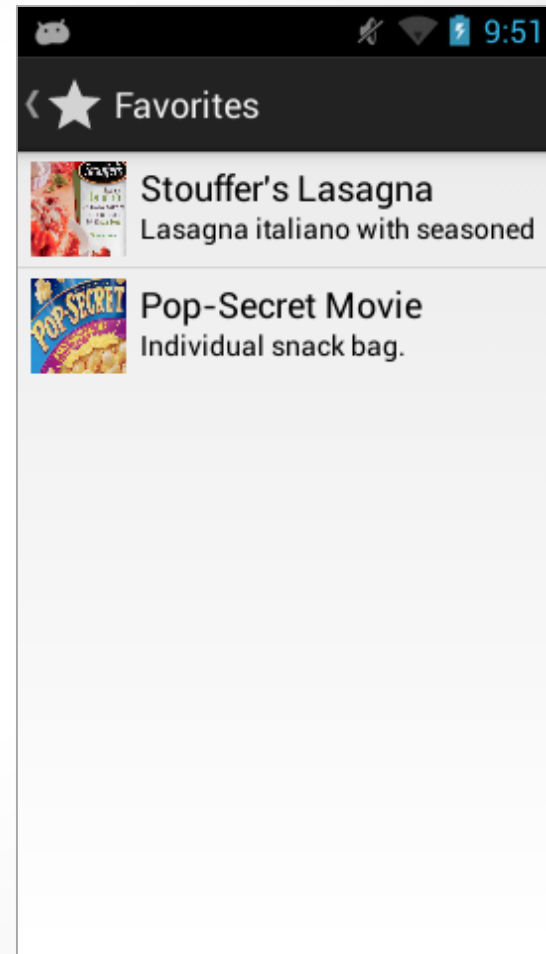
Product Description

- Displayed after a successful barcode scan, if a matching product can be found
- The user can favorite, edit, or delete the product.
- Cook button will display the first step of the cooking process



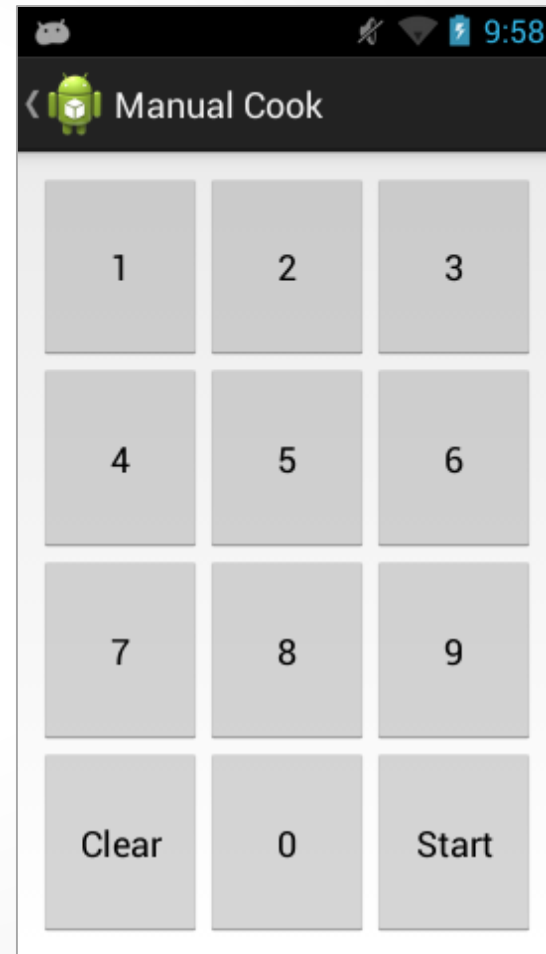
Favorites

- A table in the database is used to store a list of favorite products
- Allows quick access to frequently used products
- Quicker than scanning a barcode



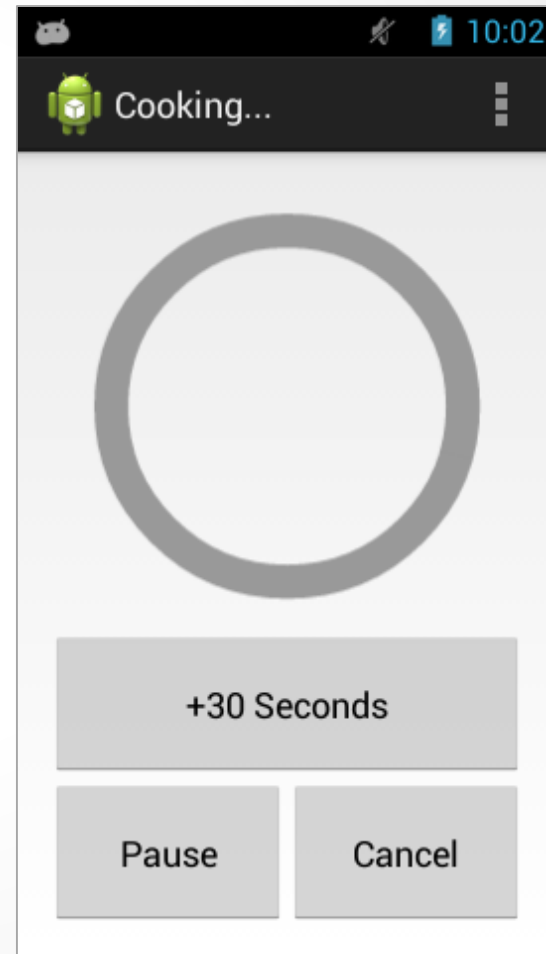
Manual Operation

- Some items don't have convenient barcodes
- Some users will prefer complete control over microwave operation
- Allow the user to manually set cook time like a standard microwave



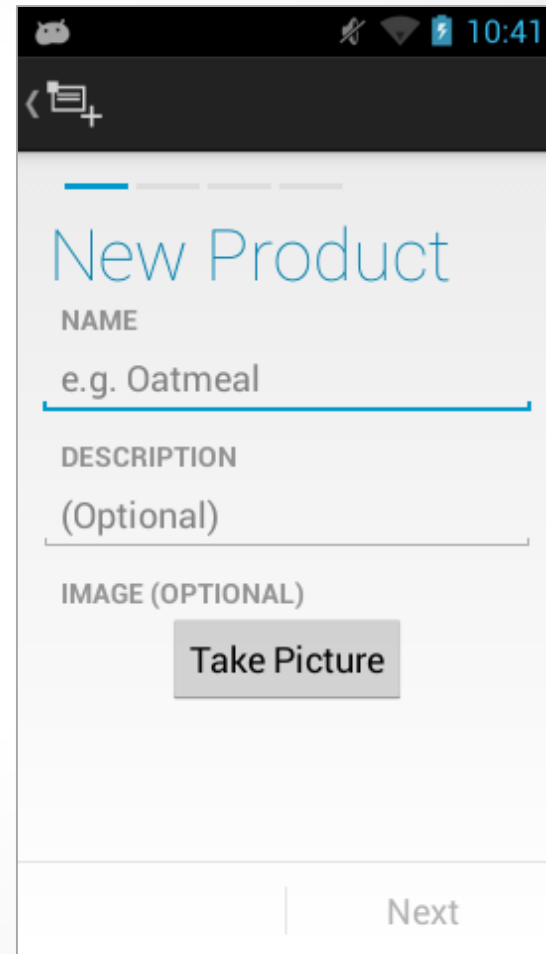
Cook Screen

- Displayed while the Memrowave is cooking
- Must remain on the screen to continue cooking
 - Avoid situations where the user cannot stop the microwave
- Countdown shown on the 7-segment display



New Product

- User can manually add product entries
- Built in camera can be used to take a picture of the product and scan the barcode
- User will manually enter cook time and power level
- Product is saved to the local database

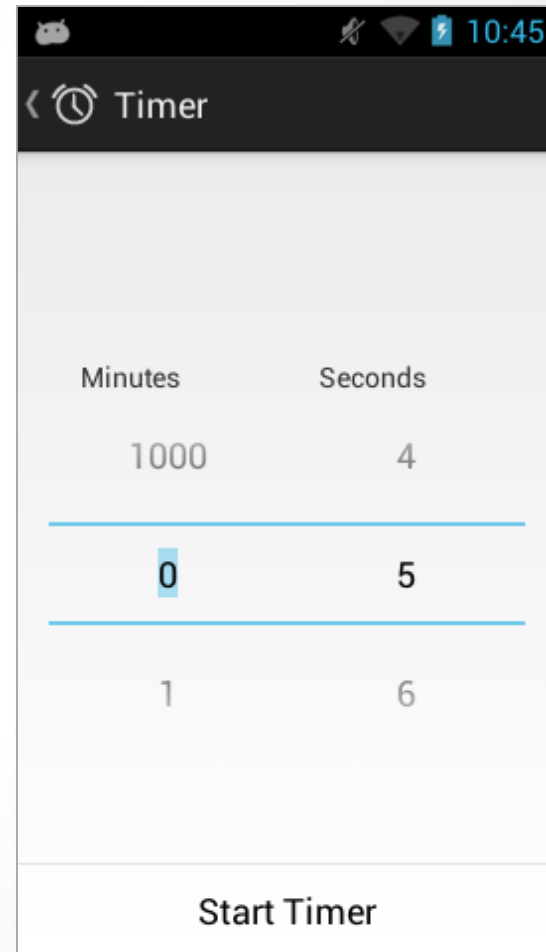


The screenshot shows a mobile application interface for adding a new product. At the top, there is a black status bar with an Android logo, signal strength, Wi-Fi, battery, and the time 10:41. Below the status bar is a dark navigation bar with a back arrow and a plus sign icon. The main content area has a light gray background and contains the following elements:

- A blue horizontal line followed by the title "New Product" in blue text.
- A label "NAME" in gray text.
- A text input field containing "e.g. Oatmeal" with a blue underline.
- A label "DESCRIPTION" in gray text.
- A text input field containing "(Optional)" with a gray underline.
- A label "IMAGE (OPTIONAL)" in gray text.
- A gray button labeled "Take Picture".
- A white bar at the bottom with a vertical line and the text "Next".

Timer

- Reuses the cook screen to count down without cooking
- Remaining time displayed on the 7-segment display
- Beeps upon completion



Powering Systems

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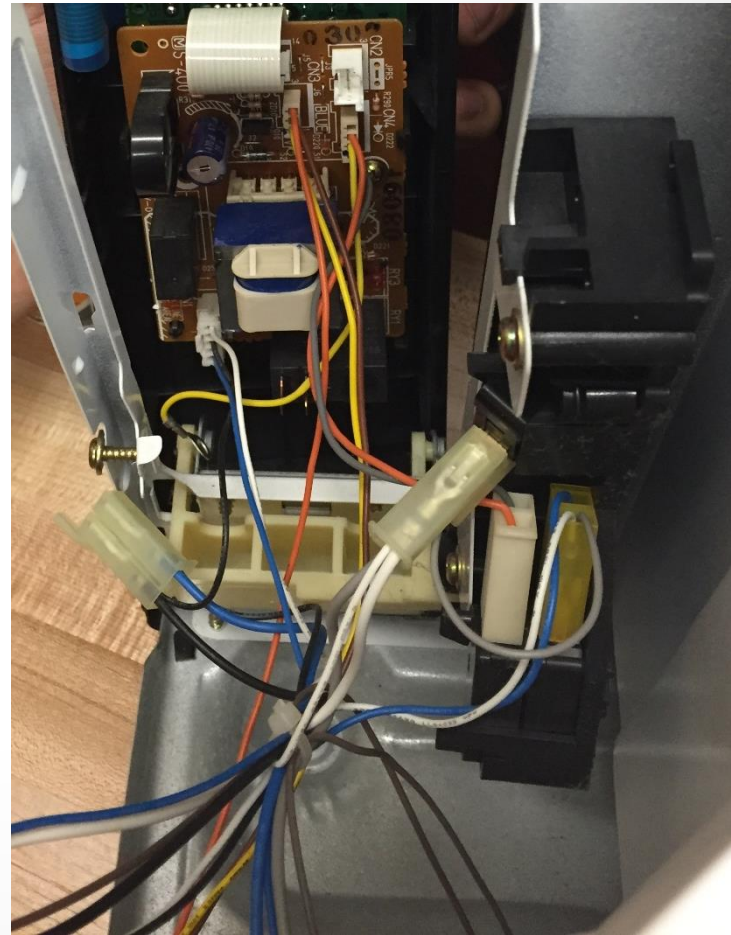
Powering elements in the Memrowave

Structure

- AC Components
- Internal Light
- Turntable Motor
- Cooling Fan
- Magnetron Transformer
- DC Components
- Beagle Bone Black
- LCD Display
- WIFI Module
- Camera
- 7 Segment Display

AC Power

- All components require 120 V
- Reuse of the most of the microwave's original wiring layout
- Adjustments made to door switches and magnetron relay



DC Components

| Component | Operating Voltage | Max Operating Current(mA) | Power(W) |
|-------------------|-------------------|---------------------------|----------|
| BeagleBone Black | 5 | 500 | 2.5 |
| LCD Display | 5 | 250 | 1.25 |
| WIFI Module | 5 | 500 | 2.5 |
| Camera | 5 | 500 | 2.5 |
| 7 Segment Display | 3.3 | 600 | 1.98 |
| MSP430 | 3.3 | 500 | 1.65 |
| | | Total Power | 12.4 |

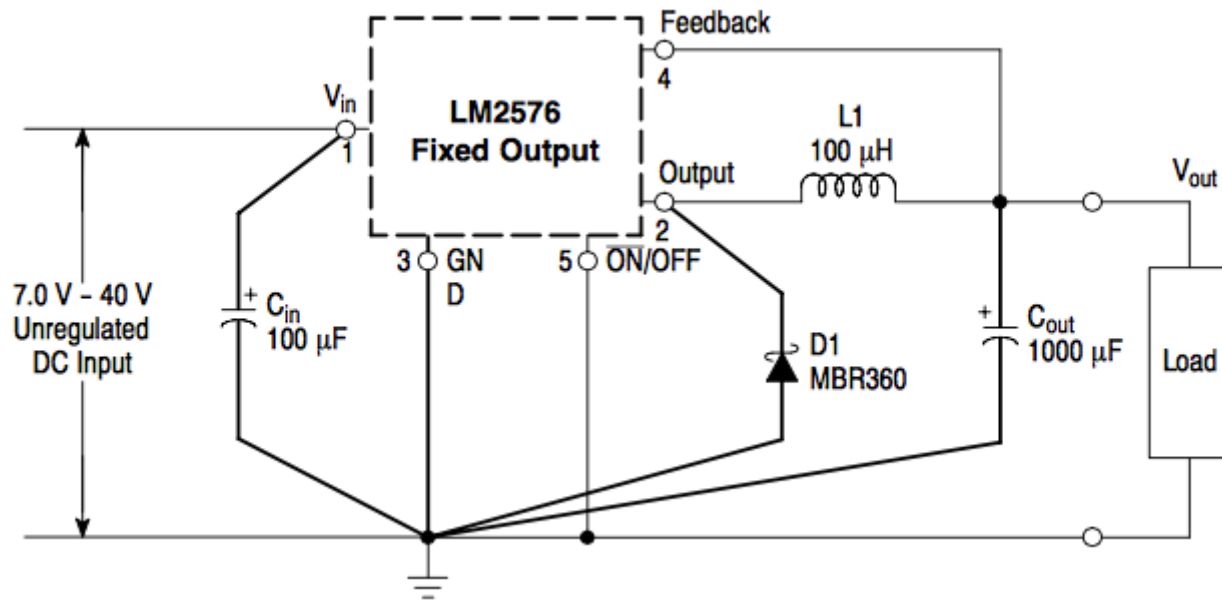
DC Power Supply

- Maximum of 15 watts of power delivery
- Switching Regulator Design
- Minimize use of microwave real estate

Switching Regulator Design

- Maximum current requirement of 3 A
- Allows for a more compact design
- More efficient, 80-95%
- Requires more components
- EMI filtering/RF Considerations

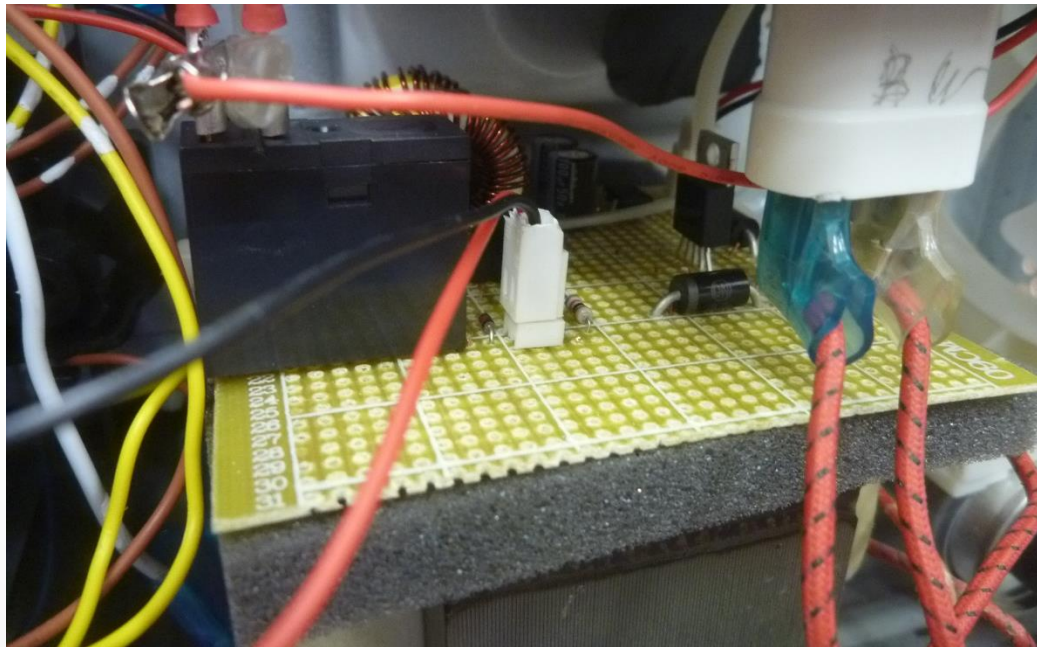
Schematic



ON Semiconductor- LM2576, 5V 3A
\$2.35/ea

Mounting

- All internal assembly
- Two PCBs
- Able to acquire proper operation without extra shielding



Electrical Hardware

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Microwave electrical components

Electrical Hardware

- Controlling microwave's electronics
- The relays and switches used to control the hardware
 - Control the Magnetron
 - Lights
 - Fan
 - Turntable
 - Door safety
- Circuit Design
- Printed Circuit Board

Electronics

- The Memrowave made use of
 - The original magnetron
 - The Lights
 - Fan
 - Turntable
- Electrical systems added to the chassis
 - The Control PCB
 - A USB camera and USB antenna
 - The beagle housed inside a 3D printed case.

Controlling AC elements

- The Memrowave has a familiar functionality to standard microwaves
 - Components are only used when needed
 - Power distributed effectively
 - Safe operation
- Make use of switches
 - Reuse the mechanical switches for the ovens door
 - Utilize relays to control power
 - Relays are controlled via the MSP430 slave

Control system

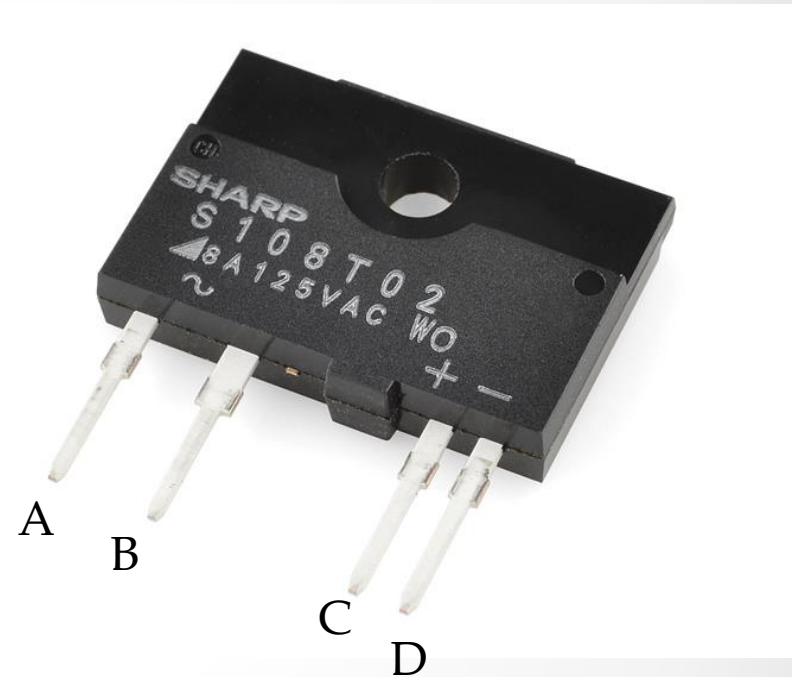
- In order to switch the relays we will utilize an MSP430 microcontroller
 - The MSP430 is the slave to the beaglebone master
 - The MSP430 will be mounted to the PCB
 - The GPIO pins will output an on and off signal
- The MSP430 output current may not be efficient when operating relays
 - To guarantee optimal currents to the relays BJT transistors are used
 - Make use of Three GPIO pins
 - Magnetron
 - Fan/Light/Turntable
 - Piezo Speaker

Door Switch

- The mechanical switch in the door was reused
 - This switch protects a user from the magnetron when the door is open
 - Opening the door will pause the cycle
- The door switch is connected to the slave MSP430 using the fabricated PCB
 - The MSP430 monitors the voltage on a GPIO
 - When the door is open the voltage drops to zero

Relays

- The Memrowave's operation uses a Solid State Relay and a mechanical relay
- Lower current components are switched using a 8Amp Solid State Relay made by Sharp
 - These elements are:
 - Light
 - Fan
 - Turntable



- The MSP430's GPIO pin is used to apply a 3.3V potential to the transistor's base, which biases 3.3V across pins C to D
- The AC signals are switched using pins A and B

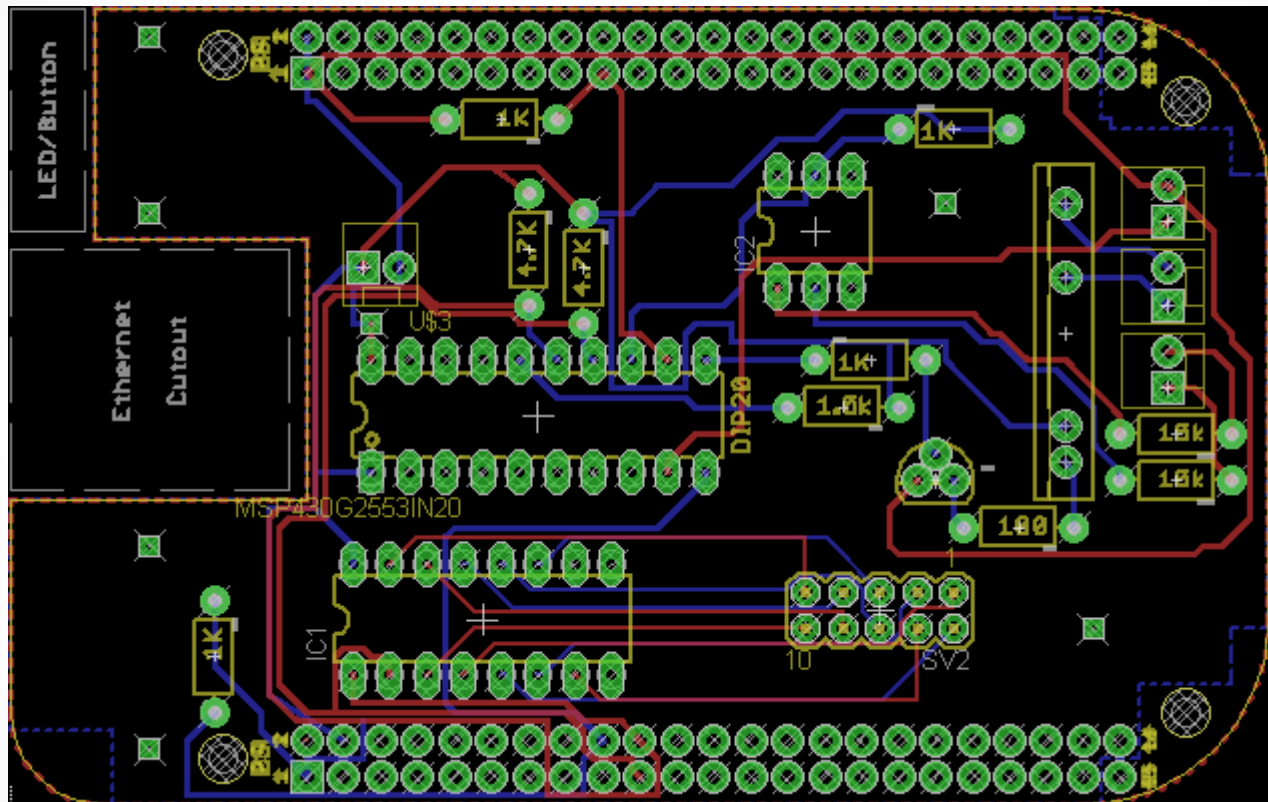
Magnetron Relay

- The magnetron's transformer draws a 9Amp current
 - Switching the magnetron required a more robust relay
- A 16A Amp Panasonic relay was mounted to the microwave power PCB solve this issue
 - This relay did not fit between the PCB and LCD cape

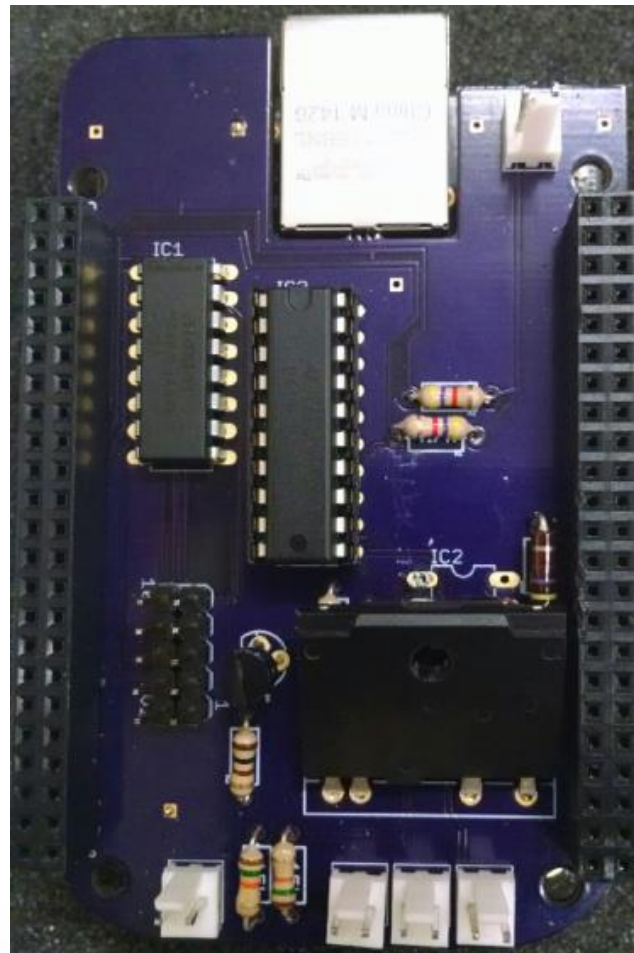


- The MSP430's GPIO pin is used to apply a 3.3V potential to the transistor's base, which applies 20V across pins C to D
- The magnetron's AC signal is switched using pins A and B

Control PCB layout



Final PCB



Administration

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Budget

Progress

Labor Distribution

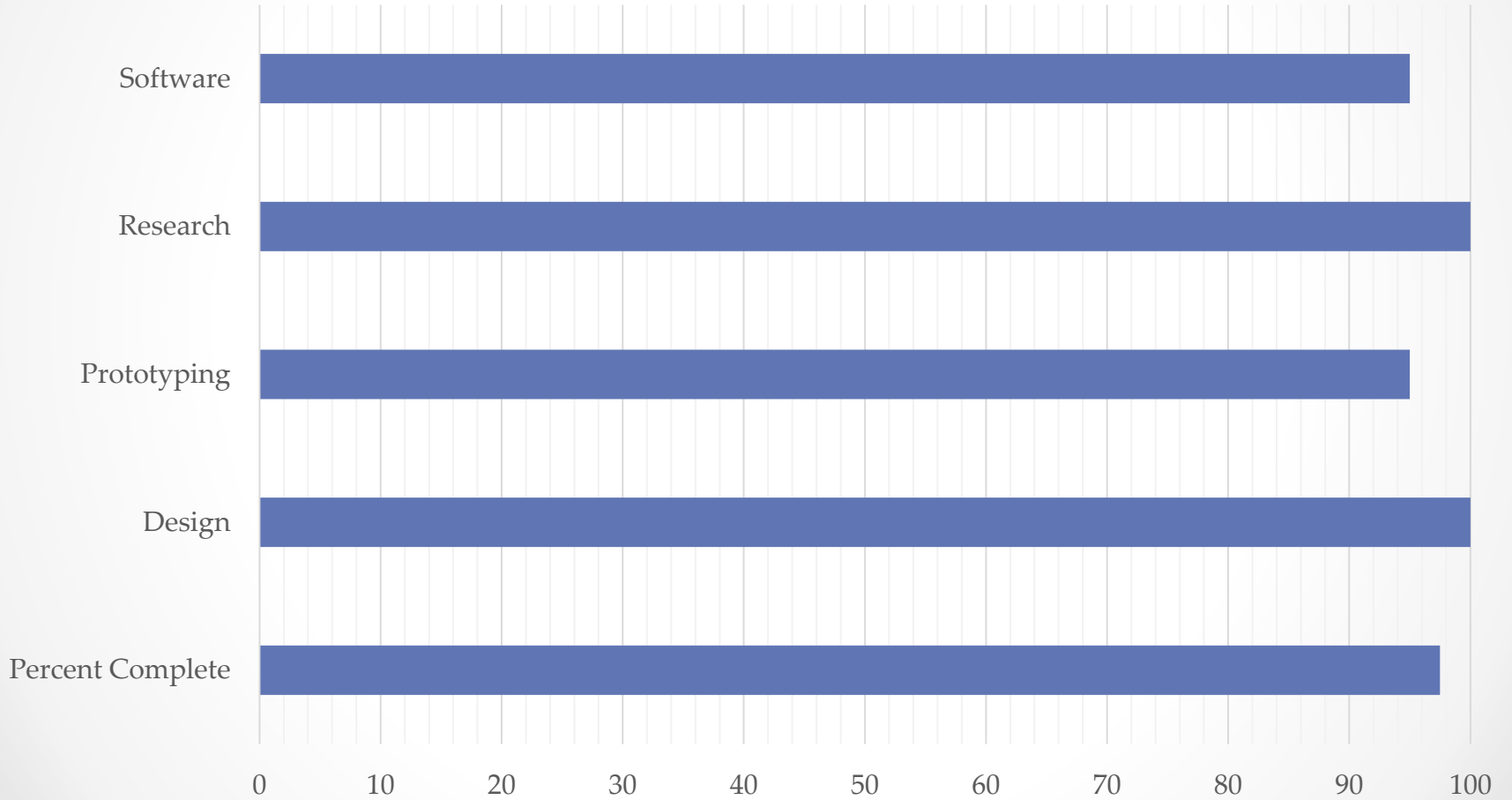
Challenges

Milestones

Budget

| ITEM | Estimated Cost | Actual Cost |
|-------------------|----------------|-------------|
| Beagle Bone Black | \$50 | \$50 |
| Camera | \$40 | \$27.02 |
| LCD Screen | \$100 | \$60 |
| Microwave | \$250 | \$ 0 |
| Power supply | \$10 | \$37.98 |
| Microcontroller | \$11 | \$0 |
| Relays and Misc. | \$10 | \$27 |
| PCB fabrication | \$60 | \$36.55 |
| WIFI | \$25 | \$14.99 |
| Total | \$556 | \$268.53 |

Progress



Distribution

| | Power/ PCB mgt | User interface/ App | Control system/ PCB | Software |
|---------|-------------------|---------------------------|---------------------------|----------|
| Winston | | X | | X |
| Andy | | X | | X |
| Darren | X | | | |
| Joseph | | | X | |

Challenges

- Initial implantation of I2C
- First time working with PCB designs
- Inexperience with eagle schematic
- Problems mounting new hardware in the microwave's chassis
- Integrating Wi-Fi and camera with Android hardware abstraction layer

Milestones

- Creating the user interface in android
- Testing control circuits on bread board
- Implementing I2C communication
- Controlling the 7-segment display
- Implementing the web database
- Having the MSP430 control all the sub systems
- Created a function switching regulator on a bread board
- Ordering and fabricating the control PCB and power PCB

Questions

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Demo

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