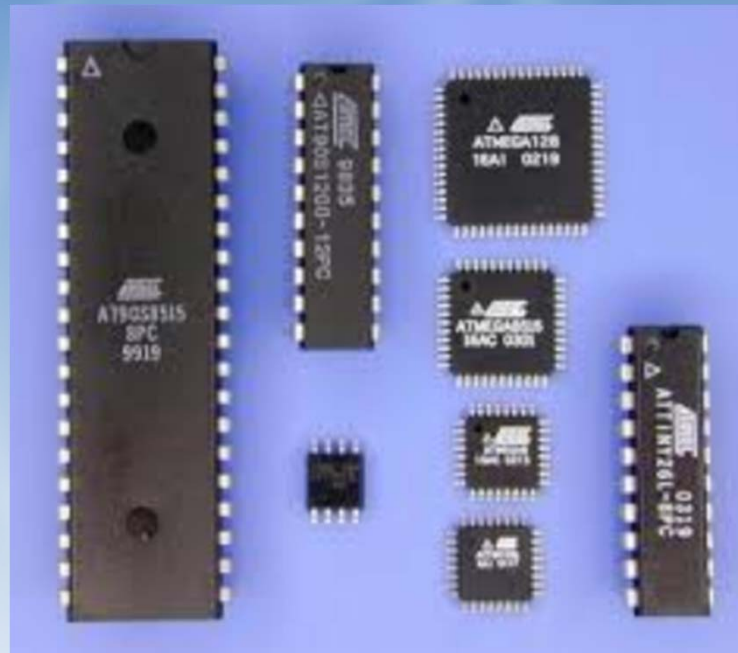


Introduction to Microcontrollers



Jerry Spring VE6TL

Outline

- Introduction - History
- Microcontroller vs Microprocessor
- What are the choices?
- What can I do with a microcontroller?
- What do I need to buy?
- What do I need to learn?
- Ham radio projects

But first... a little digital humour

*Why do electronic engineers
always confuse Halloween
and Christmas?*

Because 31 Oct = 25 Dec

Homebrewing – A Bit of History



Many
homemade
parts

High
Voltage

Big

Kit Building– 1960s

Hi-Fi & Tape, Ham & CB Radio, Kits, Test Equipment!

ELECTRONICS ILLUSTRATED

Publishers of MECHANIX ILLUSTRATED

MARCH • 35 CENTS



BUILD THIS WIRELESS FM MIKE

All About Electroplating

Science Fair™

INSTRUCTION MANUAL PRICE: 50¢



ELECTRONIC PROJECT KIT #28-131
"VOX" (Voice Operated Switch)

Discover the convenience of voice command in controlling tape recorders, electric trains, model cars and for switching on and off many other electrical items. This sensitive "VOX" kit can also be used in many other applications, such as protecting your home and property through a sound sensitive alarm.

The "VOX" kit is actually a sound-sensitive switch consisting of an electronically controlled relay circuit. This circuit amplifies a small audio signal received from the microphone. This is done by using two NPN Silicon Transistors (Q1 & Q2), which are direct coupled to form a high gain audio amplifier. The signal is then fed through the sensitivity control (R7) to a NPN Silicon Transistor (Q3) and a PNP Germanium Transistor (Q4), which are also direct coupled to form a high gain detector circuit for controlling the relay. A 100 MFD Electrolytic Capacitor (C5) is used to remove the audio signal and to provide a DC holding signal which determines the length of time the relay remains energized when there is no longer a signal from the microphone.

Radio Shack Corporation, 1800 W. Park Avenue, Department 7, Channahon, Illinois 61413

No
homemade
parts

Low Voltage

Smaller

Tinkering – 1970s

HOW TO "READ" FM TUNER SPECIFICATIONS

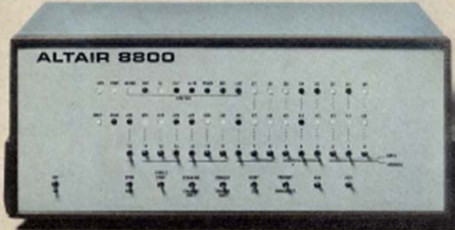
Popular Electronics

WORLD'S LARGEST-SELLING ELECTRONICS MAGAZINE JANUARY 1975/75¢

PROJECT BREAKTHROUGH!

World's First Minicomputer Kit to Rival Commercial Models...

"ALTAIR 8800" SAVE OVER \$1000




ALSO IN THIS ISSUE:

- An Under-\$90 Scientific Calculator Project
- CCD's—TV Camera Tube Successor?
- Thyristor-Controlled Photoflashers

TEST REPORTS:

- Technics 200 Speaker System
- Pioneer RT-1011 Open-Reel Recorder
- Tram Diamond-40 CB AM Transceiver
- Edmund Scientific "Kirlian" Photo Kit
- Hewlett-Packard 5381 Frequency Counter



18101


Popular Electronics

WORLD'S LARGEST-SELLING ELECTRONICS MAGAZINE NOVEMBER 1979/\$1.25

Humidity Controller Saves Heating Fuel
Radioteletype Reader for Shortwave Receivers


Focus on Microcomputers:

- Personal & Very-Small-Business Computers
- CP/M—The Software Bus ● A Guide to Printers



Tested In This Issue

- Yamaha C-4 Preampifier
- Mitsubishi DT-30 Cassette Deck
- Ortofon Concorde 30 Phono Pickup
- Realistic DX-300 Communications Receiver

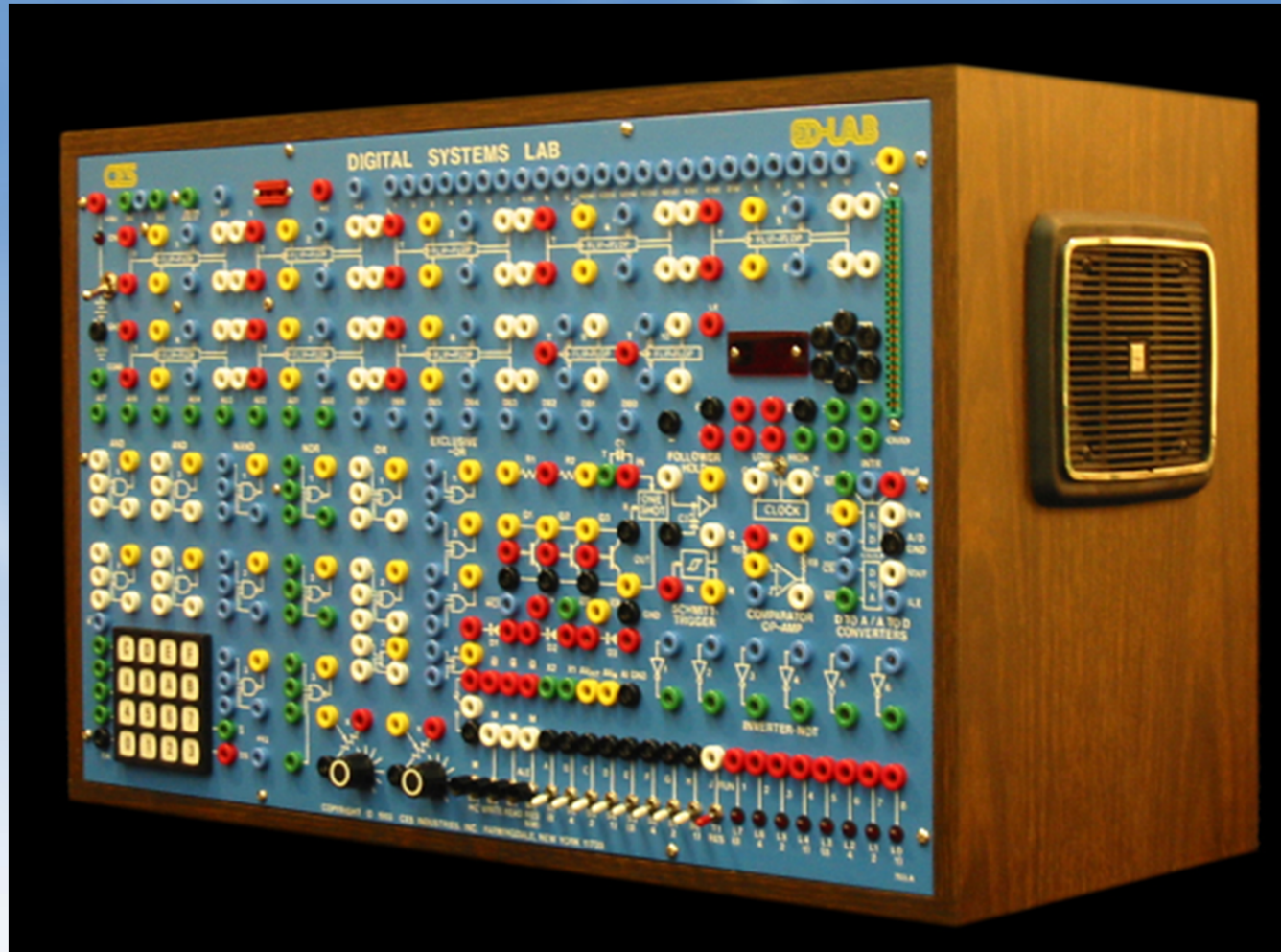


Computers
All the rage

Mini to
Micro

IC Technology

The Boolean Age – 1980s



Everything
Digital

New Chip
technologies

Architecture -
using discrete
components

Homebrewing – 1990s – 2000s



**Old and New
technologies**

**Big and
Small
components**

**Is this the
way to
attract new
hams to the
hobby?**

Post 2002 - Microcontrollers



Emphasis on creativity

Programming skills essential

No soldering – plug and play

Attracting wider audience

2010 – Arduino – Starter Kit



Emphasis on ease of use

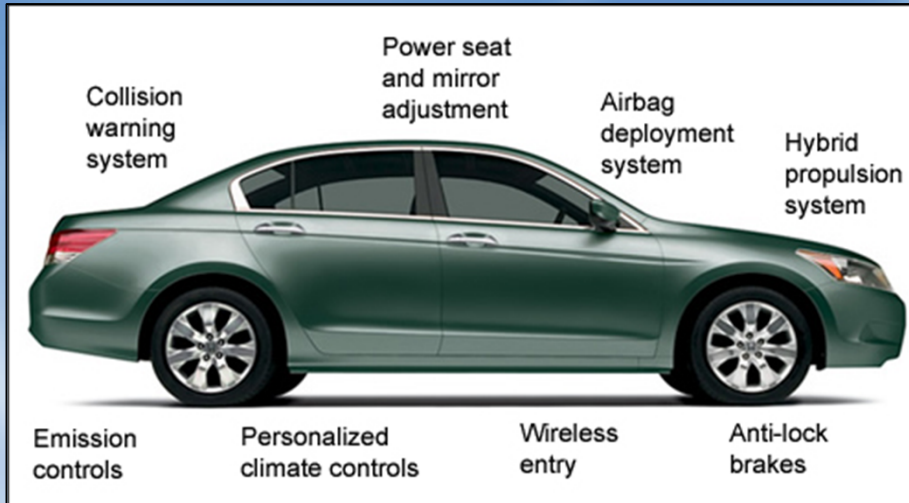
Internet user groups and tutorials

Numerous "shields"

IoT

A step back...

Why Should I Care about MCUs?



**These things are
EVERYWHERE!**

Cooling System

Coffee Maker

Microwave Oven

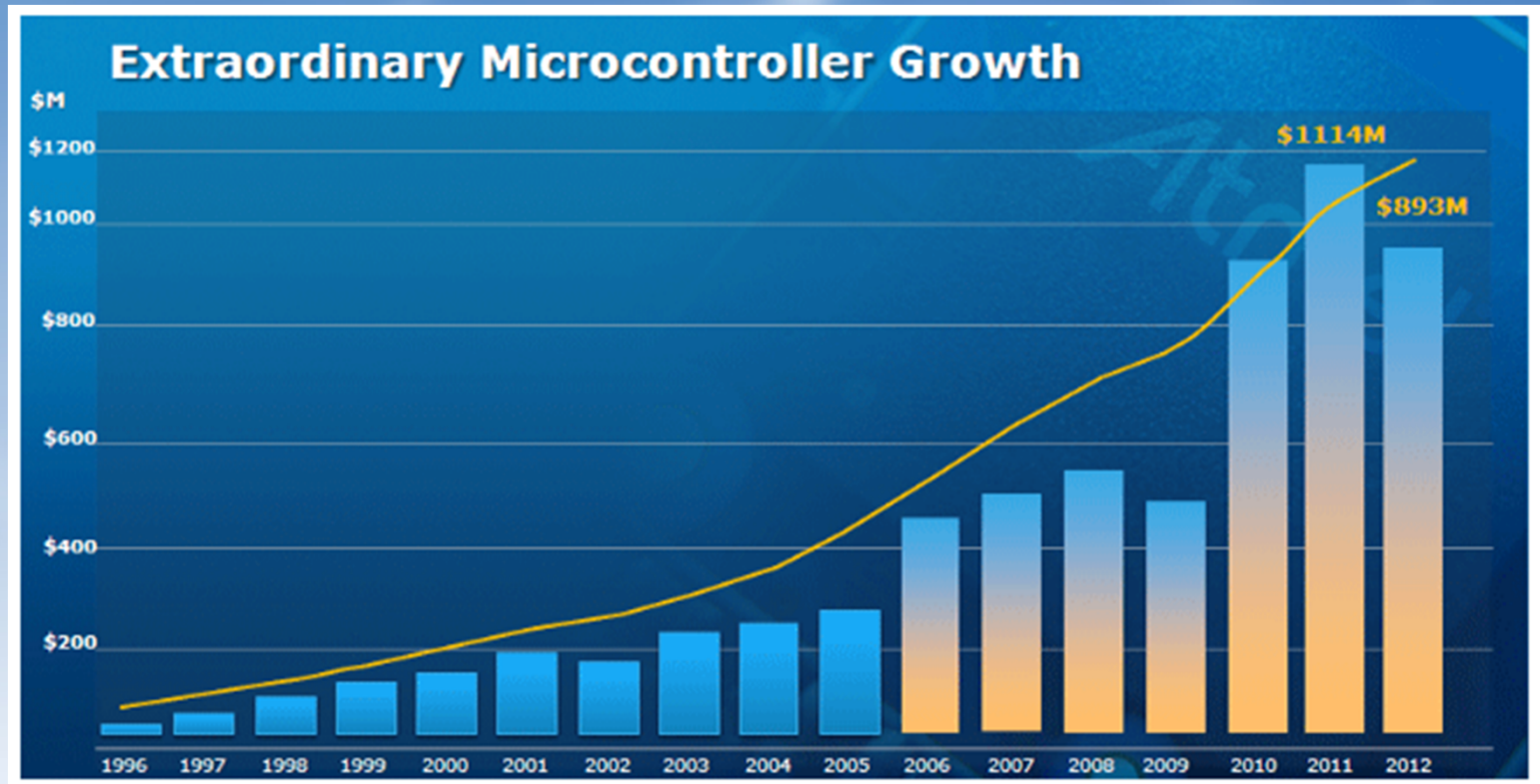


Smoke Alarm

Dishwasher

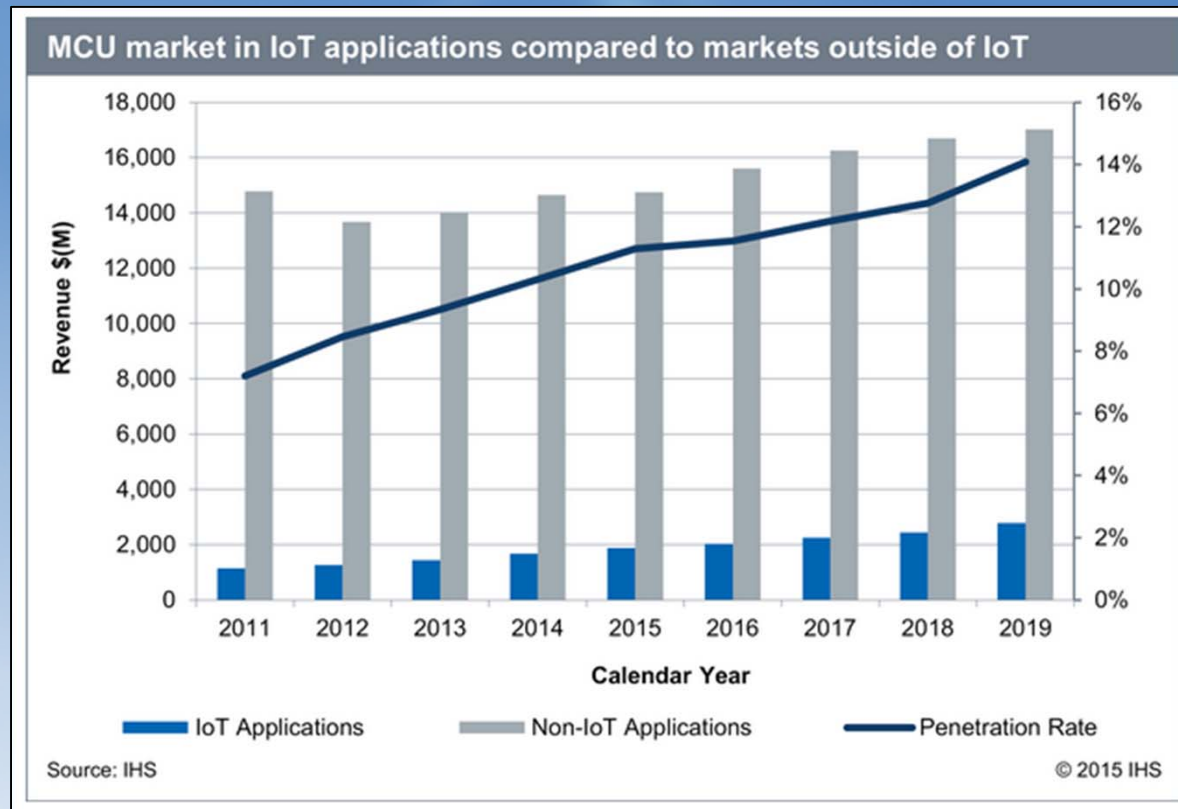
Oven Sensor

Phenomenal Growth*



*Courtesy of Atmel Corp.

Impact of IoT



“The market for MCUs used in connected cars, wearable electronics, building automation and other IoT applications is expected to grow at an overall compound annual growth rate (CAGR) of 11 percent, from \$1.7 billion in 2014 to \$2.8 billion in 2019.” - IHS

Microprocessor vs Microcontroller

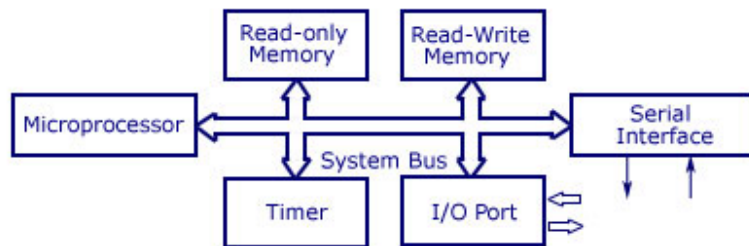
Microprocessor

- Multipurpose
- Connects to external circuits such as memory, graphics, i/o ports, etc. on mother board
- Has O/S (Windows, Linux, etc.)
- Volatile memory (reboot when power lost)
- Requires PS, Keyboard, Mouse, Display, etc.

Microcontroller

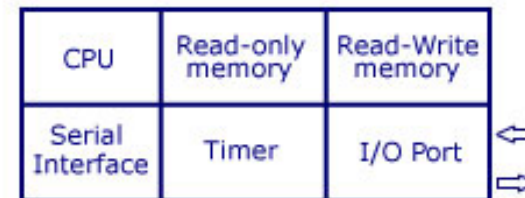
- Single Purpose
- Internal memory
- Non-volatile memory (permanent once written)
- Built-in peripherals
- Come in different sizes
- Usually does not have O/S

Schematic Arrangement of a Microprocessor Based System



www.CircuitsToday.com

Schematic Internal Architecture of a Microcontroller



Microcontroller

www.CircuitsToday.com

Microcontroller Peripherals

Four Main Types – Built-in

1. TIMERS

- Counters
- Real Time
- Pulse Width Modulation (PWM)



2. ANALOGUE

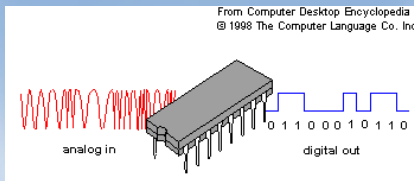
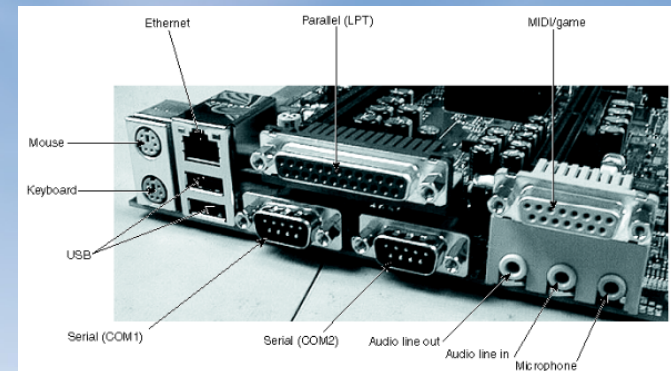
- A/D Converter

3. Digital

- I/O Ports
- LCD Control

4. Communications

- Serial (RS-232)
- USB
- Ethernet
- I2C
- Others

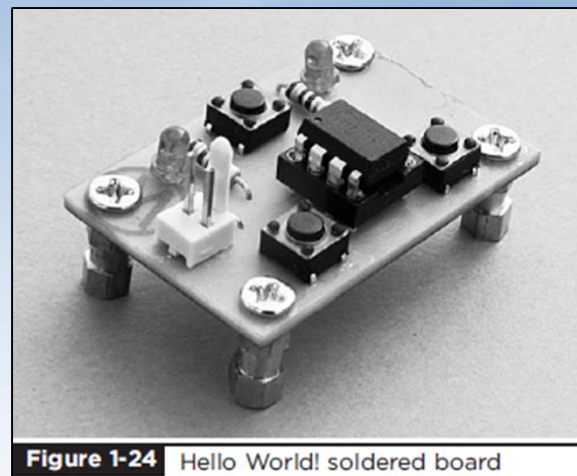
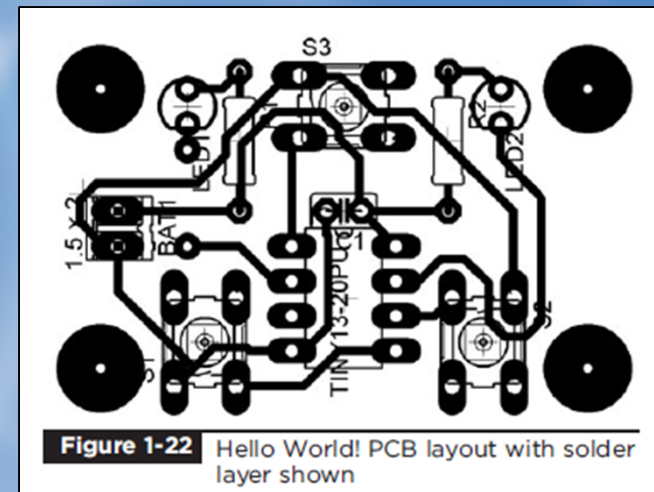
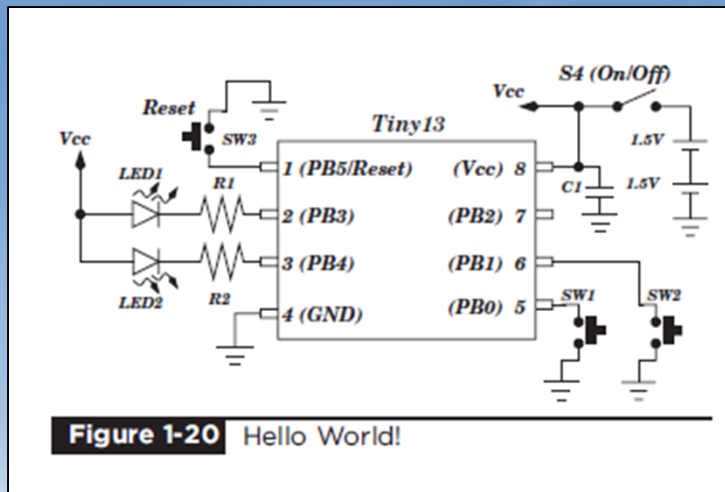


What are the choices?

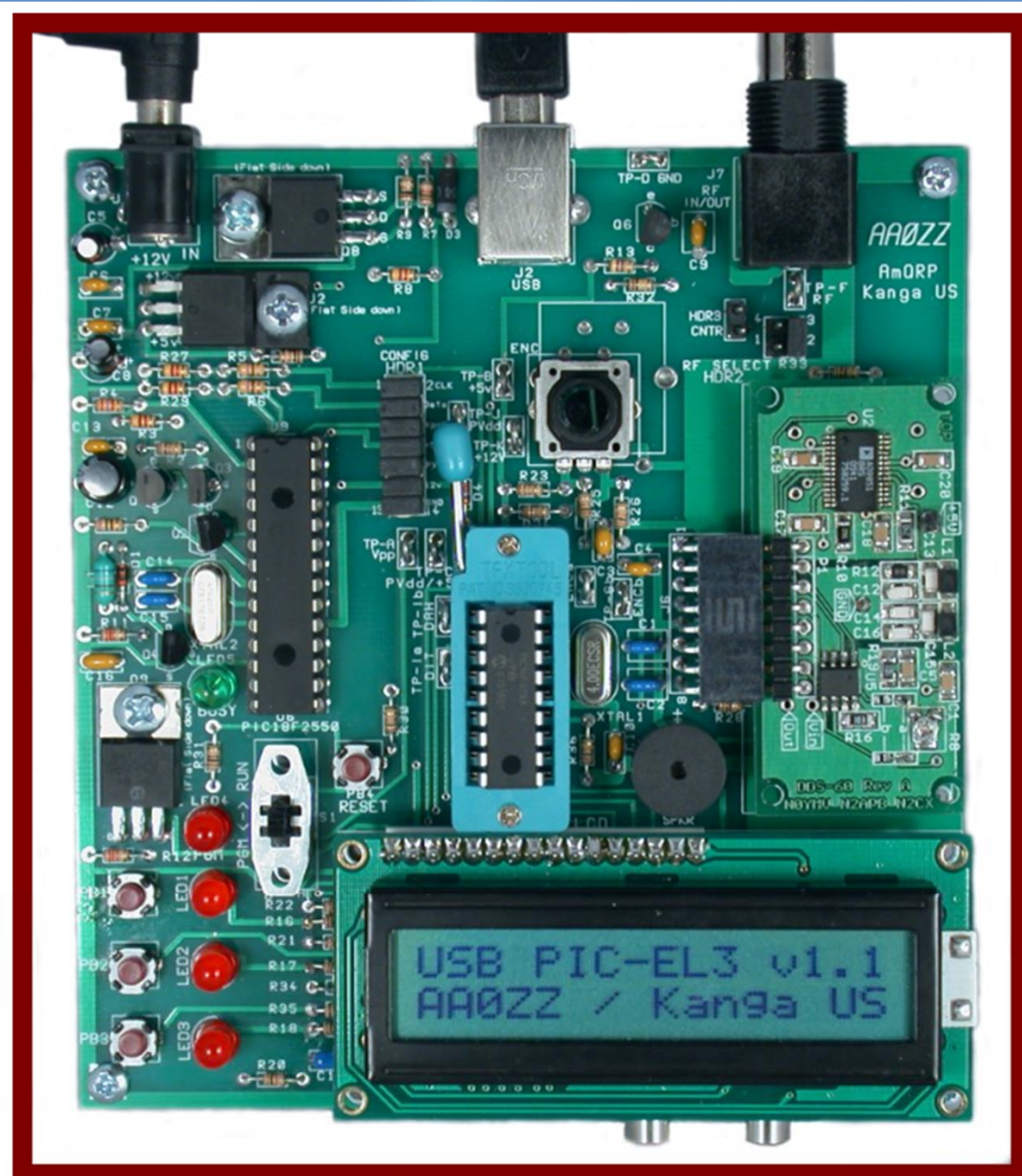
- TinyAVR
- PIC-EL III
- PICAXE
- Basic Stamp
- Texas Instruments MSP430
- ARDUINO
- ESP8266
- Many more

Tiny AVR Microcontroller

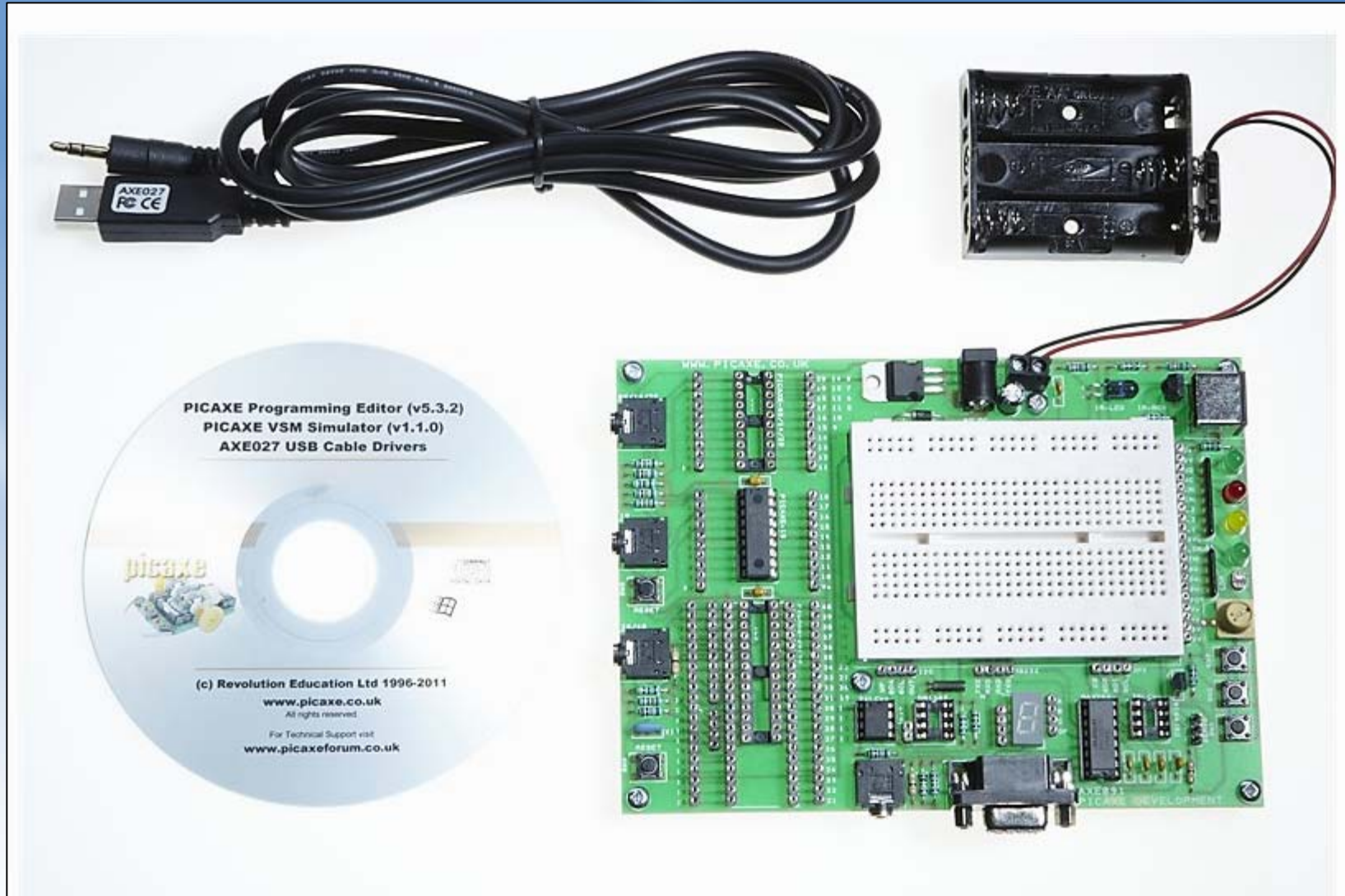
First Project: Two Switches to toggle two LEDs



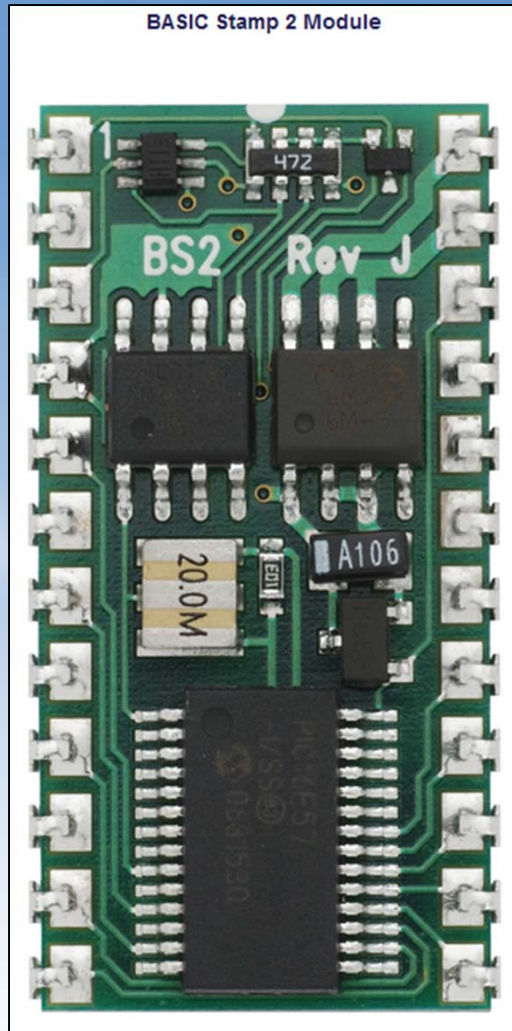
PIC-EL III BOARD



PICAXE Starter Pack - \$60



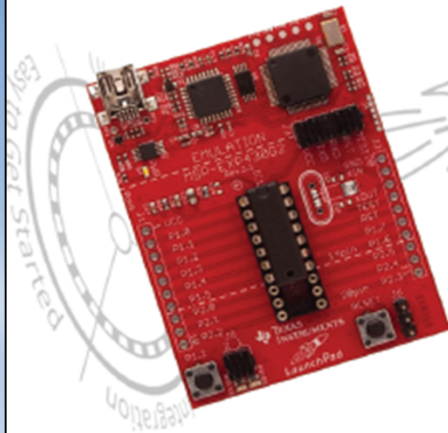
Basic Stamp - \$49



- First released in 1992
- Programmed in PBASIC
- Available add-on “carrier boards”
- 20 MHz Clock = 4,000 PBASIC Instructions/sec
- EEPROM 2 KB (~500 PBASIC Instructions)
- I/O Pins: 16 + 2 dedicated serial
- Current Draw (5 VDC): 3mA Run, 50 uA Sleep
- Source/Sink Current per I/O: 20 mA/25mA
- PBASIC Commands: 42
- Package: 24-pin DIP
- Dimensions: 1.2” X 0.63” X 0.15”
- Made by Parallax Inc. (California)
- Get Started Kit: \$79.99

Texas Instruments Launchpad MSP430

LaunchPad and the BoosterPack Ecosystem



Complete Development kit for \$4.30!

The MSP-EXP430G2 LaunchPad development kit provides all of the hardware and software needed to start MSP430 development. LaunchPad supports all MSP430G2xx Value Line MCUs. www.ti.com/launchpad

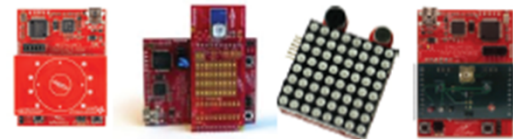
LaunchPad Features

- On-board emulation
- 20-pin DIP Socket
- 2 on-board LEDs and 2 on-board switches
- Kit includes USB cable, Quick Start Guide, 2x 10-pin male and female headers
- Includes 2 MSP430 Value Line MCUs

- **MSP430G2553:** 16kB Flash, 512B RAM, 8ch 10-bit ADC, Comparator, Capacitive Touch I/Os, Universal Serial Communication Module (I²C, UART, SPI)
- **MSP430G2452:** 8kB Flash, 256B RAM, 8ch 10-bit ADC, Comparator, Capacitive Touch I/Os, Universal Serial Interface (I²C/SPI)

Growing Ecosystem of BoosterPacks!

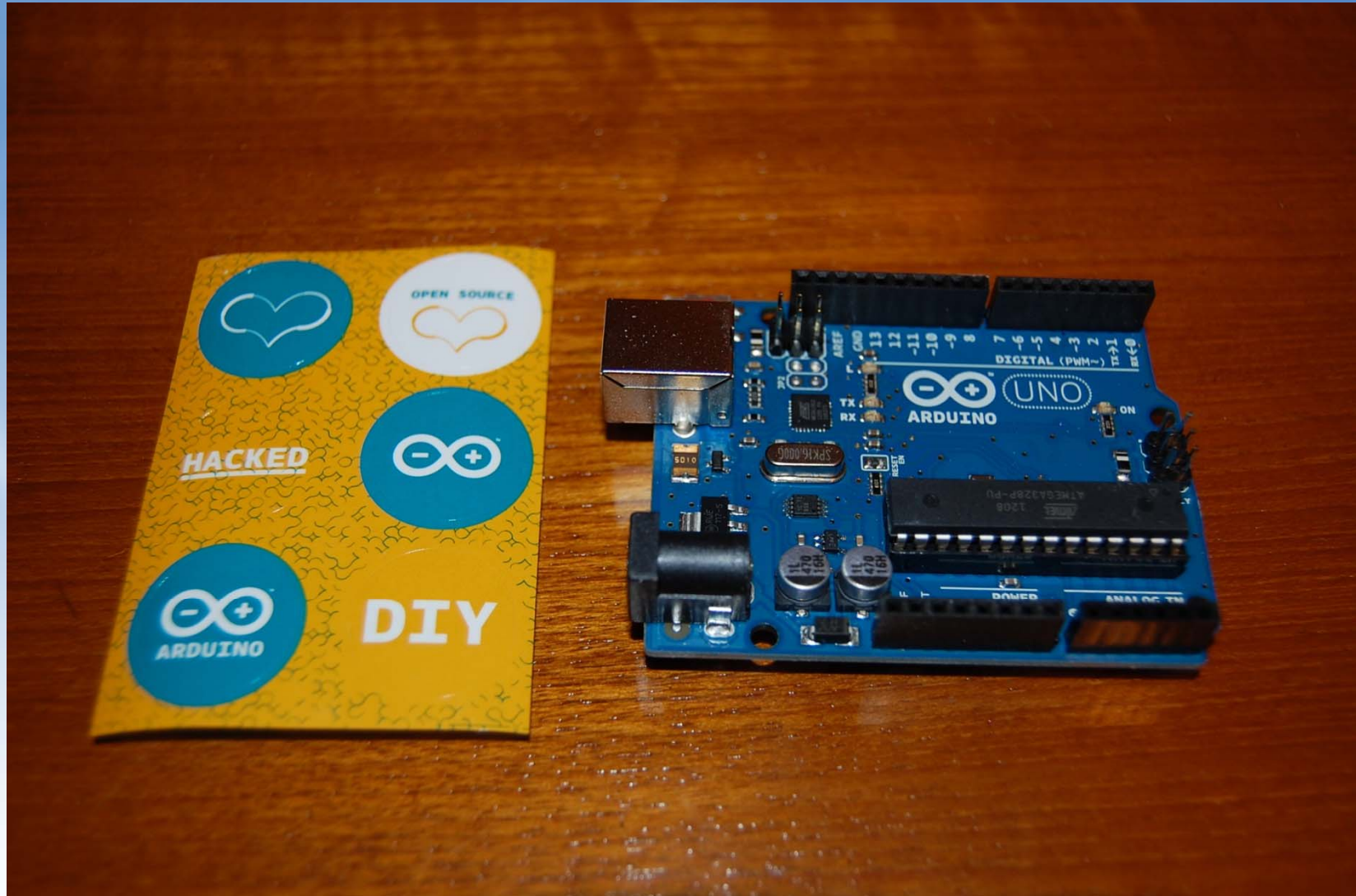
BoosterPacks are plug-in modules for the LaunchPad development kit, which enable additional functionality including wireless, capacitive touch, LED lighting and others. Each BoosterPack includes hardware, documentation and a pre-programmed MSP430 Value Line device which includes a demo application. See the complete list of BoosterPacks at www.ti.com/boosterpack



Raspberry Pi



Arduino



What are the Main Differences?

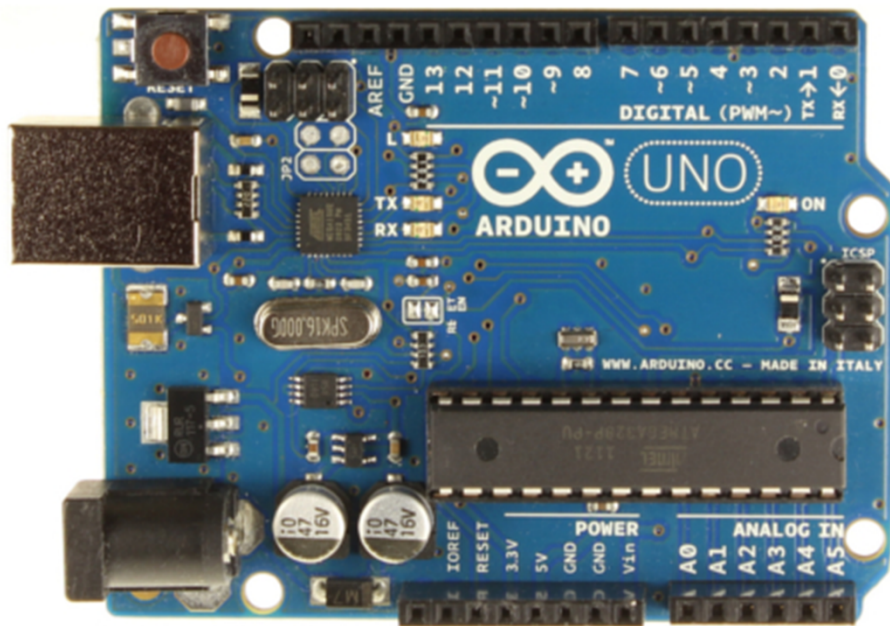
MCU	Language(s)	Advantage	Disadvantage
TinyAVR	Assembly, C	Specific Function	Programming
PIC-EL III	Assembly	Ham radio apps	Programming
TI MSP430	Assembly, C	Cheap, Low Power	Fewer shields
Basic Stamp	PBASIC	Programming, Simple	Software Flexibility
PICAXE	Basic	Programming	Speed
ARDUINO	C (Wires)	Libraries, Shields, Popularity, variety	Speed, Newer technologies
ESP8266	C	Arduino Compatibility Ethernet, Speed	Heat dissipation
Raspberry PI	Python +	Computer	Linux, Other hardware

Arduino Description

- Open-source electronics prototyping platform – Costs about \$35 (authentic)
- Millions sold to date
- Intended for artists, designers, hobbyists, etc.
- Can be stand-alone projects or can communicate with computers
 - Windows, Mac OS X, Linux
- Programs (sketches) based on simplified “C” language and make peripheral access easy to use with vast number of libraries
- Starter kits and programming guides available
- Many “flavours” available: Uno (R3), Due, Mega, Nano, Mini, Leo, LilyPad
- Many accessories available
 - Note: Daughter boards called “shields” and are “stackable”
 - Hundreds of I/O Shields available (WiFi, LCD Displays, Ethernet, Bluetooth, GPS, Motor control, etc.)
- Huge user base and support system
 - A Google search (2013) of “Arduino Projects” returned 2,750,000 results and 238,000 results for “Tutorials”

Arduino Specifications

Arduino Uno



- Microcontroller: ATmega328
- Operating Voltage: 5V
- Input Voltage: 7-12V
- Input Voltage (limits): 6-20V
- Digital I/O Pins: 14 (6 provide PWM)
- Analog Input Pins: 6
- DC Current per I/O Pin: 40 mA
- DC Current for 3.3V Pin: 50 mA
- Flash Memory: 32 KB (0.5 KB used by bootloader)
- SRAM: 2 KB
- EEPROM: 1 KB
- Clock Speed 16 MHz
- 3" X 2" Dimensions

Arduino – Other Starter Kits

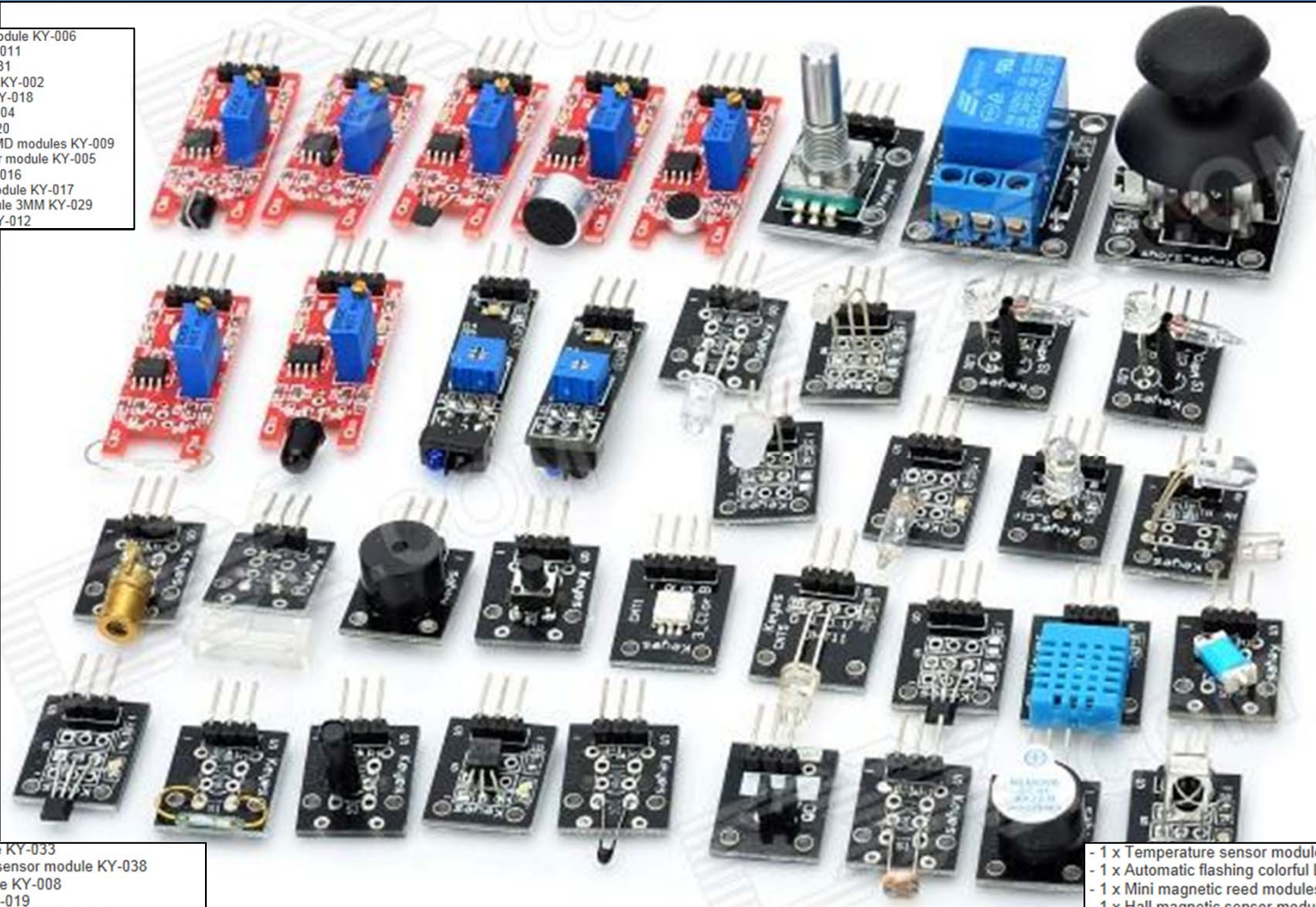


- Color: White
- Great Arduino UNO 2011 kit for starters beginners
- Package includes:
 - 1 x Arduino UNO board
 - 1 x Development expansion board
 - 1 x Breadboard
 - 1 x LED emitter kit (red / blue / yellow; each 5pcs)
 - 5 x 10K resistors
 - 5 x 1K resistors
 - 8 x 220R resistors
 - 1 x 74hc595
 - 2 x Buzzers
 - 1 x Seven-segment display (1-digit)
 - 1 x Seven-segment display (4-digit)
 - 10 x Push button switches
 - 3 x Light dependent resistors
 - 1 x Adjustable resistor
 - 1 x LM35 temperature sensor
 - 1 x 1602 LCD display
 - 1 x PS2 joystick
 - 1 x Stepping motor
 - 1 x Stepping motor driver board
 - 1 x Steering engine
 - 1 x RGB module
 - 30 x Breadboard cables
 - 10 x Dupont lines
 - 1 x 2.54mm pin header
 - 2 x Mercury switches
 - 1 x Flame sensor
 - 1 x Infrared receiver
 - 1 x USB cable (80cm)
 - 1 x Remote control (1 x CR2025 included)
 - 1 x Battery case

\$55 Shipped Free to Canada

Arduino – Sensors Galore!

- 1 x Small passive buzzer module KY-006
- 1 x 2-color LED module KY-011
- 1 x Hit sensor module KY-031
- 1 x Vibration switch module KY-002
- 1 x Photo resistor module KY-018
- 1 x Key switch module KY-004
- 1 x Tilt switch module KY-020
- 1 x 3-color full-color LED SMD modules KY-009
- 1 x Infrared emission sensor module KY-005
- 1 x 3-color LED module KY-016
- 1 x Mercury open optical module KY-017
- 1 x Yin Yi 2-color LED module 3MM KY-029
- 1 x Active buzzer module KY-012

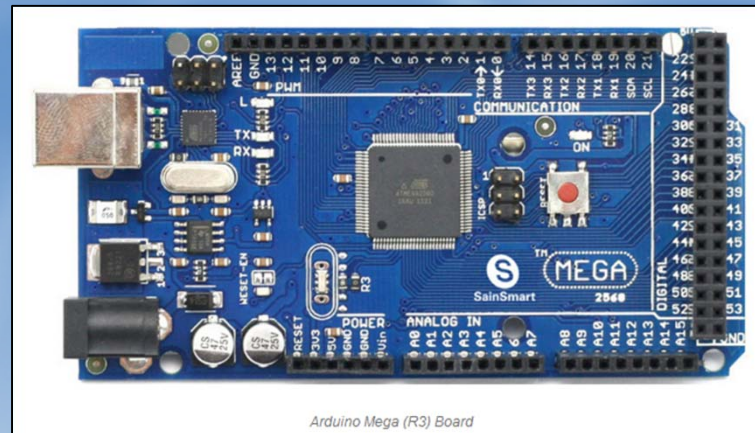
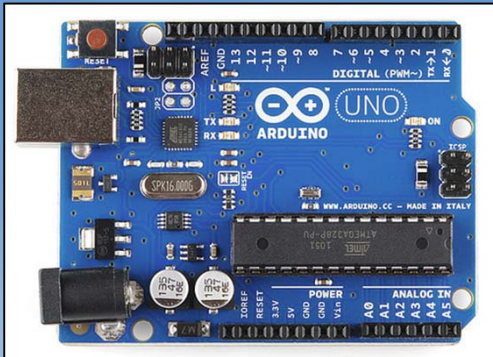


- 1 x Hunt sensor module KY-033
- 1 x Microphone sound sensor module KY-038
- 1 x Laser sensor module KY-008
- 1 x 5V relay module KY-019
- 1 x Temperature sensor module KY-001
- 1 x Temperature sensor module KY-028
- 1 x Linear magnetic Hall sensors KY-024
- 1 x Flame sensor module KY-026
- 1 x Sensitive microphone sensor module KY-037
- 1 x Temperature and humidity sensor module KY-015
- 1 x XY-axis joystick module KY-023
- 1 x Metal touch sensor module KY-036
- 1 x Box

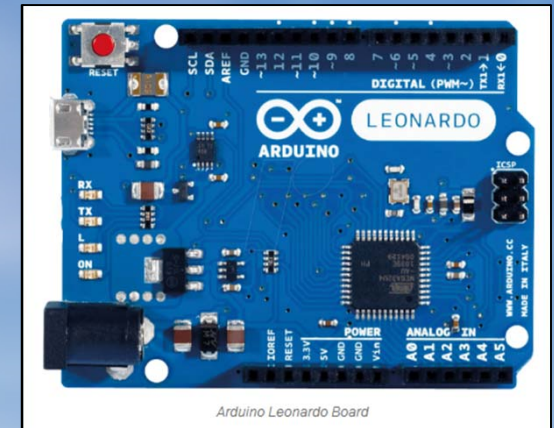
\$55 Shipped Free to Canada

- 1 x Temperature sensor module KY-013
- 1 x Automatic flashing colorful LED module KY-034
- 1 x Mini magnetic reed modules KY-021
- 1 x Hall magnetic sensor module KY-003
- 1 x Infrared sensor receiver module KY-022
- 1 x Class Bihor magnetic sensor KY-035
- 1 x Magic light cup module KY-027
- 1 x Rotary encoder module KY-040
- 1 x Optical broken module KY-010
- 1 x Detect the heartbeat module KY-039
- 1 x Reed module KY-025
- 1 x Obstacle avoidance sensor module KY-032

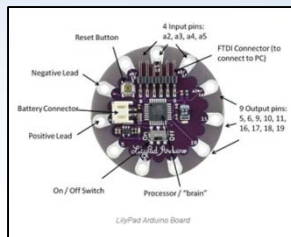
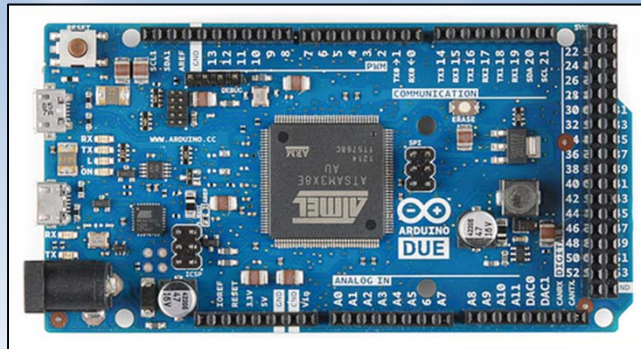
Arduino – The Collection



Arduino Mega (R3) Board



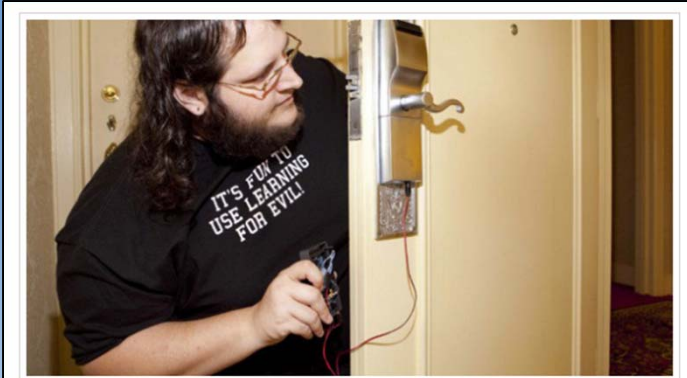
Arduino Leonardo Board



Board	Processor	Memory	Digital I/O	Analogue I/O
Arduino Uno	16Mhz ATmega328	2KB SRAM, 32KB flash	14	6 input, 0 output
Arduino Due	84MHz AT91SAM3X8E	96KB SRAM, 512KB flash	54	12 input, 2 output
Arduino Mega	16MHz ATmega2560	8KB SRAM, 256KB flash	54	16 input, 0 output
Arduino Lilypad	8MHz ATmega32u4	2KB SRAM, 32KB flash	9	4 input, 0 output
Arduino Leonardo	16MHz ATmega32u4	2.5KB SRAM, 32KB flash	20	12 input, 0 output

Arduino – Sample Projects

Hacking hotel room locks



Last summer a black hat called Cody Brocious (aka Daeken) managed to gain access to 4 million hotel rooms with Arduino board. Probably not an usual project, but it definitely deserved a place in this list! [Paper](#) and [PDF slides](#) available online.

The Inebriator

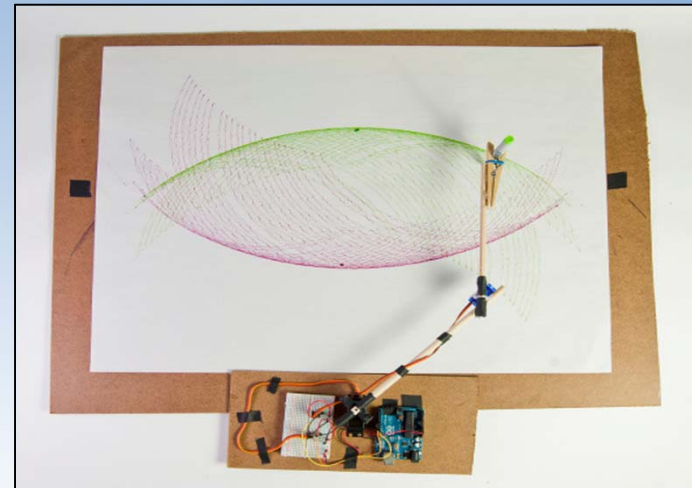


Disco Planet

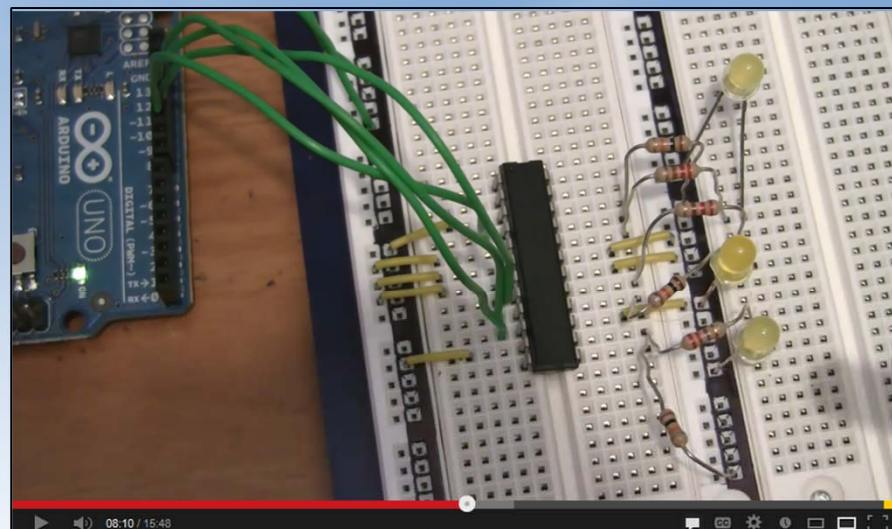
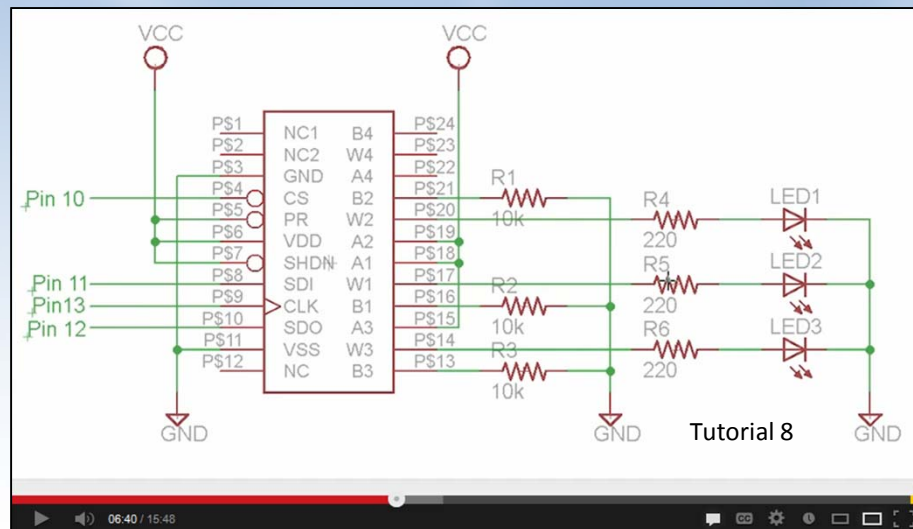
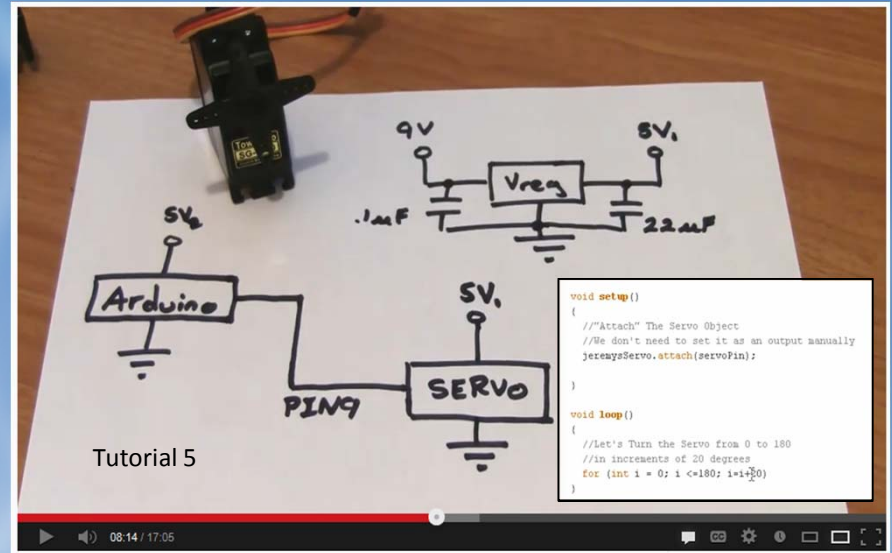


A huge disco ball made of 800 LEDs. [Project Page](#).

Arc-O-Matic Art Bot



Arduino – Online Tutorials

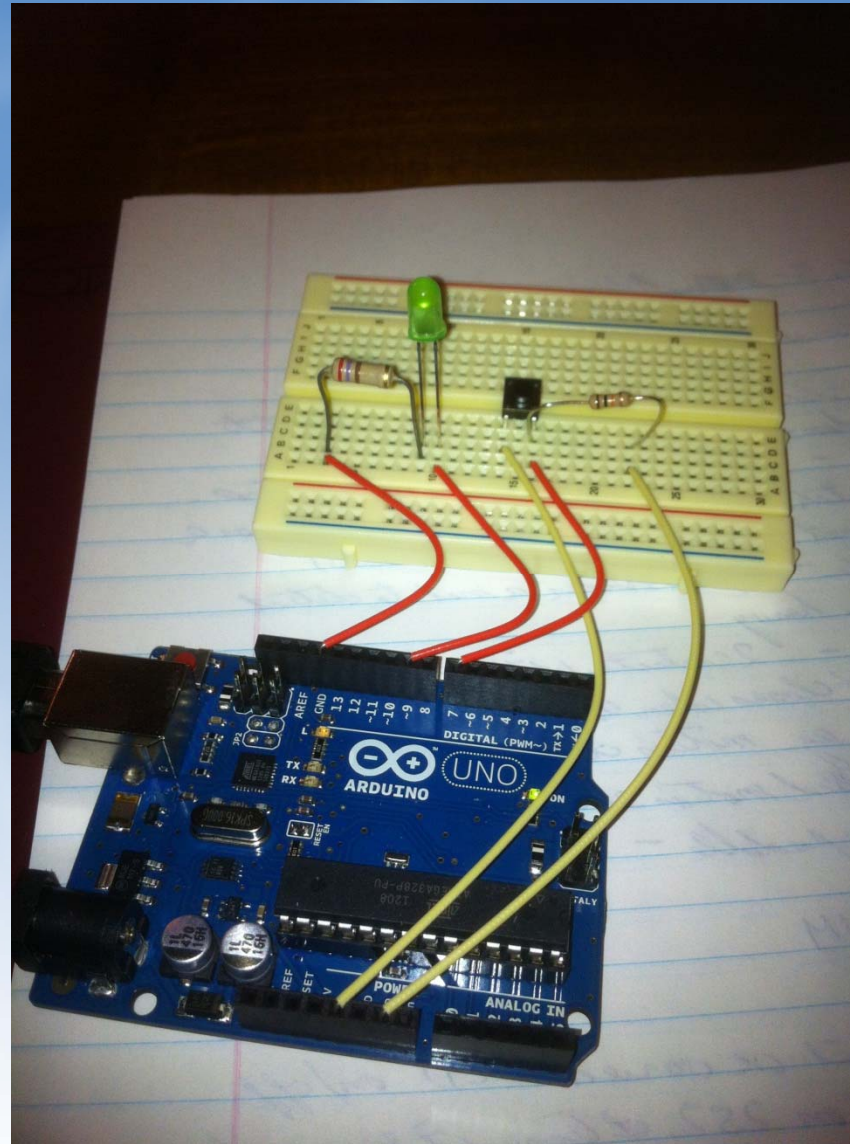


Arduino – Online Tutorials

Topics

- Getting Started
- Turning LEDs on/off with pushbuttons
- Analogue Inputs
- Motors and Transistors
- Serial Communication and Processing
- I2C and Processing
- SPI Interfaces
- Wireless Communication
- Interrupts and Hardware
- SD Cards and Data Logging
- RFID Cards
- Liquid Crystal Displays (LCD)
- Lasers
- Robotics

Arduino – First Projects



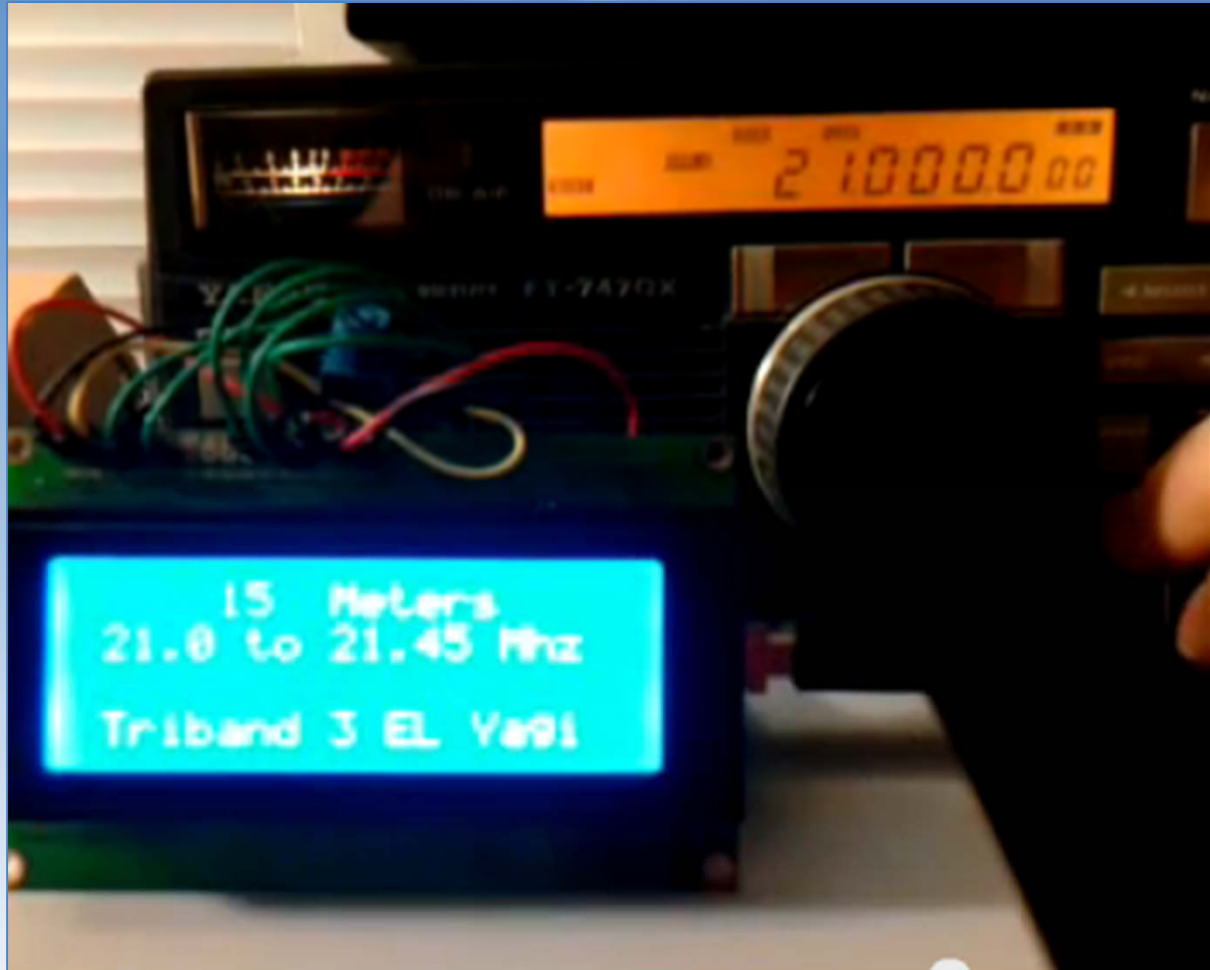
Arduino – Sample Program

```
//Turning on LED when switch closed
int switch; // Declares switch an integer variable

void setup() // Required for each program
{
  pinMode(10, OUTPUT); // Set pin 10 to output for LED
  pinMode(11, INPUT); // Set pin 11 to input to read switch
  digitalWrite(11,HIGH); // Turn on internal pull up resistor
}

void loop() // Repeat what is inside loop
{
  switch = digitalRead(11); // Store the value of the switch (high or low)
  if(switch == 0) // If the switch is pressed (Low=0), LED on
    digitalWrite(10,HIGH); //turn on LED
  else // Otherwise, turn the switch off
    digitalWrite(10,LOW); //turn LED off
} // End of loop()
```

Arduino – HF Antenna Switch

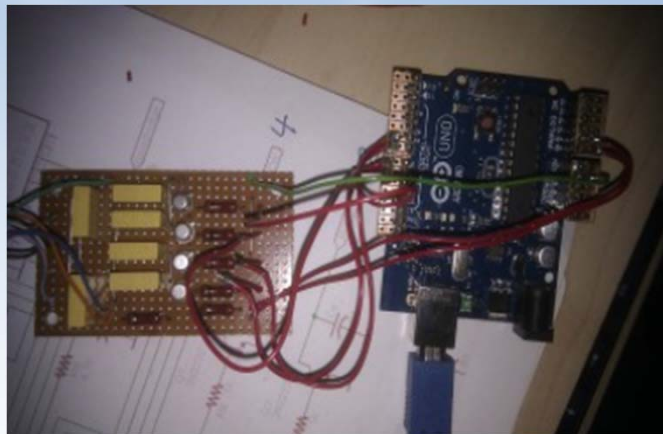


Reads band data from rig and automatically selects antenna – KC8GRQ

Arduino Rotator Controller for EME – G4HSK



- Yaesu G-5500 rotator with elevation and azimuth control
- Interface includes Arduino Uno, switching board, LCD interface, 2X20 LCD module, PstRotator Software



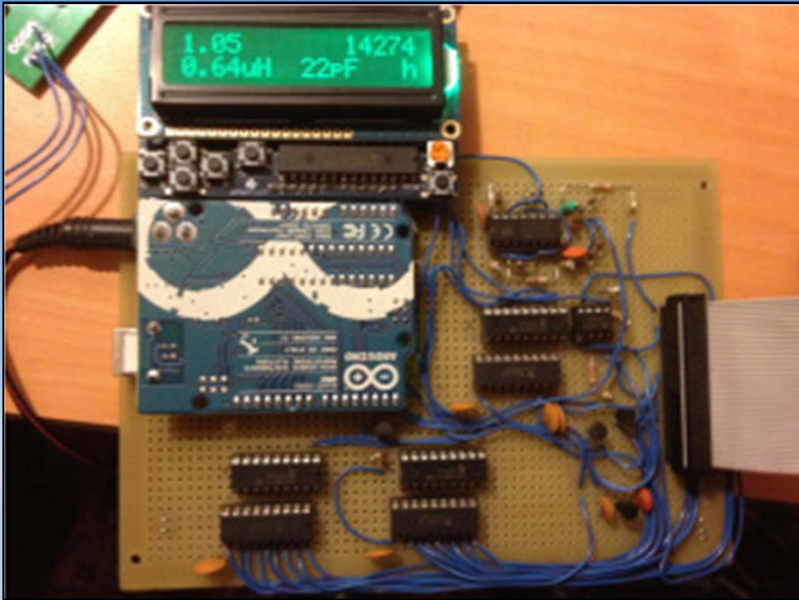
Homebrew Switching Board



All modules wired together

Arduino – Radio Artisan K3NG

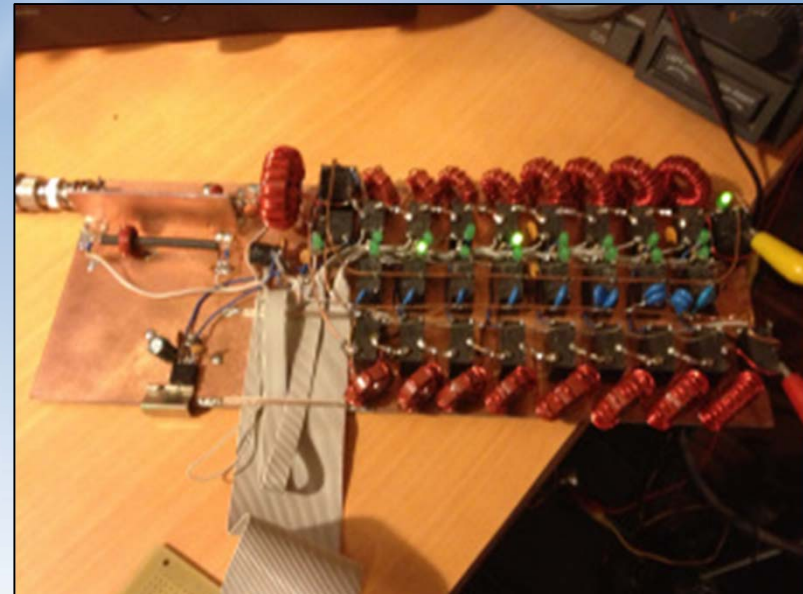
Website dedicated to Ham Radio Arduino projects



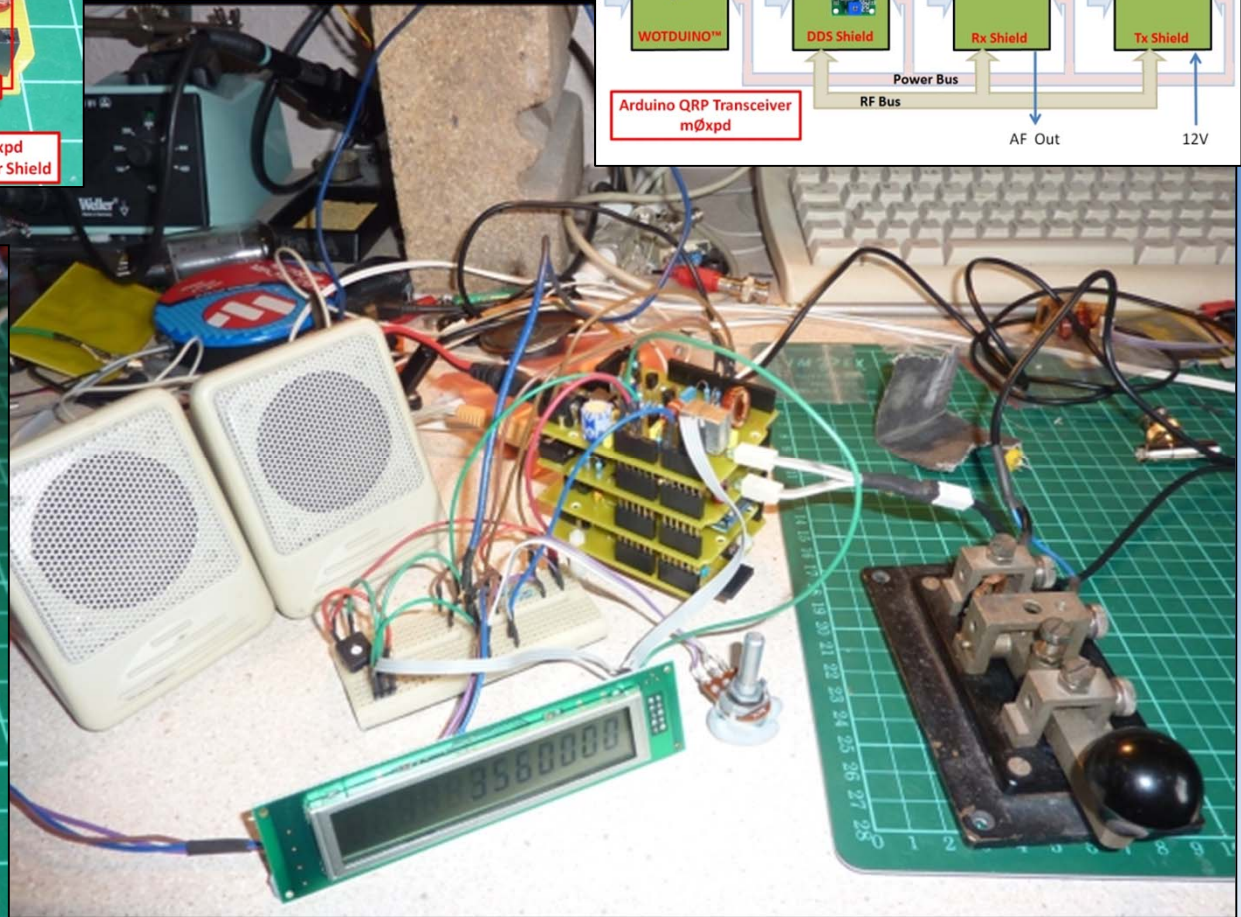
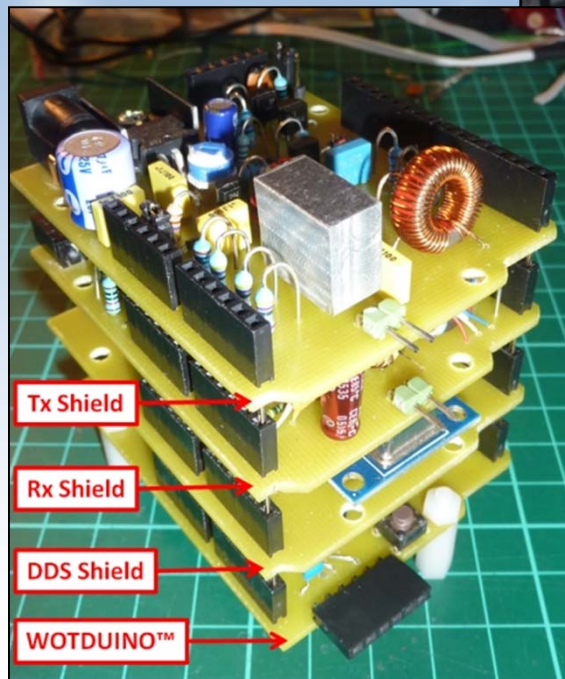
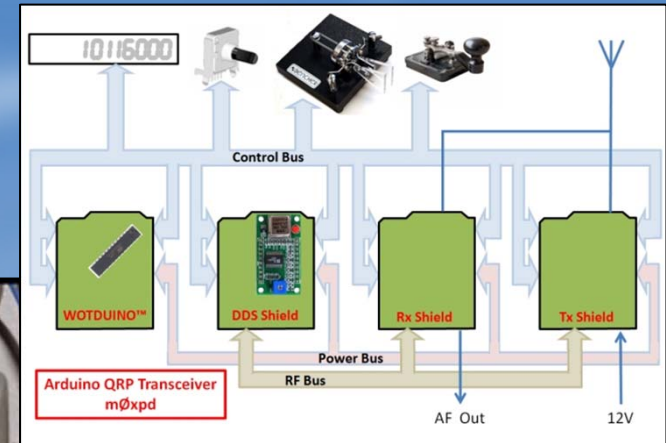
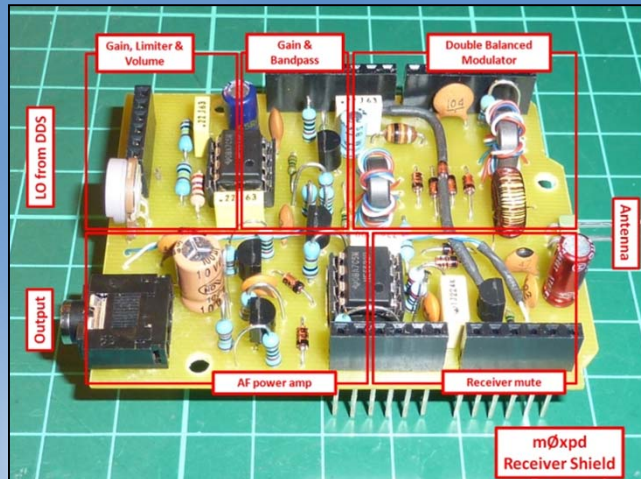
- Downloadable sketches
- Diagrams and photos
- Discussion forums
- Resource links

Current Projects:

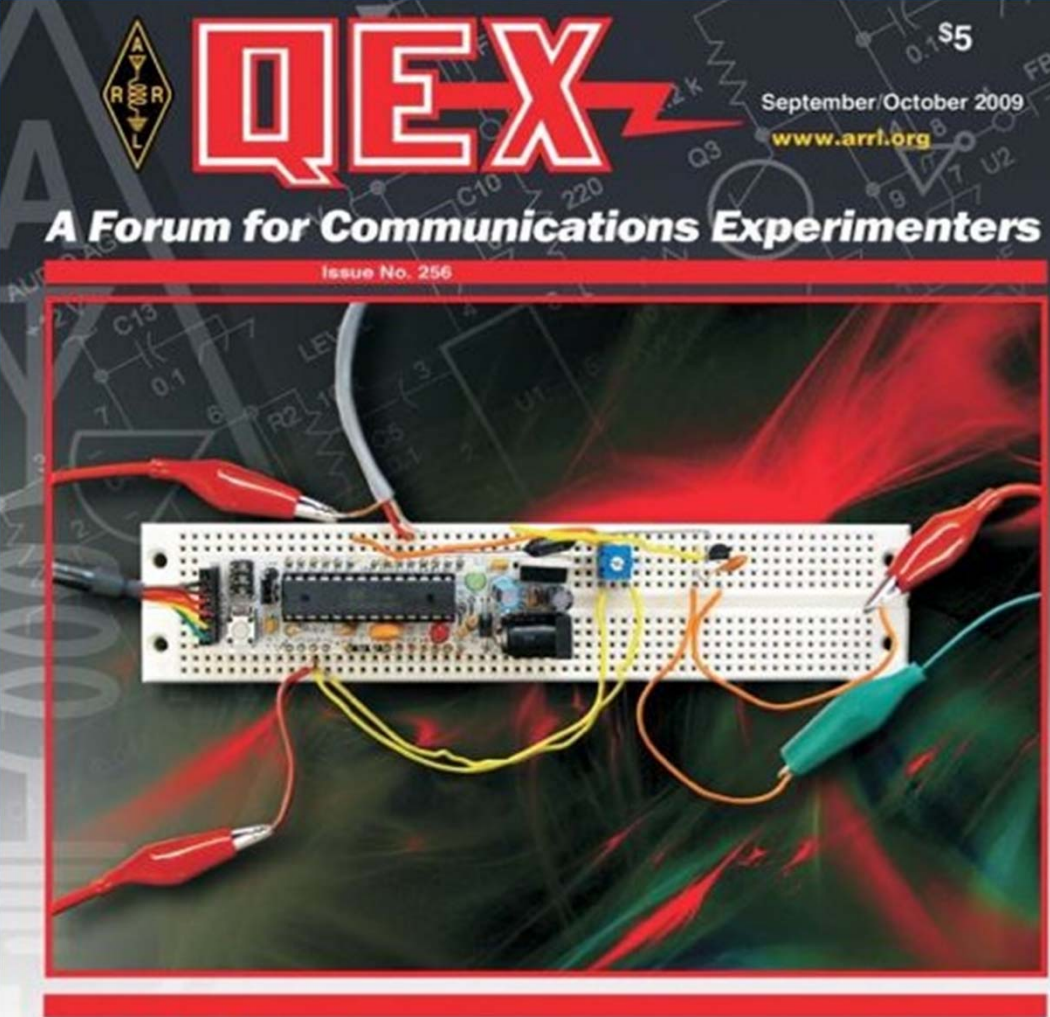
- Arduino controlled beacon
- CW Keyer
- Rotator controller
- Antenna tuner



Arduino – QRP Transceiver! M0XPD



Arduino – Ham Radio Reference



QEX \$5

September/October 2009
www.arrl.org

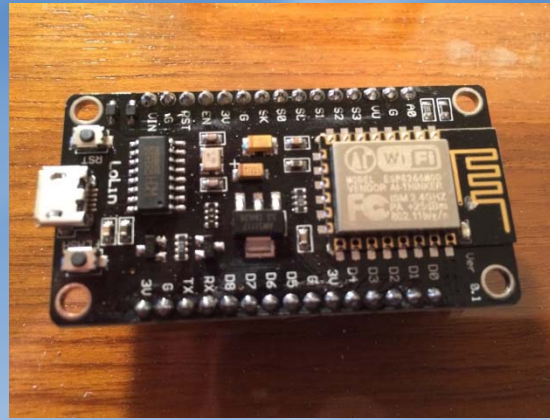
A Forum for Communications Experimenters

Issue No. 256

KC4IFB introduces the Arduino microcontroller board as a development platform. He shows us how to design and program an electronic keyer in this issue.

Arduino – The Future

ESP8266MOD (NodeMCU)



Arduino and WiFi on a chip for about \$10 CDN
Faster, Smaller, Cheaper, More storage, More accurate

32-bit [RISC](#) CPU: [Tensilica](#) Xtensa LX106 running at 80 MHz*

64 KB of instruction RAM, 96 KB of data RAM

External QSPI flash - 512 KB to 4 MB* (up to 16 MB is supported)

[IEEE 802.11](#) b/g/n [Wi-Fi](#)

Integrated [TR switch](#), [balun](#), [LNA](#), [power amplifier](#) and [matching network](#)
[WEP](#) or [WPA/WPA2](#) authentication, or open networks

16 [GPIO](#) pins

[SPI](#), [I²C](#),

[I²S](#) interfaces with DMA (sharing pins with GPIO)

[UART](#) on dedicated pins, plus a transmit-only UART can be enabled on GPIO2

1 10-bit [ADC](#)

* Both the CPU and flash clock speeds can be doubled by overclocking on some devices. CPU can be run at 160 MHz and flash can be sped up from 40 MHz to 80 MHz. Success varies chip to chip.

Ham Radio - Projects

NEW BOOK!

Ham Radio for Arduino and PICAXE

Easy to build microcontroller weekend projects—for use in the shack, in the field, and on the air!

Edited by Leigh L. Klotz, Jr,
WA5ZNU

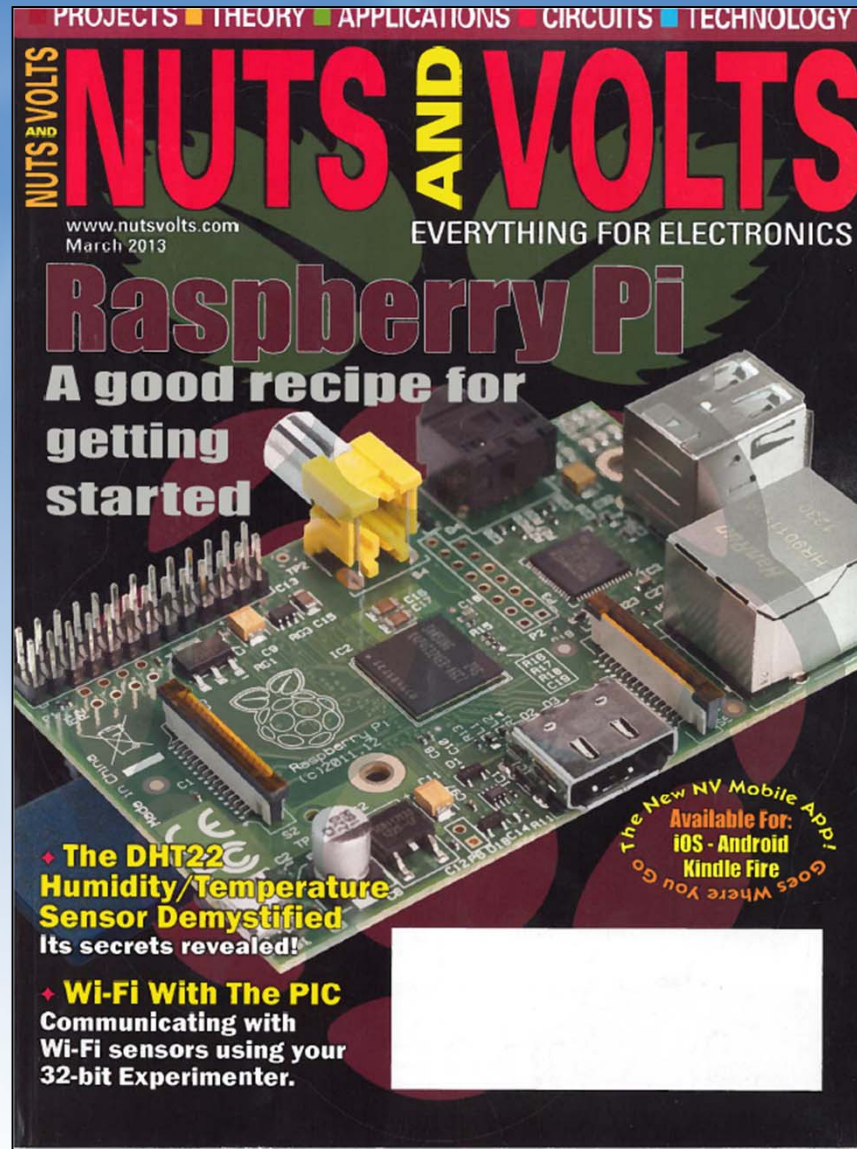


Projects:

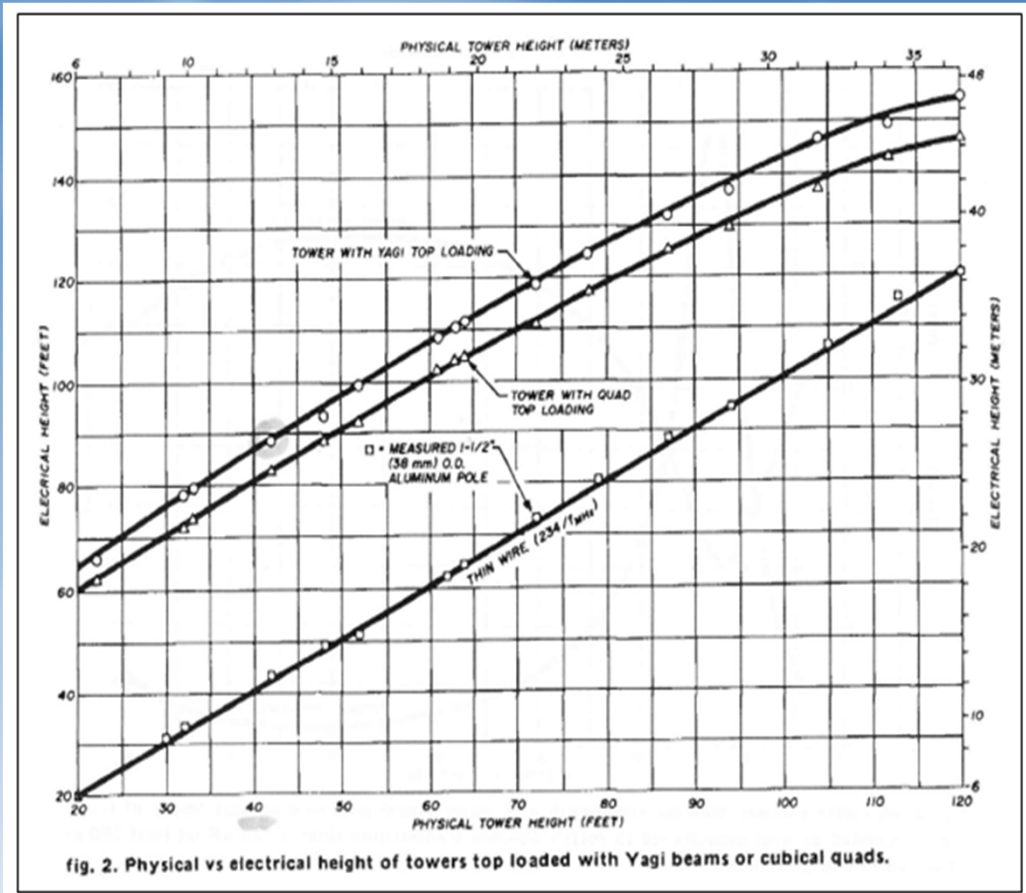
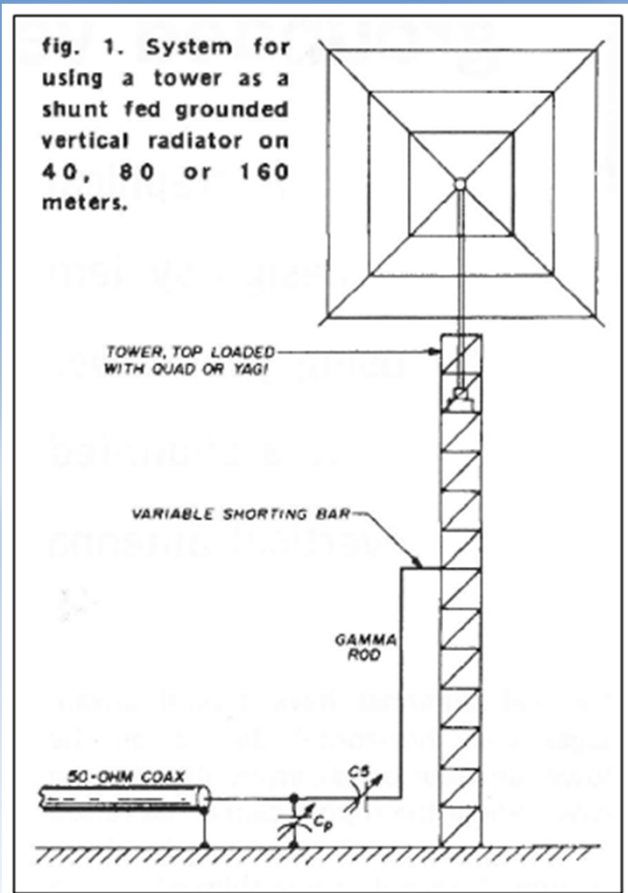
- APRS Data Logger
- QRSS Beacon
- Multimode Transmitter Shield
- High Voltage, High Frequency, and High Temperature Data Logger
- Receive-Only, Low-Power APRS iGate
- PICAXE Keyer and CW Beacon Keyer
- Solar Tracker
- Nanokeyer
- Handheld Radio Talk Timer
- APRS Messenger
- DTMF Controlled SSTV Camera
- APRS Display
- Waterfall
- SWR Scanner

...and more projects using the Arduino, PICAXE, and ATtiny microcontrollers

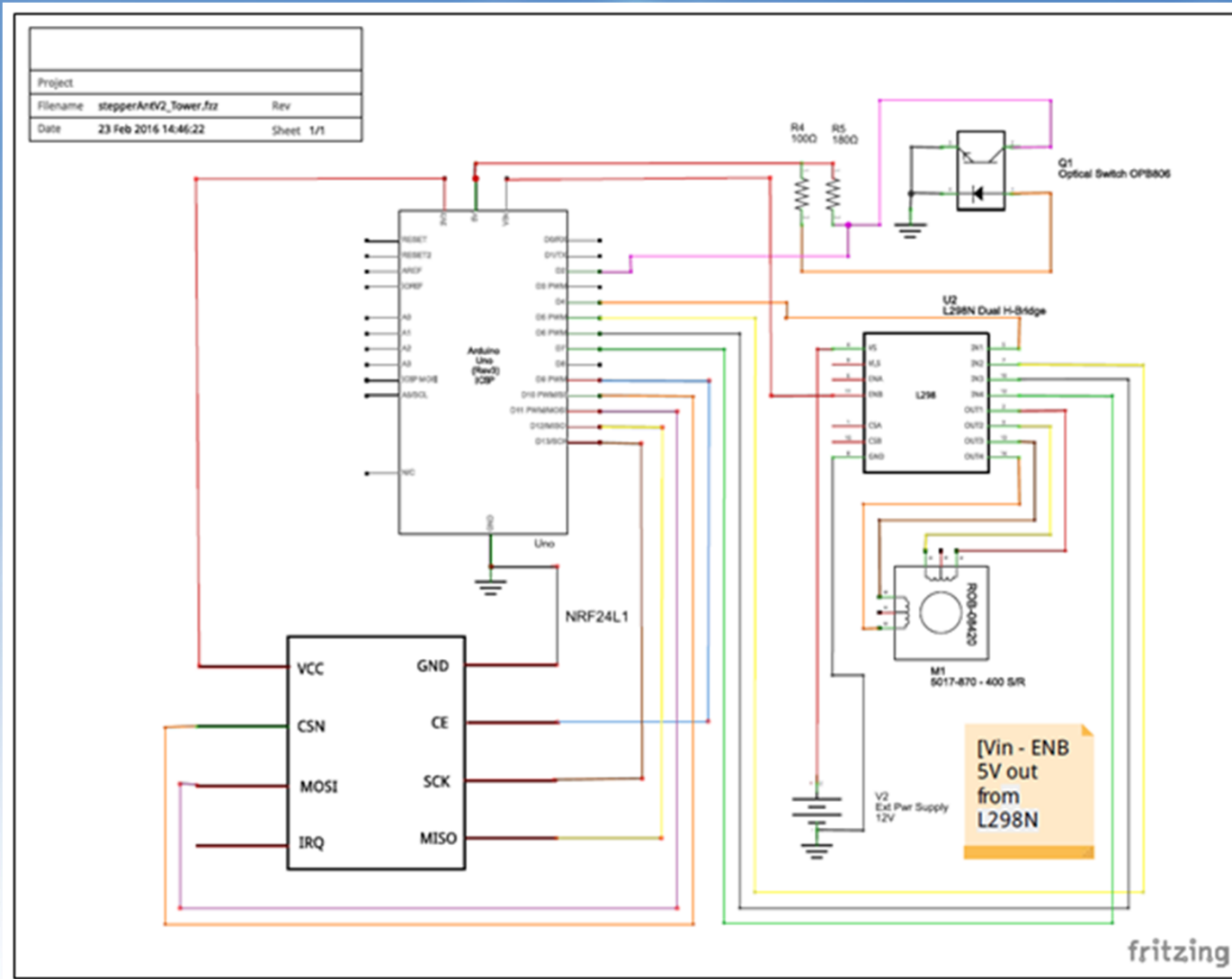
Recommended Reading



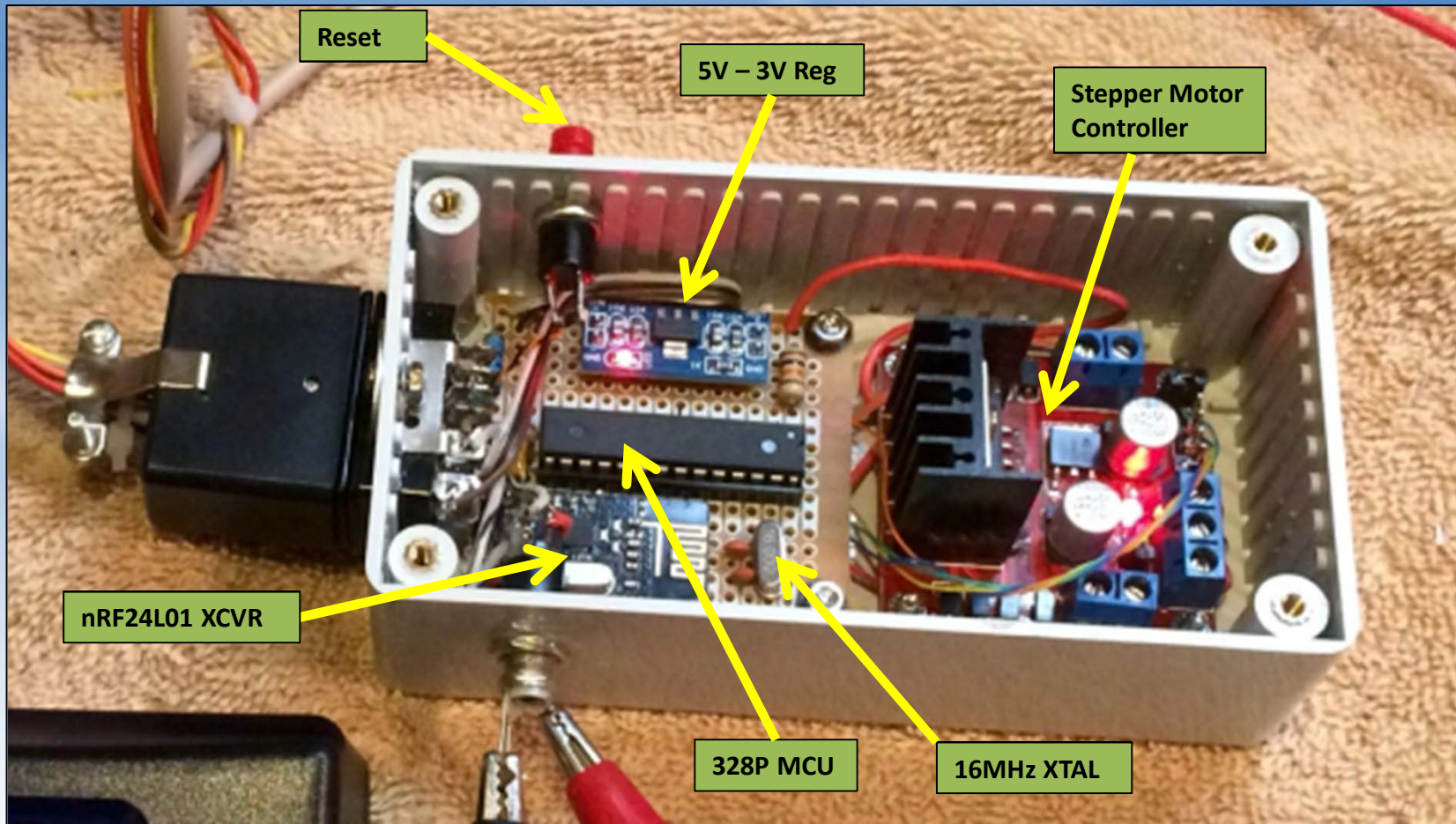
Shunt-fed Tower Project



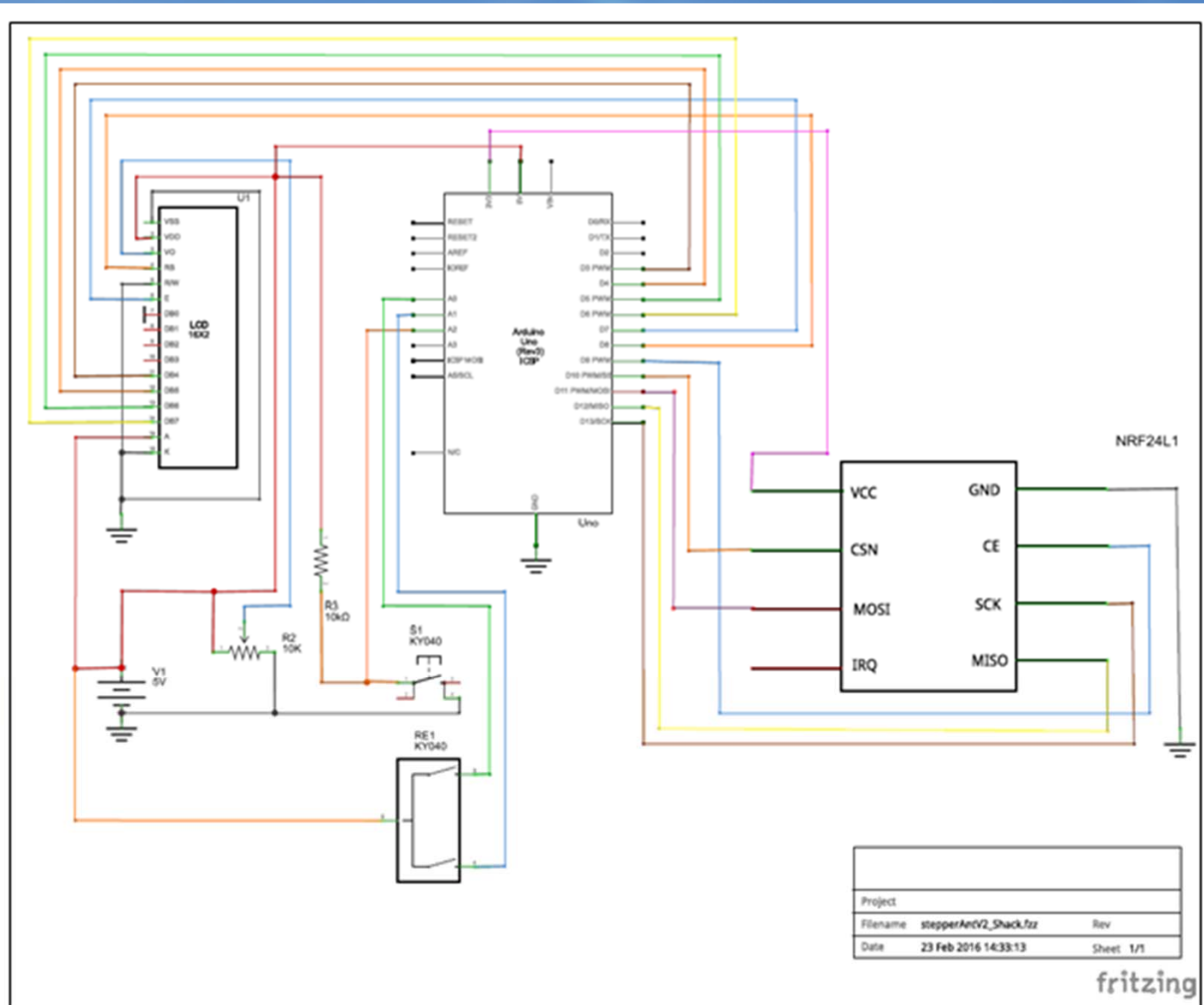
Shunt-fed Tower Project – Tower Unit Schematic



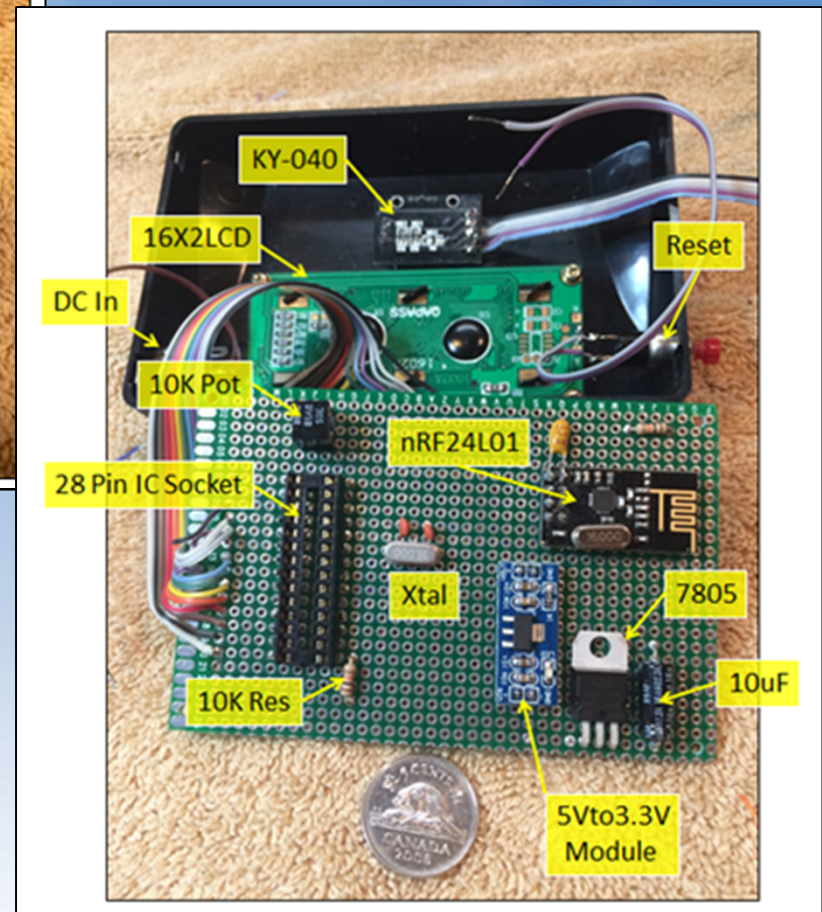
Shunt-fed Tower Project – Tower Unit Device



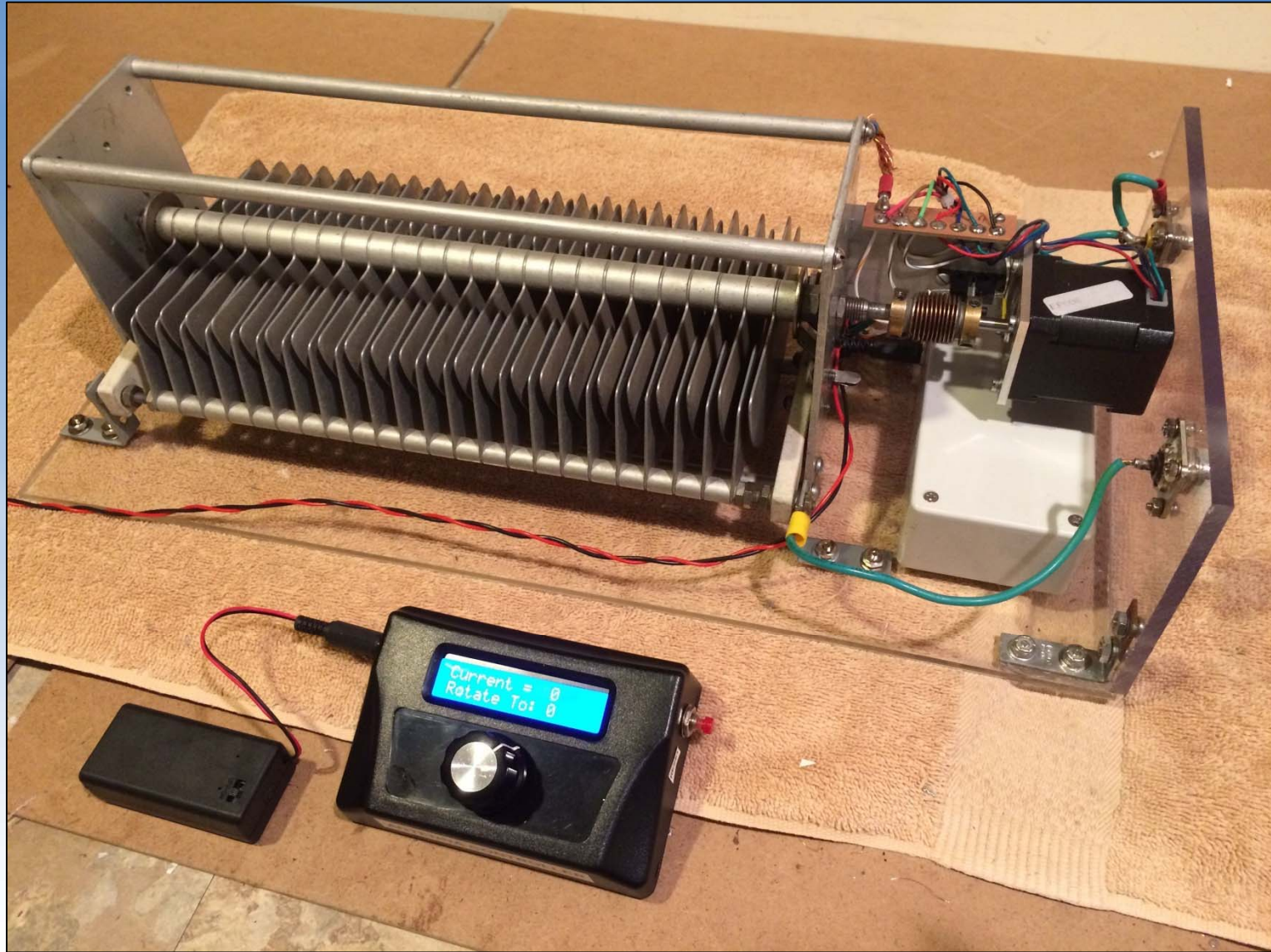
Shunt-fed Tower Project – Shack Unit Schematic



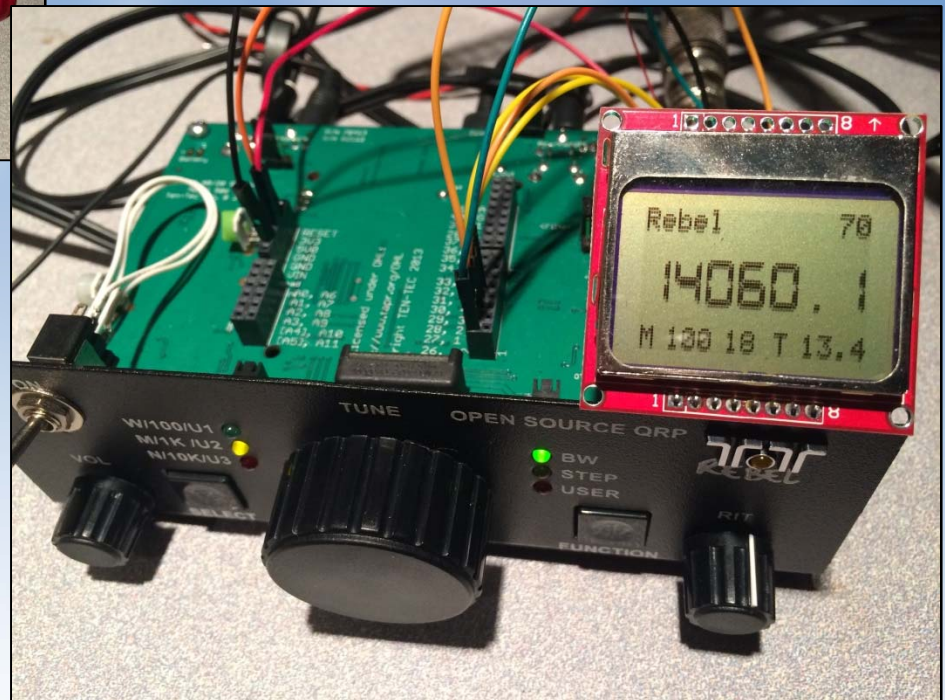
Shunt-fed Tower Project – Shack Unit Device



Shunt-fed Tower Project – Final Configuration



The Rebel by TenTec - Arduino-based QRP Transceiver



Summary

- Microcontrollers such as the Arduino are leading a revolution in new applications, including amateur radio
- Microcontrollers are inexpensive, safe to use (no high voltages), and ubiquitous
- Other inexpensive hardware, such as the Raspberry Pi, Beaglebone Black, etc. provide complementary platforms that can lead to new technologies – Examples include prosthetic limbs, robotics, quad copters, high altitude balloon measurements, home brew satellites, etc.
- The technology continues to evolve by getting smaller, faster, lighter, smarter, and using less energy.

THANK
YOU