Using Microcontrollers in Amateur Radio, an AZ EL Controller Application

A Presentation For The Southwest Ohio Digital Symposium

Presented by Bill Erwin – N9CX   January 10, 2009

Things I Hope To Leave You With

- Share my experience with the rotor controller project
  - Explain why I made the choices I did
  - How it works
  - Status of the project

- But more than that:
  - Why a microcontroller was a good choice for this project
  - What software development environments are all about
  - Tempt you to consider experimenting with microcontrollers

Feel free to ask questions at any time !

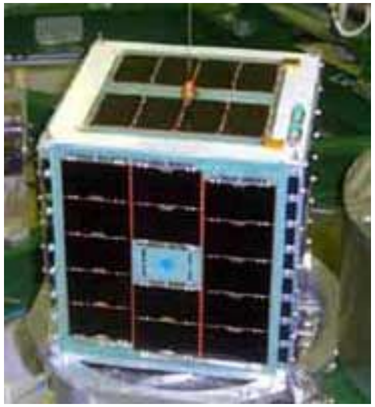
Motivation For This Project

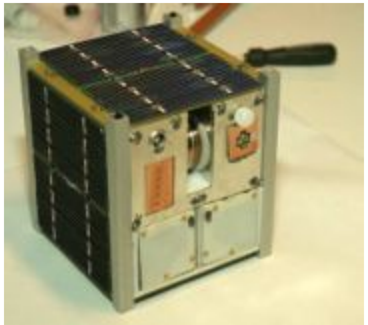
- Developed an interest in LEO (Low Earth Orbit) satellites
  - Led to an interest in a better antenna system
  - Wanted to track LEOs with small beam antennas
- Commercial rotors & controllers are available
  - Didn’t want to commit that much money at this stage of interest
- Decided to use inexpensive rotors & build my own controller

Low Earth Orbit Satellites

- Basically LEOs are orbital repeaters
- AMSAT has a lot of information on the WEB
- LEOs offer some special challenges
  - They move fast.
  - Short contacts
  - Low RF power

LEO Satellites Vary In Both Size & Complexity





AO-51 (Echo)

~800 km orbit

voice repeater

PakSat BBS

PSK31 Digital

SuitSat-1 (AO-54)

Russian space suit

Launched from ARISS ~355 km

telemetry only

temp & battery

N-Cube2

10x10x10 CM

I LITER VOLUME

(University Projects)

~690 km orbit

Satellite QSOs Are Interesting!

- There are a lot of "things" involved in working the LEO satellites!
  - Computer screen
  - Keyboard
  - Mouse
  - Downlink frequency
  - Uplink frequency
  - Doppler effects
  - Code paddles or a microphone
  - Azimuth of the satellite
  - Elevation of the satellite

So Many things – So Little Time!

- The window for a QSO is often less than 8 minutes.
- If you can automate a few “things”, your QSOs may have more “talk” time.
- This project is about automating the rotors for directional azimuth & elevation antennas.

My Approach To The Project

- Research the WEB for similar projects
- Evaluate what I might do that is different
- Understand how rotors work
- Keep it (relatively) cheap
- Breadboard parts of the design to verify critical assumptions

- Rotor controller needs an LCD display & flashing LEDs!

Why Use A Microcontroller Anyway?

What Can Microcontrollers Do For You?

Many Packages Can Be Replaced By One

Choices To Make

- Features
- Rotors
- Software Development tools & Environment
- Microcontroller

Desirable Features

- Work with the Nova tracking software
- Have 2 main modes: “manual” & “autotrack”
- Self-calibrate to any Pulser type rotor
- Remember antenna position during powerdown.
- Reliable beam positioning – within 5 degrees.
- Easy to update the controller software.
- Minimize cost

The Rotor – You must understand the thing you are trying to control!

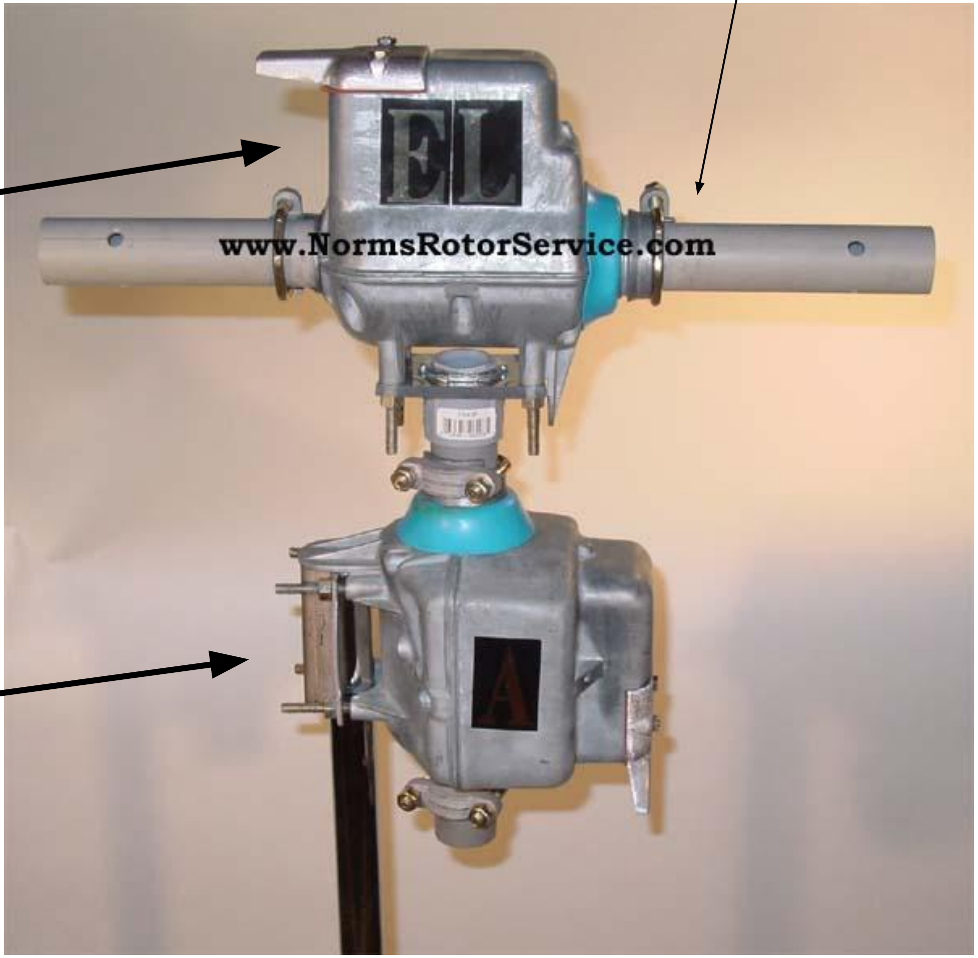
The Alliance U100

Yes – You Can Stack Them

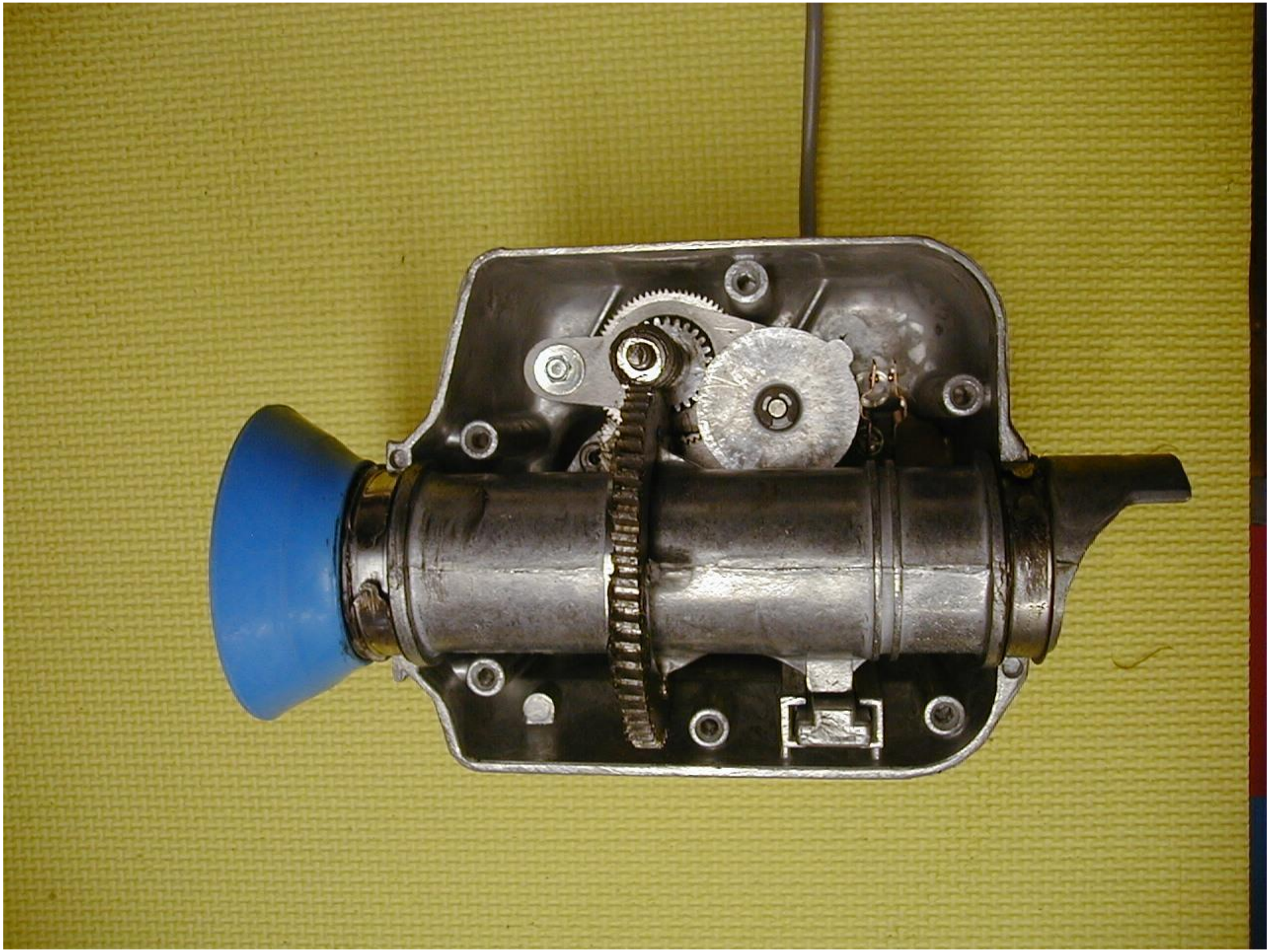
The ability to put a pipe through the rotor body is fairly unique.

Elevation

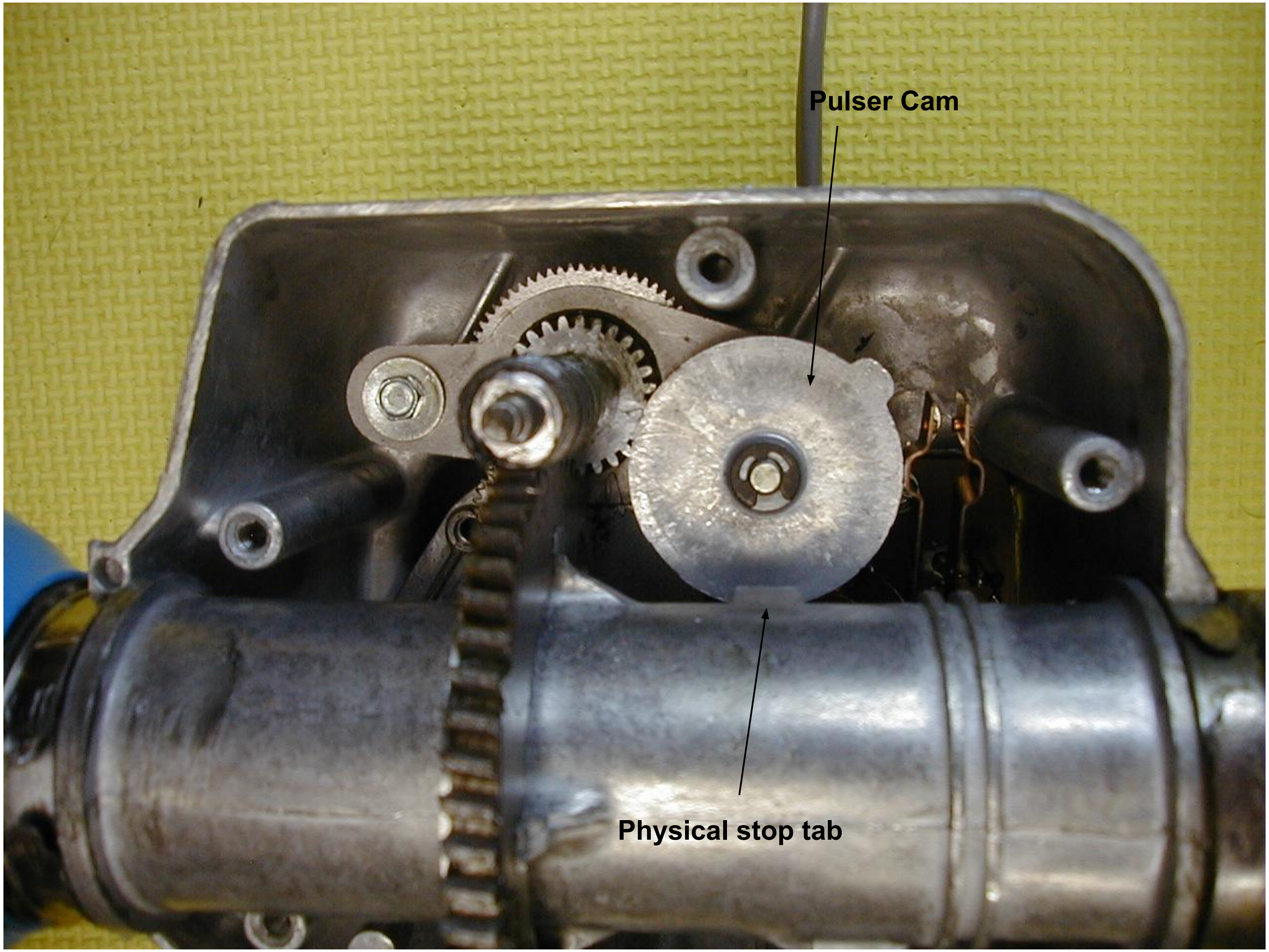
Azimuth



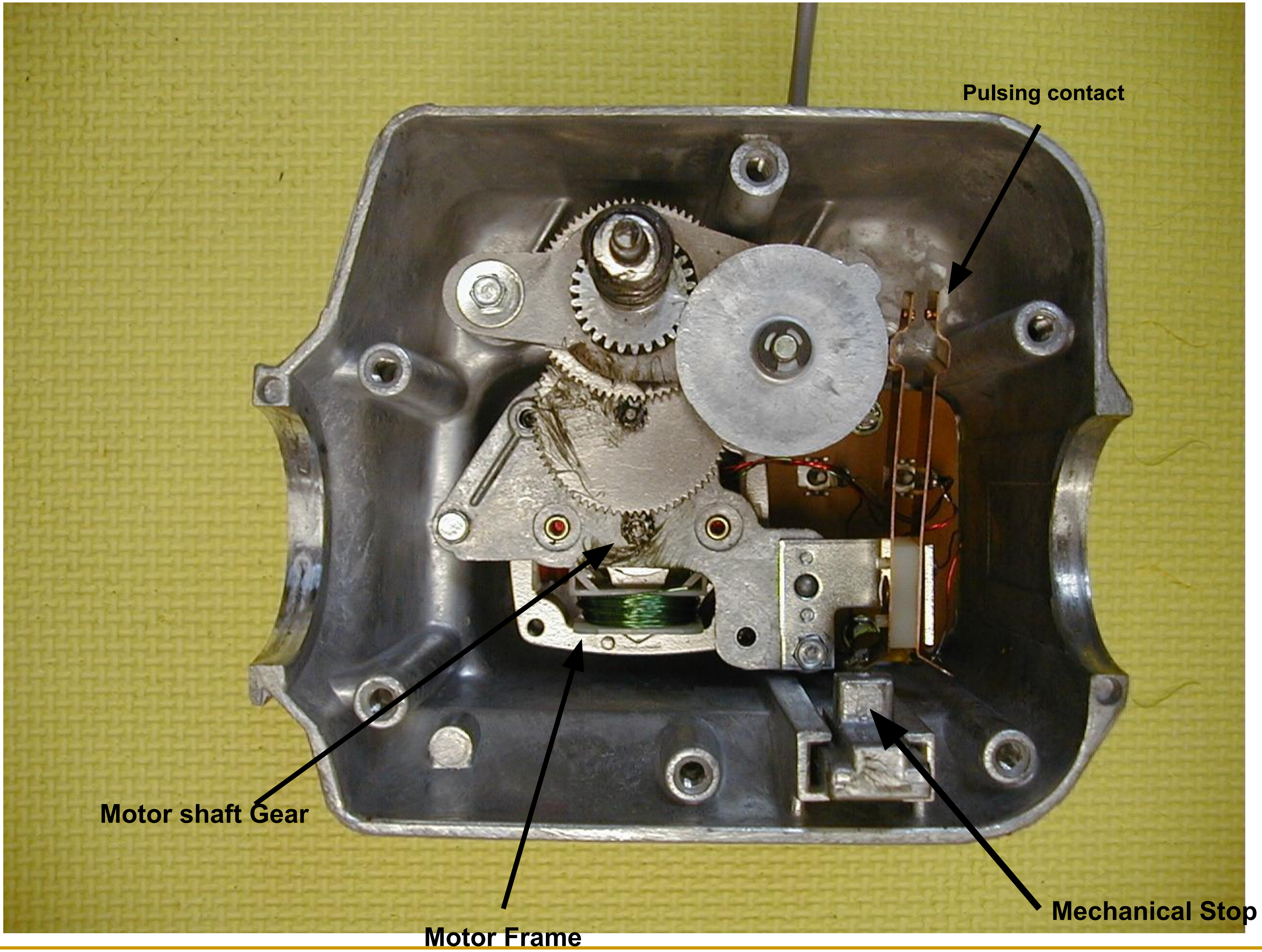
Anatomy Of A U100 Rotor #2



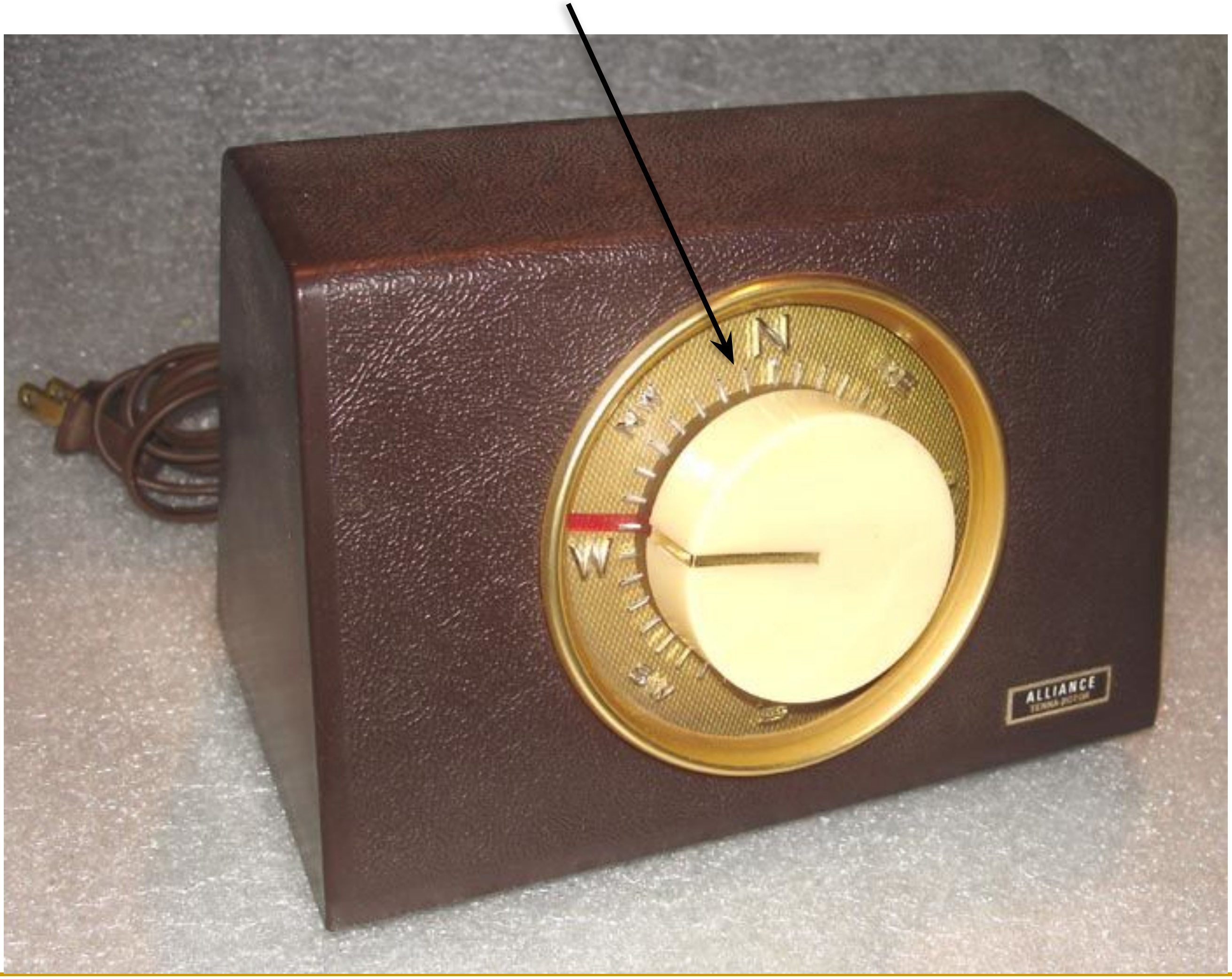
Anatomy Of A U100 Rotor #3



Anatomy Of A U100 Rotor #4

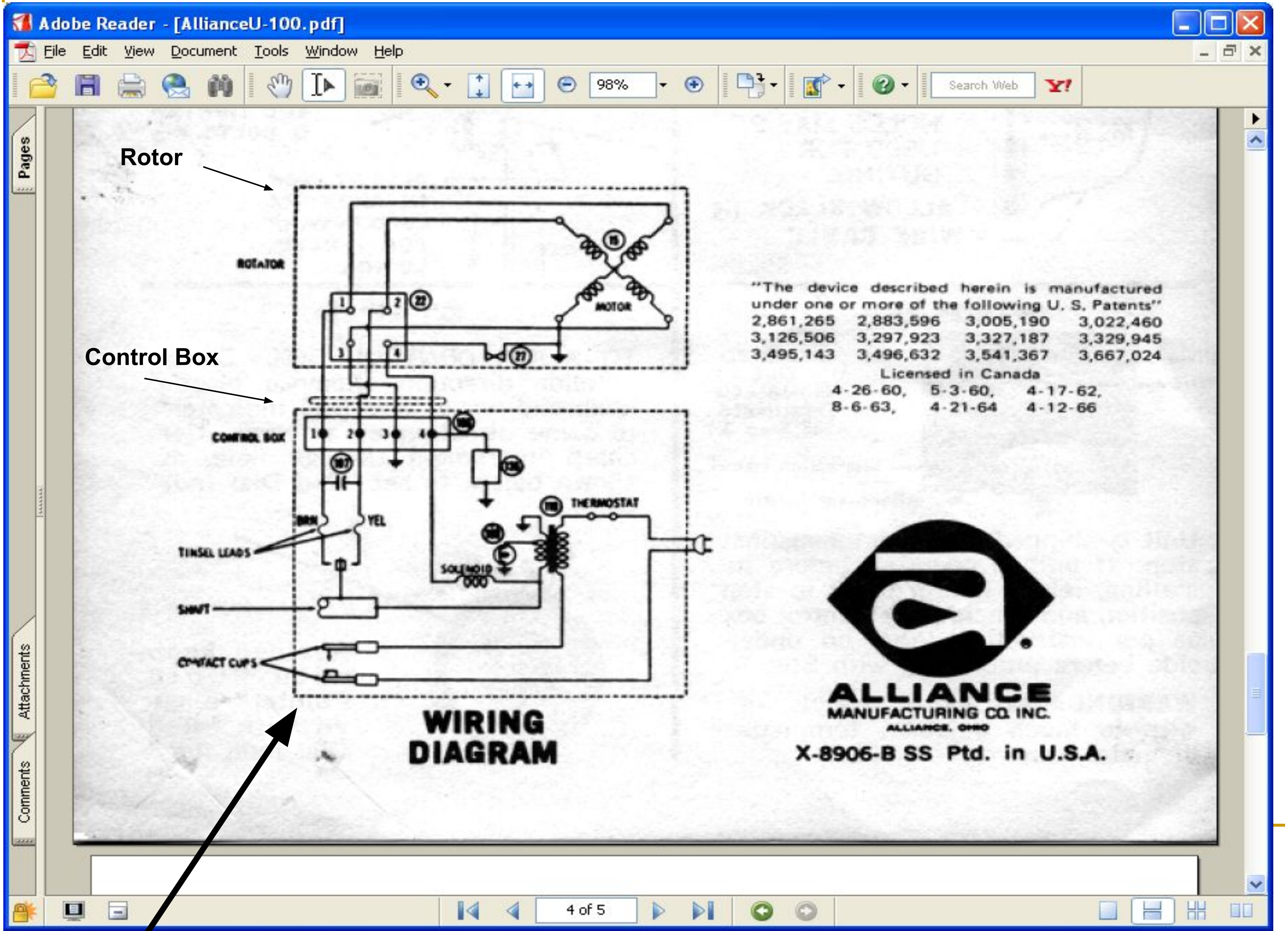


Commercial Controller for the U100 Rotor



10 degree graduations on the dial

The Original U100 Rotor Schematic Diagram



WIRING DIAGRAM

"The device described herein is manufactured under one or more of the following U. S. Patents"

2,861,265	2,883,596	3,005,190	3,022,460
3,126,506	3,297,923	3,327,187	3,329,945
3,495,143	3,496,632	3,541,367	3,667,024

Licensed in Canada

4-26-60, 5-3-60, 4-17-62,
8-6-63, 4-21-64 4-12-66

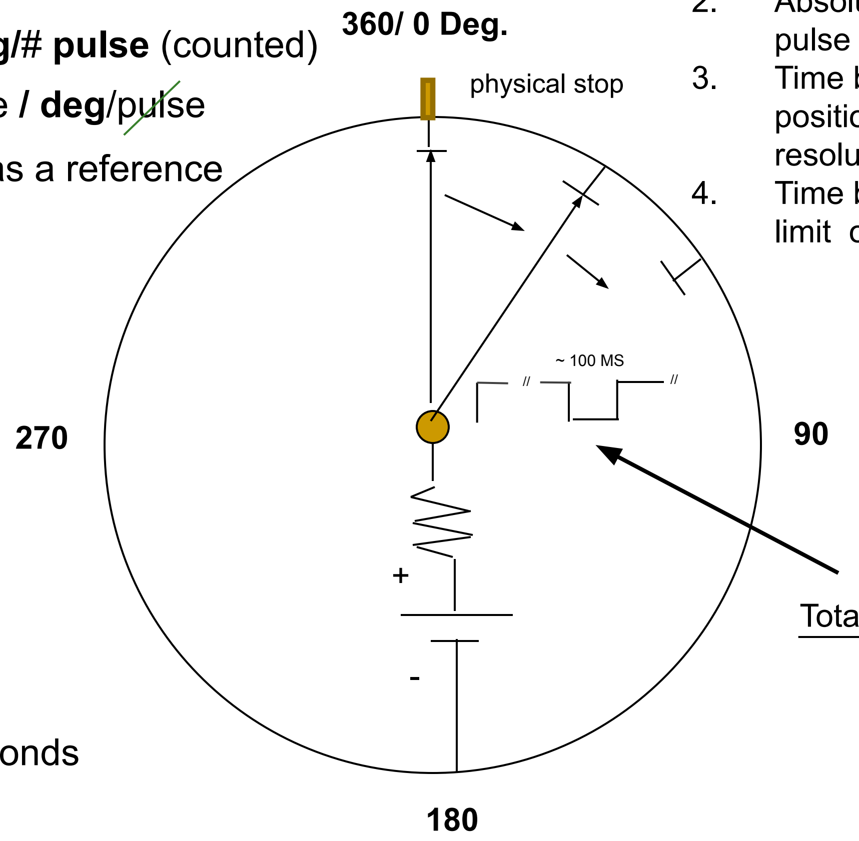
ALLIANCE
MANUFACTURING CO. INC.
ALLIANCE, OHIO

X-8906-B SS Ptd. in U.S.A.

Model of the U100 Rotor

Calibration Mode calculates:

1. deg/pulse = 360 **Deg/# pulse** (counted)
2. tics/deg = **tics**/~~pulse~~ **/ deg**/~~pulse~~
3. Use physical stops as a reference

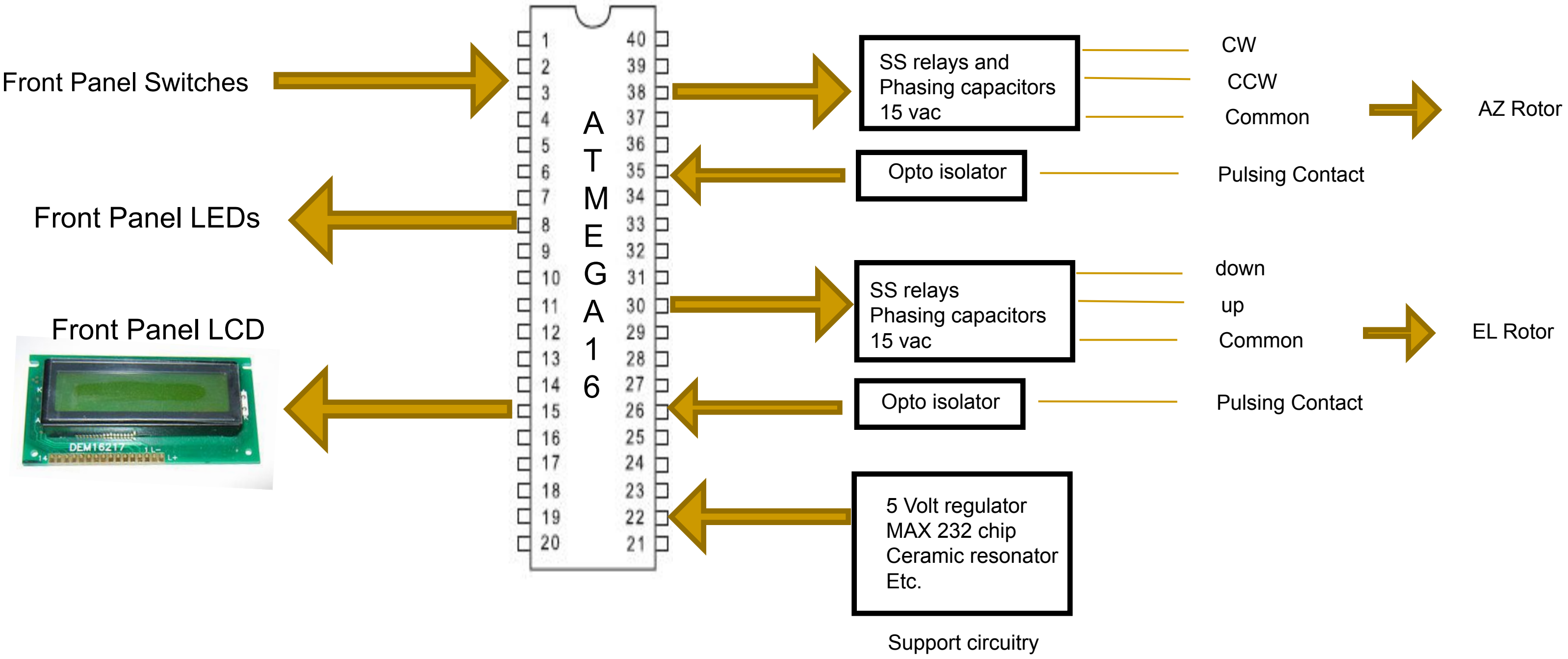


Strategy

1. Do an initial calibration to detect rotor's pulse characteristics.
2. Absolute direction is known at each pulse & at rotor physical stops.
3. Time between pulses to estimate position of rotor to a finer degree of resolution.
4. Time between pulses to detect rotor limit or problems.

Note – A "tic" is 5 milliseconds

Block Diagram Of the Rotor Controller



Front Panel Switches

Front Panel LEDs

Front Panel LCD

SS relays and
Phasing capacitors
15 vac

CW

CCW

Common

AZ Rotor

Opto isolator

Pulsing Contact

SS relays
Phasing capacitors
15 vac

down

up

Common

EL Rotor

Opto isolator

Pulsing Contact

5 Volt regulator
MAX 232 chip
Ceramic resonator
Etc.

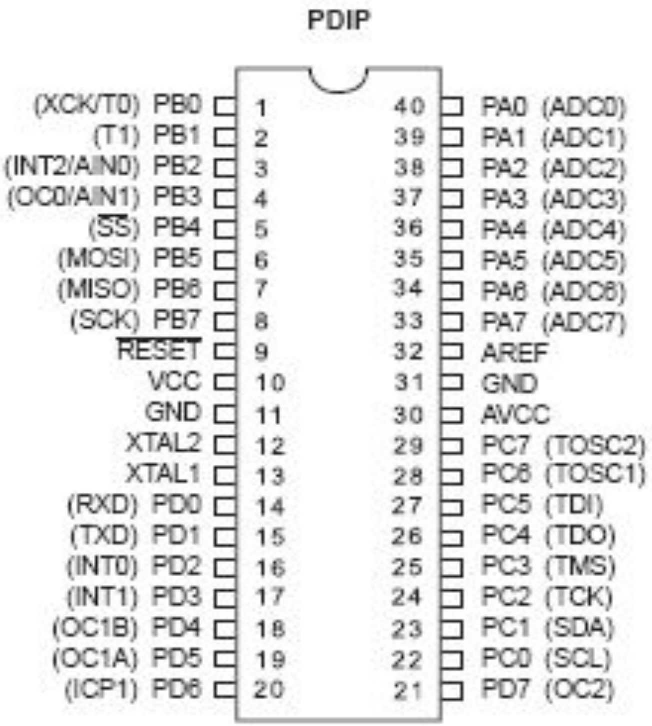
Support circuitry

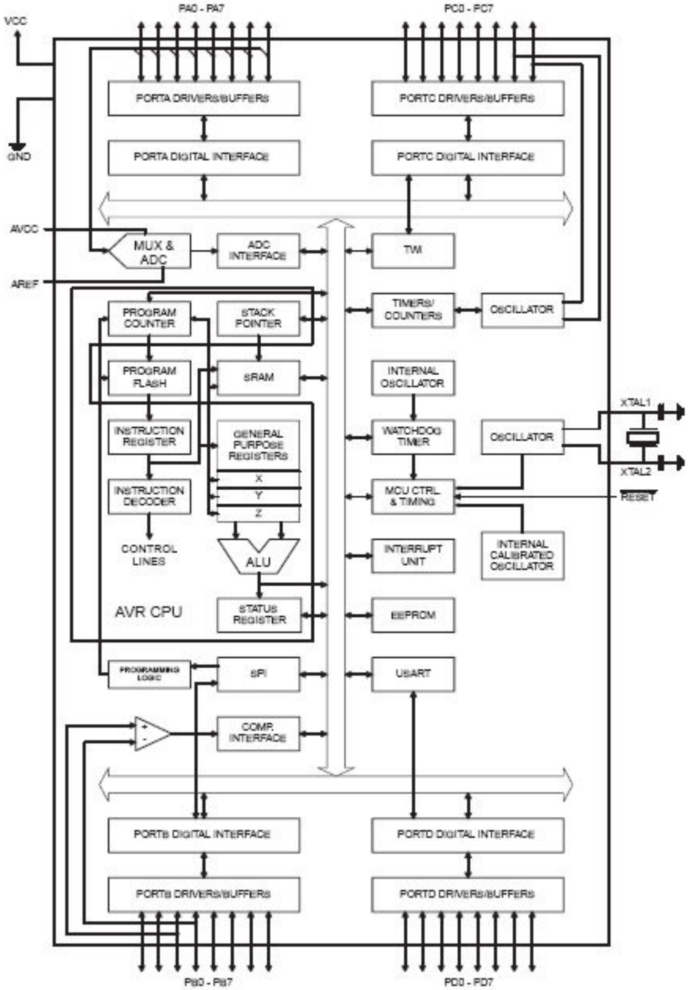
Note - This diagram does not indicate pin assignments

A FEW OF THE ATMEGA 16 FEATURES

- **THE DATA SHEET IS 358 PAGES !**
- **– 32 x 8 General Purpose Working Registers**
- **– Up to 16 MIPS Throughput at 16 MHz**
- **– 16K Bytes of In-System Self-programmable Flash program memory**
- **– 512 Bytes EEPROM**
- **– 1K Byte Internal SRAM**
- **– Two 8-bit Timer/Counters with Prescalers**
- **– One 16-bit Timer/Counter with Prescaler**
- **– Real Time Counter with Separate Oscillator**
- **– Four PWM Channels**
- **– 8-channel, 10-bit ADC**
- **– Byte-oriented Two-wire Serial Interface**
- **– Programmable Serial USART**
- **– Master/Slave SPI Interface**
- **– 32 Programmable I/O Lines**
- **YOU CAN NOT USE ALL AT SAME TIME – SHARE I/O PINS**

Microcontroller – Atmel Atmega16





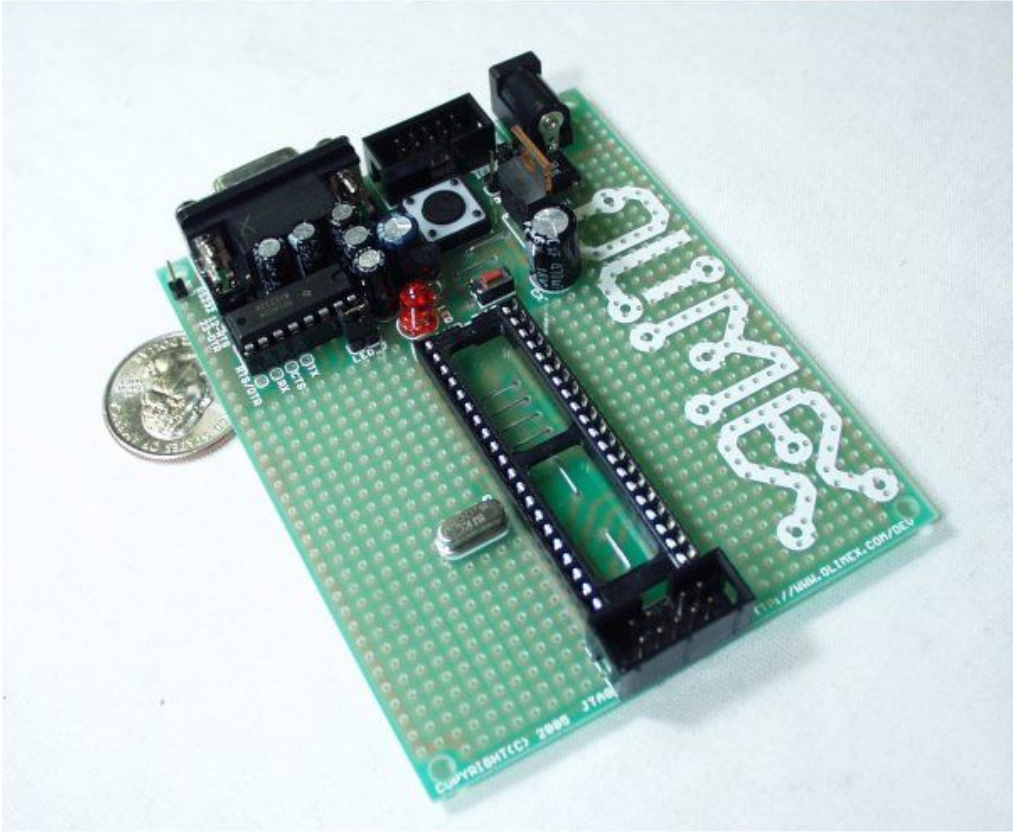
YOU GET A LOT OF FUNCTIONALITY IN A SINGLE PACKAGE

Microcontroller – Save Time By Buying a Proto board

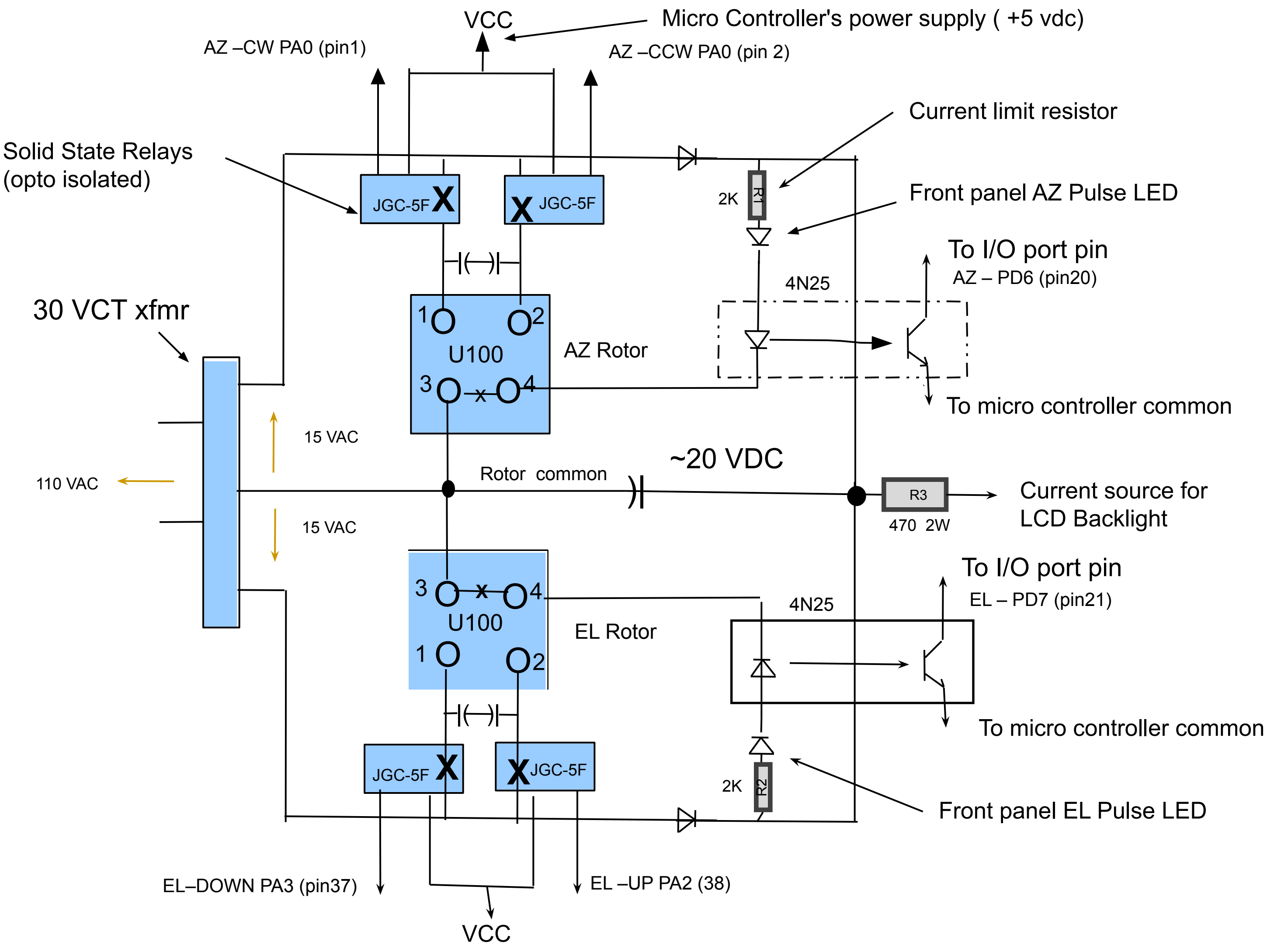
I use this development board for almost all of my projects.

Saves a lot of soldering and cost about $17.00

I get it from “Spark Fun”.



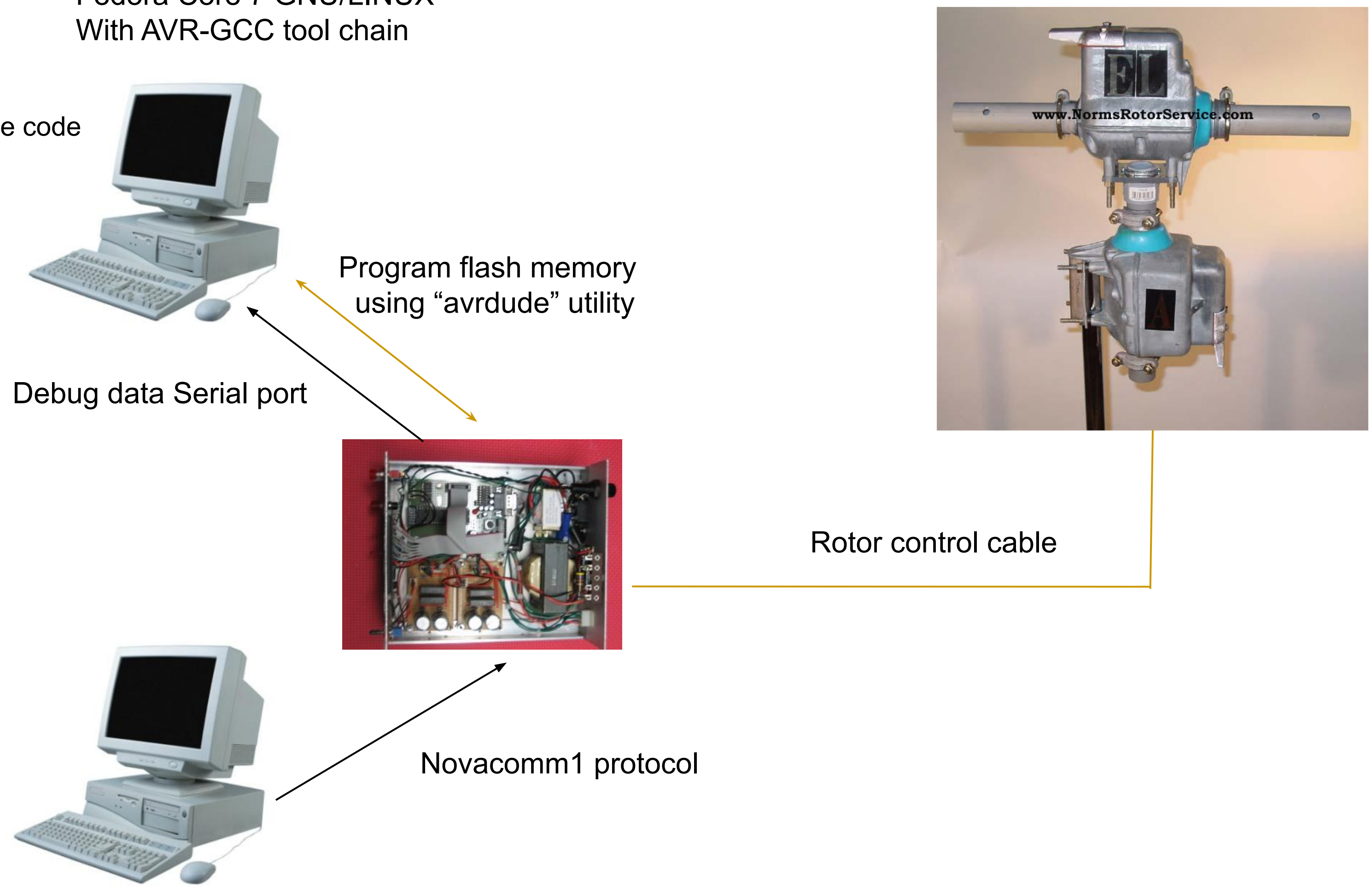
Partial Schematic of the Rotor Controller System – Rotor interfaces



Front Panel Switches – Interface to the Microcontroller

- Micro Controller Port assignments (Active low)
  - Port A Pin 0 - Azimuth ClockWise (CW)
  - Port A Pin 1 - Azimuth Counter ClockWise (CCW)
  - Port A Pin 2 - Elevation Up
  - Port A Pin 3 - Elevation Down
  - Port A Pin 4 - Calibrate momentary pushbutton
  - Port A Pin 5 - Auto Track momentary pushbutton
  - Port A Pin 6 - Azimuth Pulse input
  - Port A Pin 7 - Elevation Pulse input
- LCD Port assignments (4 bit data interface)
  - Details are in a header file

Development Environment



Fedora Core 7 GNU/LINUX
With AVR-GCC tool chain

Write/debug source code

Program flash memory
using “avrdude” utility

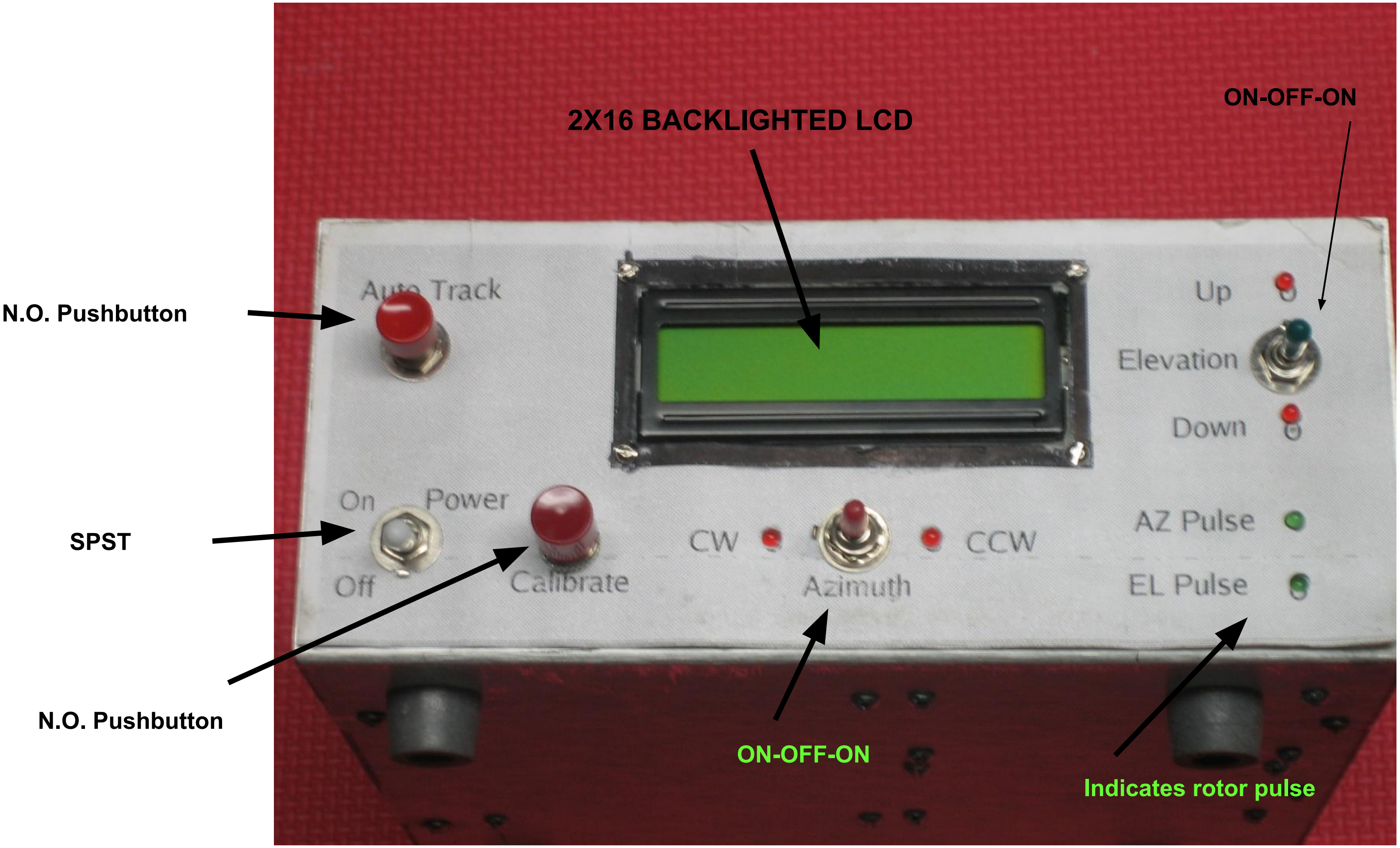
Debug data Serial port

Rotor control cable

Novacomm1 protocol

Windows – running NOVA

Features On My Rotor Control Box



2X16 BACKLIGHTED LCD

ON-OFF-ON

N.O. Pushbutton

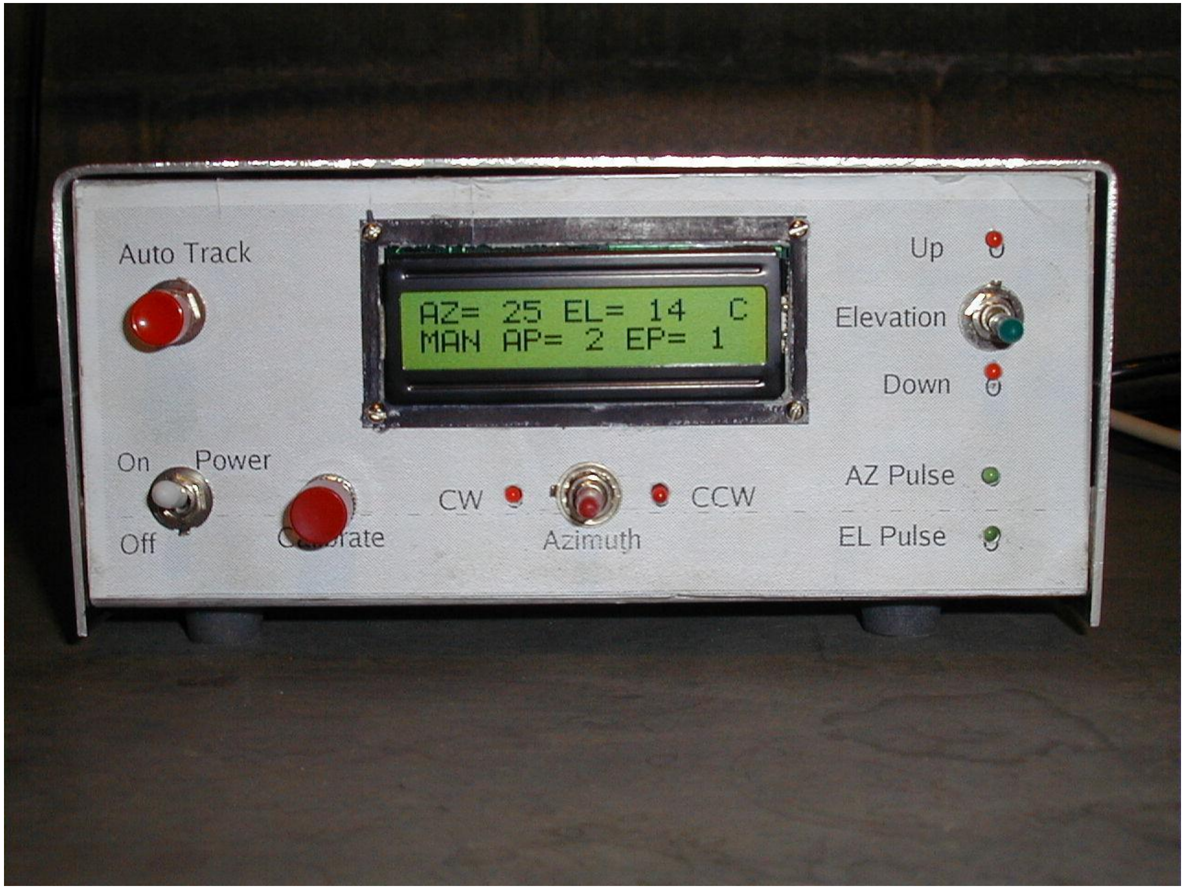
SPST

N.O. Pushbutton

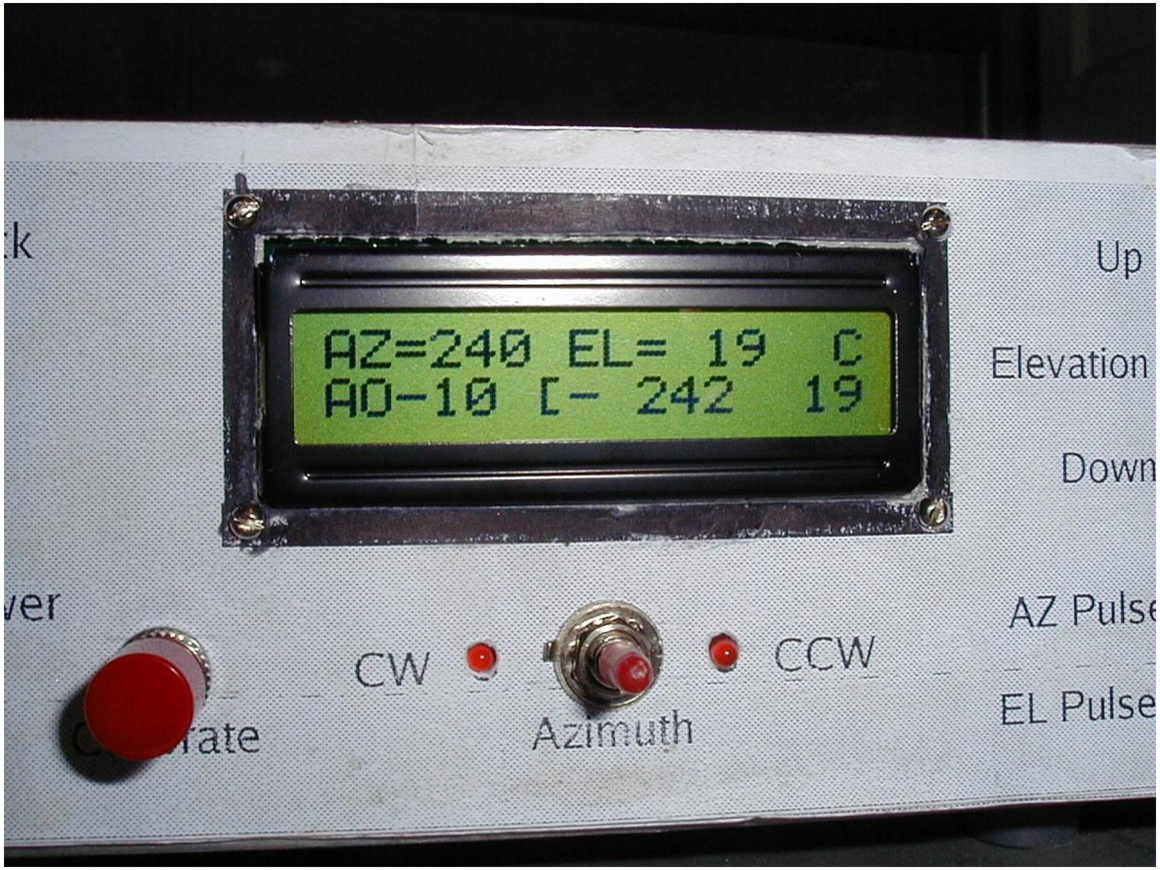
ON-OFF-ON

Indicates rotor pulse

Manual Mode - AZ & EL Reading

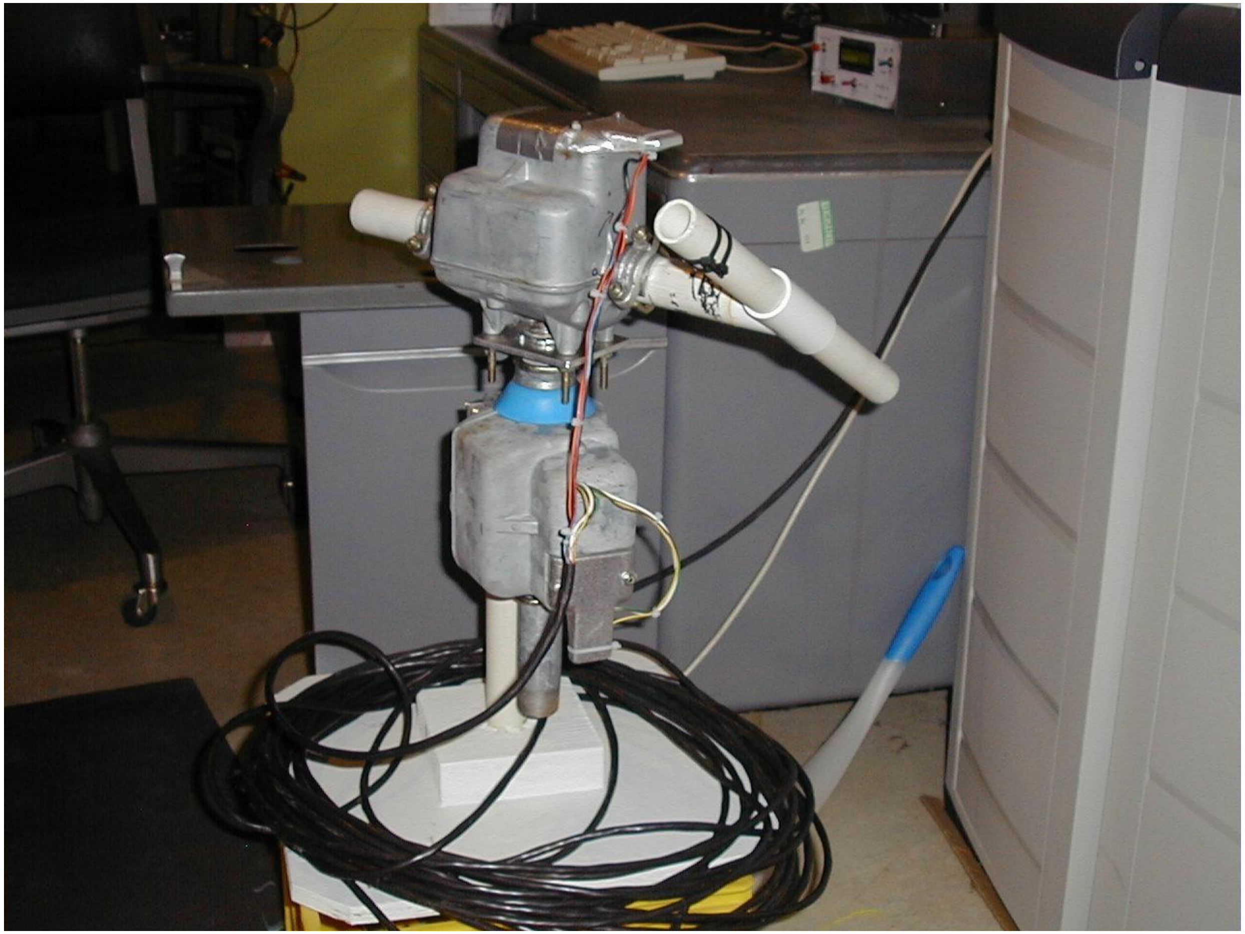


Auto track mode – tracking AO-10 satellite

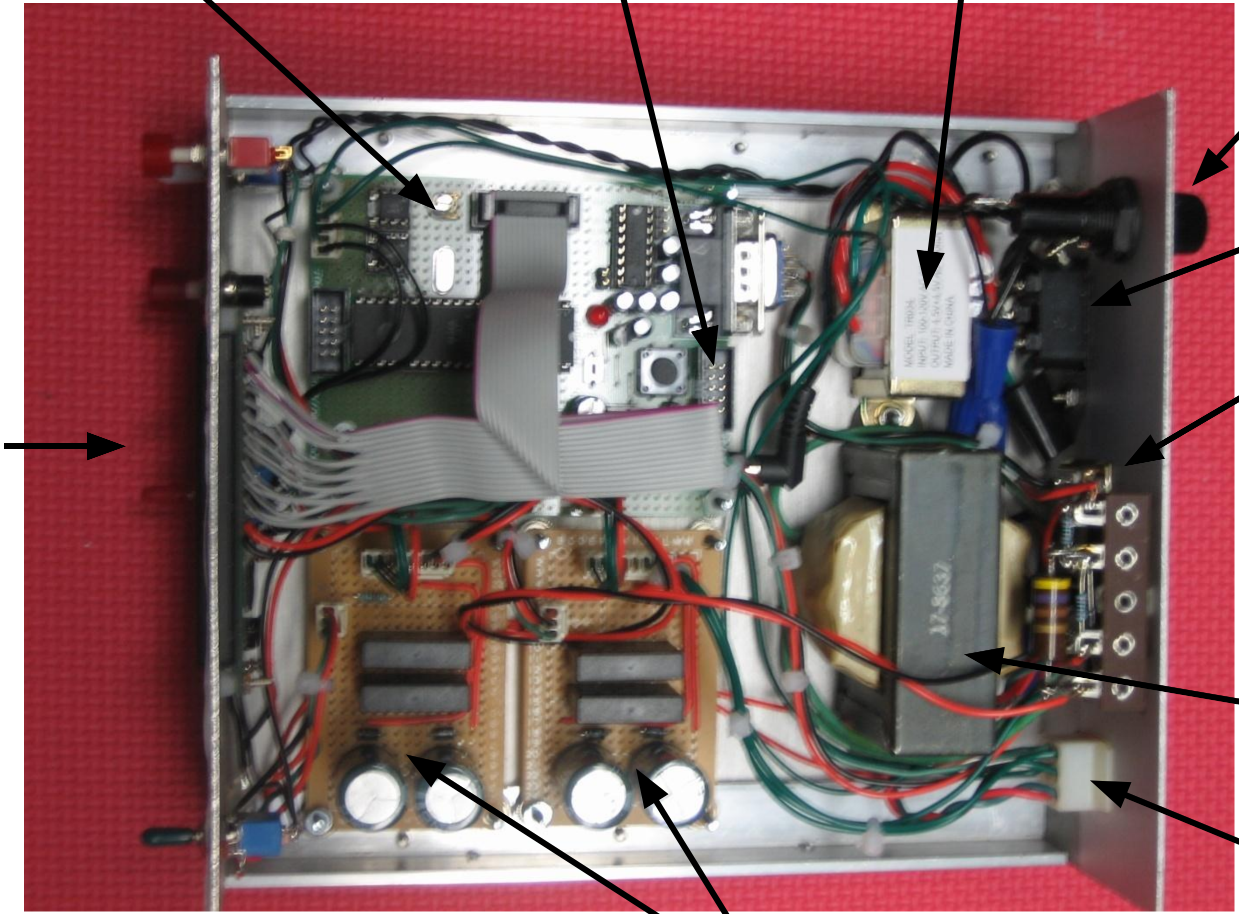


```
AZ=240 EL= 19   C
AO-10 [- 242   19
```

The Rotor Teststand



A Look Under The Hood



Programming header

Xfmr for controller board

Controller Board

Fuse holder

PWR cord connector

Serial in from PC
Serial out for debug

Front Panel

Rotor power

Rotor wires plug
In here.

Phasing caps/SS relay boards

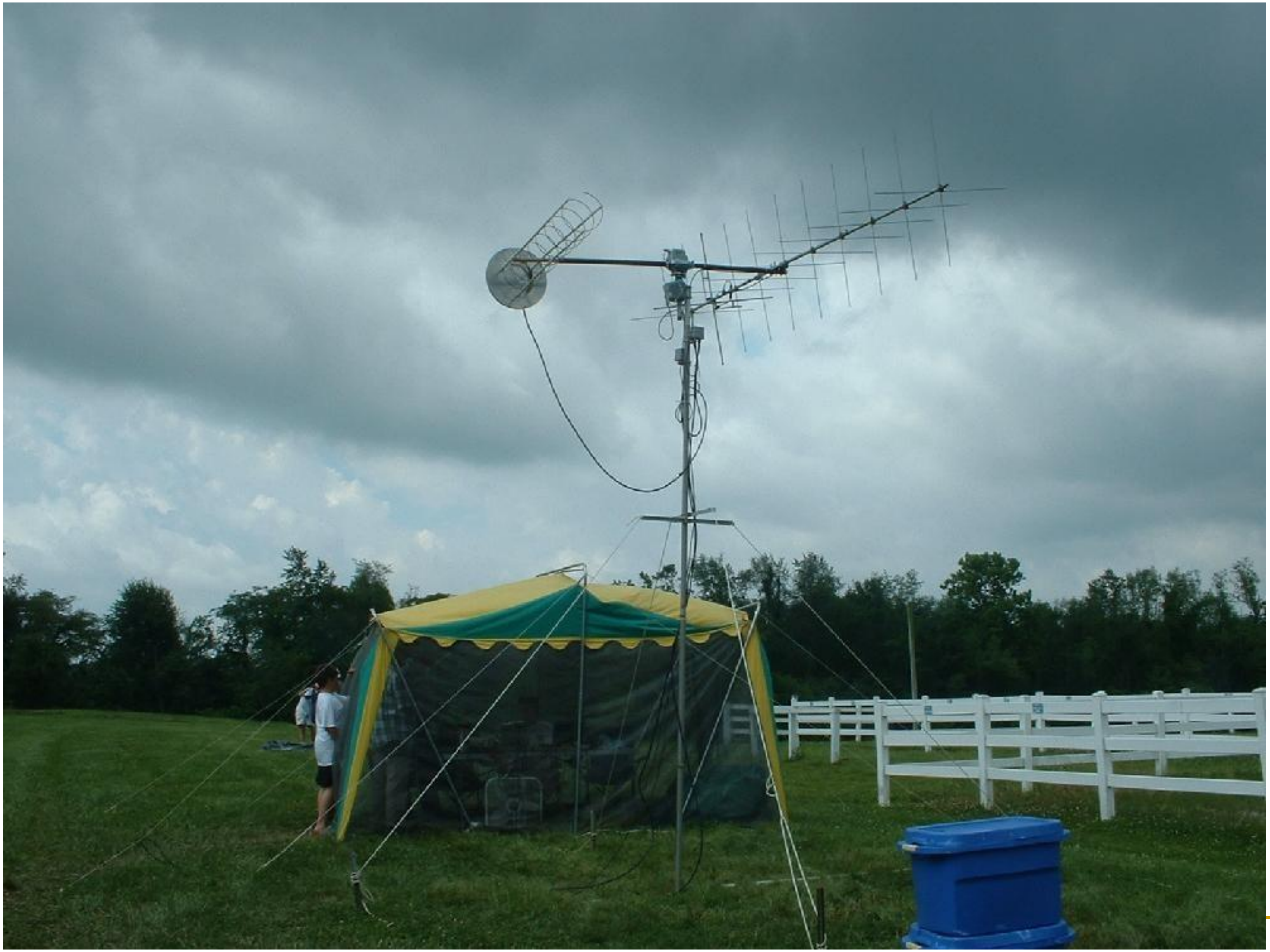
A Few Software Statistics

- ATMEGA 16 Controller
  - 16KBytes Flash (Program) memory
  - 512 Bytes of EEPROM
  - 1 K SRAM
- Software Sizes
  - Program 13394 Bytes
  - Data 262 Bytes – Initialized read only data
  - BSS 399 Bytes – initialized read/write data
  - Total 13995 Bytes
- 30 source files
  - All source is written in "C"
- AVR-GCC Tool Chain programs

High Level Software Design

- BACKGROUND processing every 5 milliseconds
  - Watch every switch in the system
    - Monitor & debounce every switch in the controller
    - Advertise debounced state to the FOREGROUND processing
  - Maintain software timers
    - Decrement every interrupt (5 ms)
- FOREGROUND processing
  - Manage a simple “state machine” based on operating modes:
    - Calibrate
    - Initialize
    - Manual
    - Auto
  - Manages the front panel LCD display & LEDs
  - Fault detection/recovery strategy

Field Day 2008 Satellite Antenna Setup



Performance Of The Controller

- Used successfully in last two Field Days
- Sensitive to drag on the beams – coax
  - False detection of physical stop or obstruction
    - Dressing the coax better resolved this
    - Have changed "late pulse" detection parameters
- Be sure the beams are oriented properly before raising the mast <Hi Hi>
- I consider it a success but it has not seen extensive use

Things Left Undone

- Need to get a better schematic in electronic form
  - Scattered around in a notebook now
- Finish the front panel
  - Print another front panel template and put plastic over it
- Need to paint the box
- Understand other Pulser rotors better (AR-22)
  - Mainly for azimuth rotor use
  - Motor power requirements may not be compatible
- Adapt to “Potentiometer” type rotors - Perhaps
  - Made some accommodations, but didn’t finish this
- A few things in the software to clean-up

Closing Thoughts About Antenna Rotors

- Pulsers have many issues to consider
  - Resolution - must interpolate
  - Calibration process
  - Must have persistent memory (power-down) for AZ & EL position
  - Can find them reasonably priced at hamfests

- Potentiometer type rotors seem less complicated
  - Always know where the rotor is
  - No persistent memory required for power-down
  - No interpolation required
  - No directional history needed
  - Less opportunity to get out of sync.
  - Nova tracking software may do most of the work for you
  - But – these rotors may be expensive!

FROM A SOFTWARE PERSPECTIVE

- This was an interesting microcontroller project!
- Microcontrollers can be used for a lot of amateur radio projects!
- If you are patient and persistent you will be successful!