The Case For CMRI On Arduino

Seth Neumann
sneumann@pacbell.net
Chuck Catania
cpcrr@charter.net

History

- Dr Chubb introduced CMRI in 1983 as an affordable hardware platform that could be programmed by model railroaders with minimal programming background
- There are > 1,000 CMRI hardware systems in use with a mixture of software (QBASIC, VBASIC, JMRI and various JMRI applications)
- CMRI has a very active user community which provides a high level of mutual support
- A series of small businesses have supported the community with kitting, assembly and programming services, the current one being SLIC Engineering (Marc Robertson)

Arduino

- Literally "Art Duino"
- Introduced in 2006 by Massimo Banzi for conceptual artists wanting a simple control system for animation
- Open Source
- Large, mutually supportive, user base in "Maker" and Robotics communities
- Many "cottage" suppliers of processors and peripherals, notably SparkFun, AdaFruit and Modern Device

State of CMRI

- About due for a 10 year refresh (since last major change with introduction of SMINI, DIN32, DOUT32)
- Challenges with cost per line with respect to alternatives
- Shift from 2 Light Emitting Diode to 3 Light Emitting Diode Signals renders SMINI's 1 input:2 output i/o ratio less useful
- Local nodes have no intelligence, limiting real-time capability
- No native servo support or any way to modulate LEDs/Lamps (fade in/fade out)

CMRI on Arduino

- Leverage inexpensive Arduino platform
  - lots of inexpensive i/o
  - Built in support for serial, servo, A/D conversion, PWM
  - Inexpensive to expand (cost dominated by interconnects)
- Use existing CMRI peripherals where possible
  - SMC-12 (Stall Motor Switch Machine Controller)
  - Twin Coil Drivers
  - DCC_OD (DCC Optimized Detector)
- Keep base level compatibility with CMRI across both Chubb BASIC and JMRI Software

Evolution of CMRI Deployments

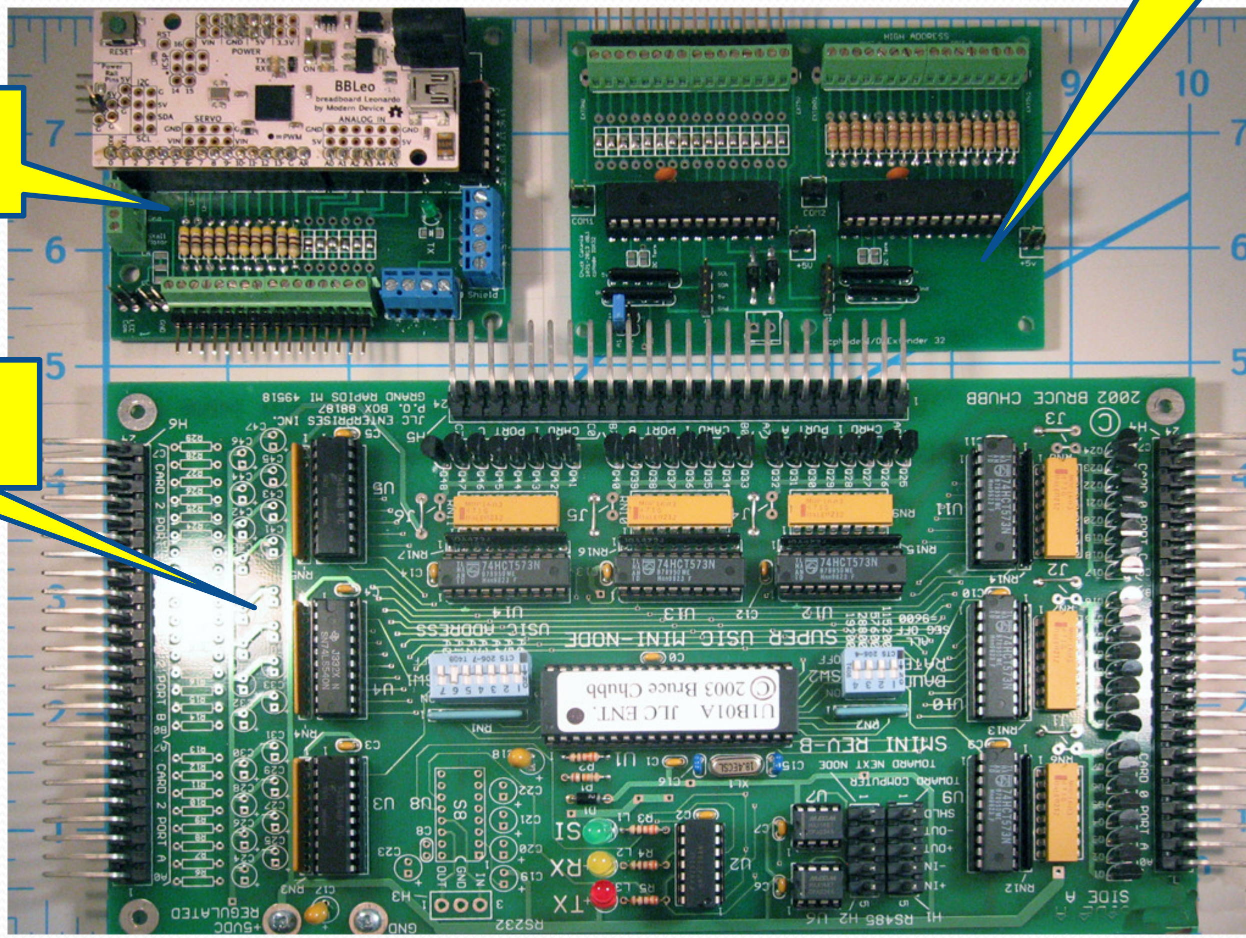
- CMRI on Arduino can be used for:

1. Lower entry costs/finer granularity allows more distributed deployment
2. Cost reduction in classic deployments
3. Some combination of both

More flexibility (byte level selection) in i/o strands less capacity

Deployment close to devices, control panels etc requires less expensive interconnects

Board Size Comparison



48 Ports
Set in 8
Port
groups

24 in
48 out

Comparative I/O And Costs

	SMINI	cpNode	cpNode Max	SUSIC MAX
Ports	72	18	144	480
Cost (A&T)	$190	$60	$160	$1,485
5v/12V output	Both	5V *	5V *	Both
Cost per line	$ 2.64	$ 3.33	$ 1.11	$ 3.09
Best For	Larger Areas distributed	Small distributed nodes	Interlockings, yard throats, cpNode Expansion	Larger centralized installs and CTC Machines

* IOX expanders offer Open Drain at up to 30mA at 5V subject to 160 mA total per chip, high voltage and current adapters are available for more extreme requirements.

Reference Board Set

- The reference boards sets are standard configurations seen in signaling and CTC installations
- They consist of:
  - EagleCad Design Files
  - Boards can be purchased from (tbd)
  - Users can download the EagleCad files and or modify and have printed by Seed
  - Standard Arduino "Sketches" configure the cpNode as SMINI or SUSIC nodes
  - Sketches may be used as is or modified to serve special requirements

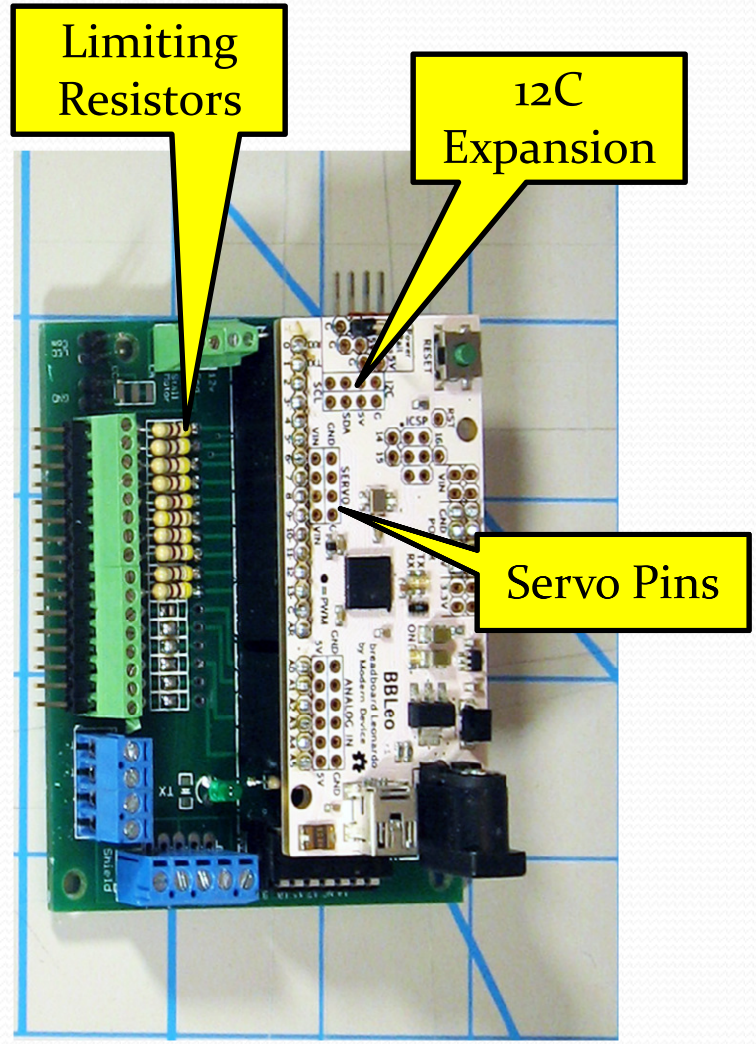
Reference Board Set

- Control Point Node (cpNode): BB Leo + RS 485 adapter, limiting resistors, single stall motor driver to support one end of one controlled siding
- 16 and 32 Port I2C expansion board for cases where more than 18 pins are required (IOX16,32)
- 16 Port Open collector Adapter (CS16)(sink or source)
- Small DCC_OD motherboard for distributed application (ODX4)

Control Point Node

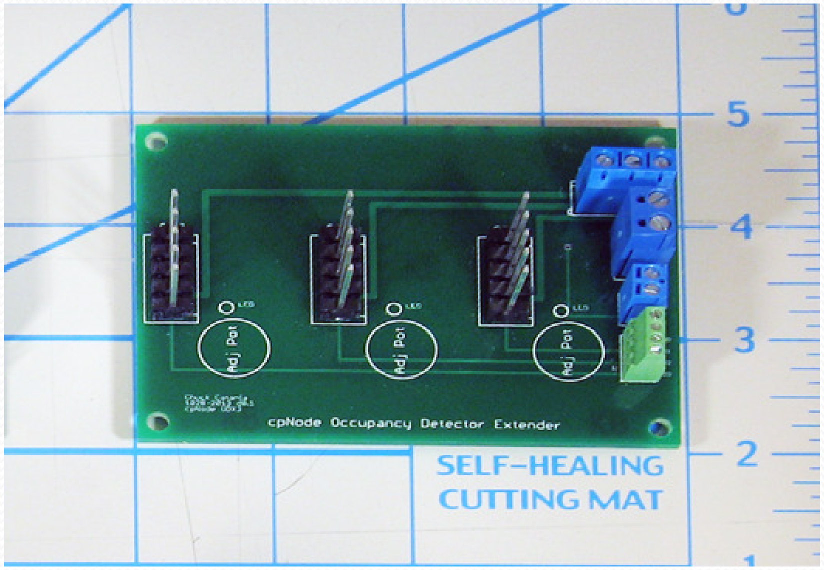
- This board supports one Control Point ("cpNode")
- BB LEO plugs into it (Arduino Shield version to follow)
- Uses RS485 transceivers and glue logic to implement CMRI bus.
- Has pads for a FET stall motor driver (or use included servo driver)
- Has pads for resistors for 10 Light Emitting Diodes
- Connectors for i/o, power
- Servo connections from BB-Leo
- Fits DIN Snap Track for easy mounting
- $60 A&T including BB-Leo*

* projected price



ODX3

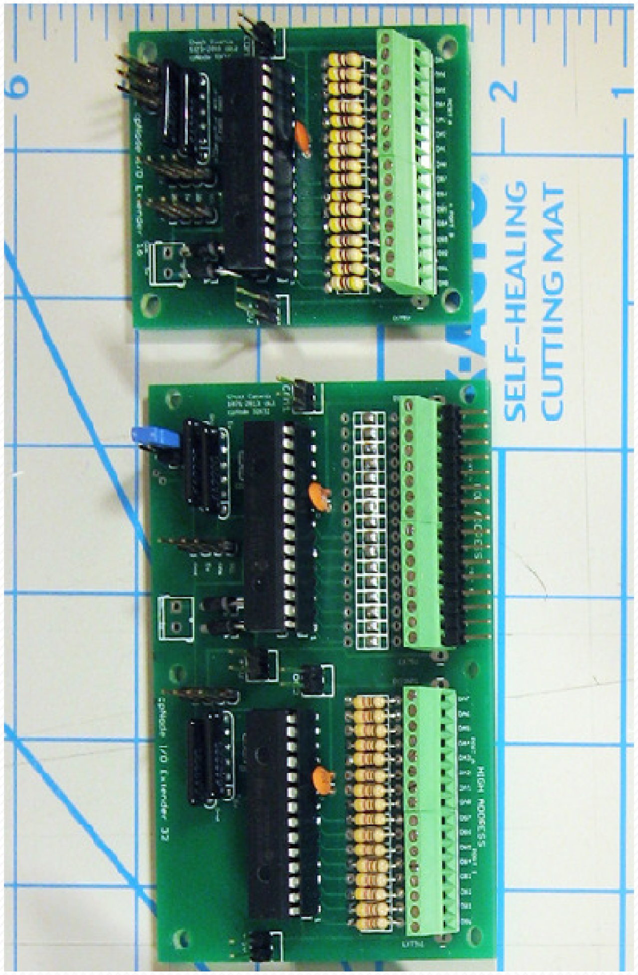
- This is a 3 position mother board for DCC_OD to support one control point (main, OS, [main|siding]) within the controlled siding*



Actual part will be ODX4 going forward

16/32 Port I2C Expansion Boards

- Simple expansion board based on the MCP23017 I2C chip. Each chip supports 16 individually programmable i/o pins.
- DIN Mount, 0.100 pin or screw term
- Chip uses BB-Leo pins 2,3 as SCLK, SD
- Outputs are open-drain at 25mA at 5V (but chip maximum of 160 mA applies)
- Since modern Light Emitting Diodes light well at 10 mA, all outputs can be used as signal drivers, but given that modern signals are 3 Light Emitting Diode no more than 6 Light Emitting Diodes will be on at once
- Can drive any logic level input (see open collector board) or 3rd party relay boards
- Up to 8 boards (128 total i/o) can be supported over 2 meters on one daisy chain
- DIN form factor
- IOX16 = $18, IOX32 = $28 (~$1 per line!)



16 Port High Current Adapter

- Provides 16 ports able to handle <500mA at <50VDC
- 0.100 inputs and outputs (headers or screw terminals)
- Used to control higher voltage and current loads (relays, incandescent lamps)
- Limiting resistors for Light Emitting Diodes
- Darlington current sink using ULN2803 chip
- Mounts to IOX16, IOX32 on edge connector
- CS16

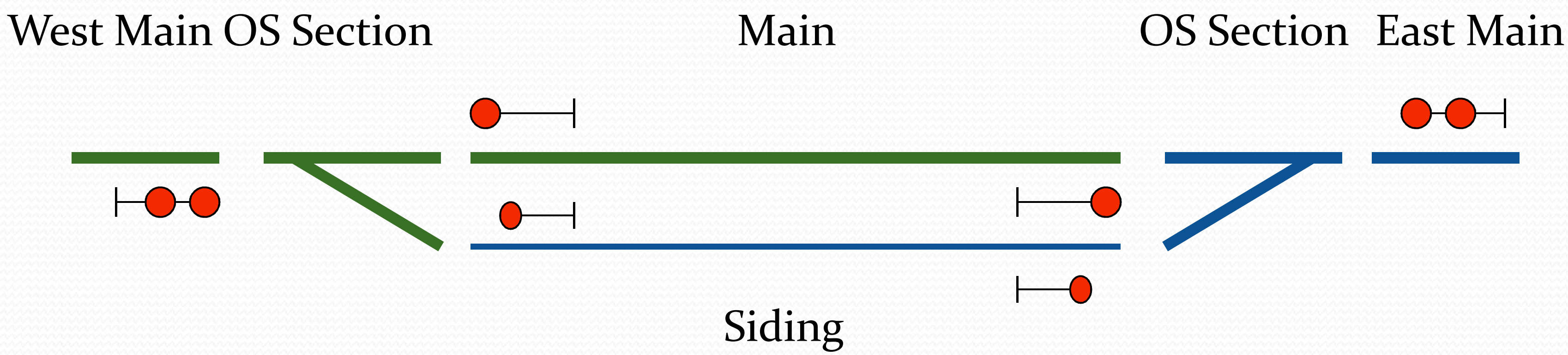
Sample of Handy 3rd Party Shields

- These are a sample of boards available in the Arduino Shield footprint
  - Adafruit – 16 servo hardware support
  - Logic level relay boards (Seeed Studio)
  - Stepper Motor
  - Sound boards
  - Many others – do an internet search

Reference Deployments

- ½ Controlled siding (one "triad")
- Complete controlled siding with "OS" Section at each end
- SMINI Alternative
- Double Track Intermediate Signal with or without Cross-Over
- Crossing

Diagram of Controlled Siding



- 6 detected blocks (inputs)
- 2 switch motors (stall, twin coil, servo etc)
- 8 x 3 Light Emitting Diode Heads (note green not used on some)

½ siding (Control Point)

- Many CMRI applications are CTC. The basic element of CTC is the "Control Point" or "OS Section." in route signaling it looks like:
  - Power Switch (1 output), can drive servo directly or stall motor driver on CP node board
  - Detection of OS, Siding or Main between control points and main on either side (3 inputs). Most model railroads only have one block between controlled sidings, so one of these may be spare
  - Control of 4 heads:
    - 2 heads on mast entering siding (5 or 6 outputs)
    - 1 head on a high mast on main between CPs (3 outputs)
    - 1 head on low mast on siding between CPs (2 or 3 outputs)
  - 2 lines for serial i/o
  - SCLK, SDA lines for I2C expansion. May be used for other purposes if no expansion required
  - Total = 20, fits on one cpNode
    - 3 input
    - 13 output
    - 2 serial
    - 2 I2C expansion*

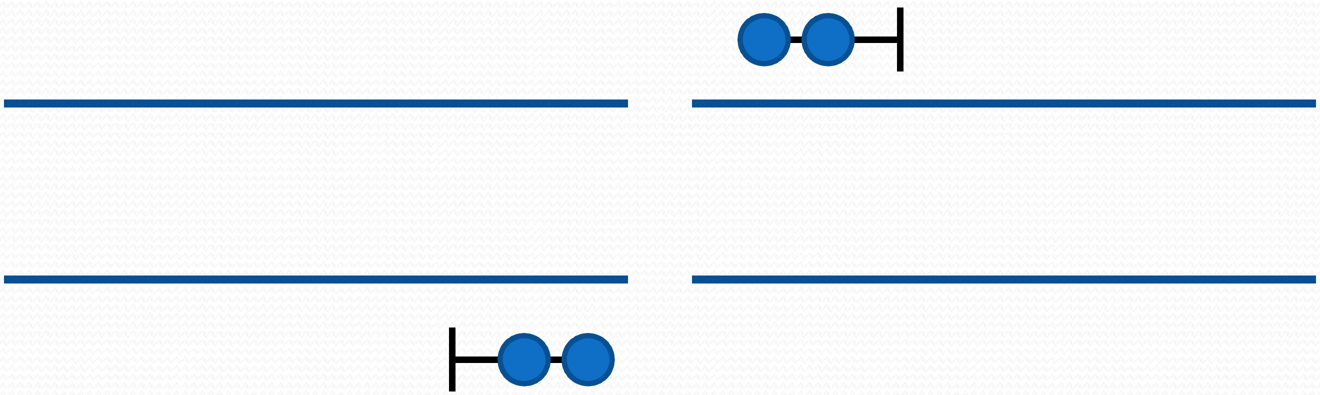
Complete Controlled Siding

- Most CMRI applications are CTC. This is the complete siding.
  - Power Switches (2 outputs), can drive servo directly
  - Detection of OS, Siding or Main between control points and main on either side (6 inputs)
  - Control of 8 heads:
    - 2 heads on mast of each entering siding (12 outputs) – really 10
    - 1 head on a high mast on at each end of main between CPs (6 outputs)
    - 1 head on low mast on at each end siding between CPs (6 outputs)
  - 2 lines for serial i/o
  - Total = 34, cpNode with 16 port I2C Expansion (IOX16)
    - 6 input
    - 26 output
    - 2 serial

SMINI Alternative

- Likely configurations:
  - cpNode (20 – 2 serial, -2 I2C = 16) + 2 * IOX32 (64) = 80 Ports
  - cpNode MAX = (20 – 2 serial, - 2 I2C = 16) + 4 IOX32 (128) = 144 Ports
  - Configured by Arduino sketch

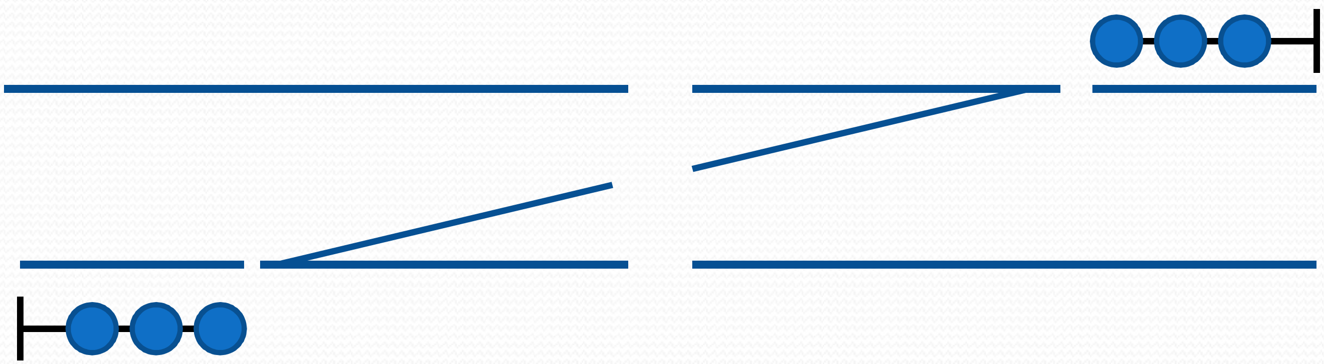
Double Track Intermediate



C&O Signaling for rule 251 (current of traffic) operation – check your prototype!

- 4 inputs (4 DCC Optimized Detectors)
- 12 outputs (4 heads at 3 Light Emitting Diodes each – lower heads may only have 2)
- Total of 16 i/o
- Fits in a cpNode

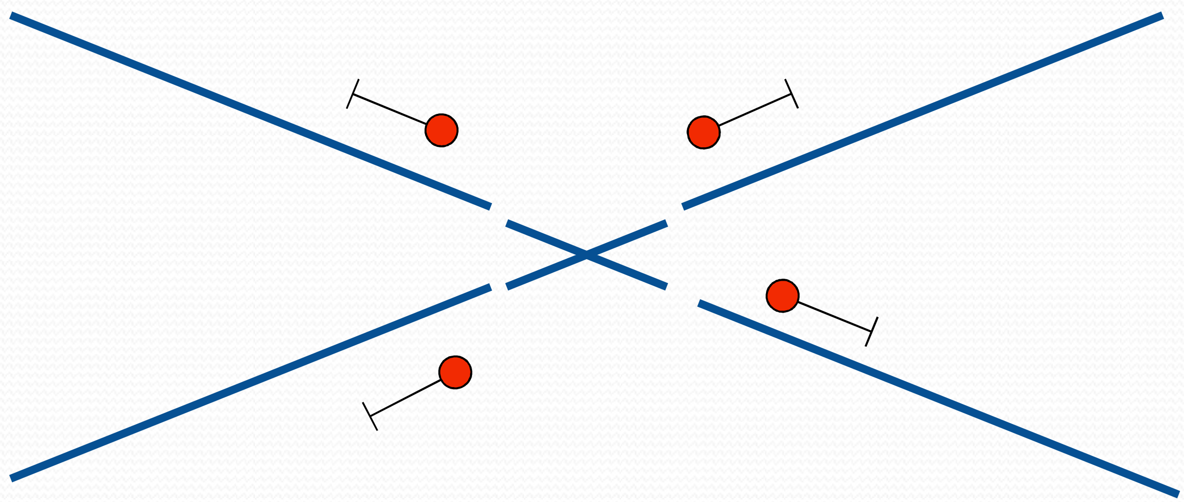
Double Track Cross Over



C&O like Signaling for rule 251 (current of traffic) operation

- 6 inputs (6 DCC_ Optimized Detectors s)
- 20 outputs (6 heads at 3 Light Emitting Diodes each – lower heads may only have 2) + 2 switch motors
- Total of 26 i/o
- Fits in a cpNode (16) + an IOX16 (16) = 32 lines with 8 lines to spare

Crossing



- 5 inputs for occupancy (if using PSXAR reverser for frog, you can get frog occupancy from it, or you can use an additional output to drive a relay(s) to switch frog polarity.) Detection of main line sections may already be handled by adjacent cpNodes
- 4 x 3 = 12 outputs for signals – signals integrated into ABS/APB occupancy logic
- Optional input to “run time” for junior road
- ~17 i/o, fits within a cpNode, or cpNode + IOX16 if you need something else in the area

Standard Arduino Configuration Sketches

- 3 input (3 Optimized Detectors), 13 output (4 signal heads, turnout motor) Stall Motor Version
- 3 input (3 Optimized Detectors), 14 output (4 signal heads, servo, servo polarity control) Servo Version
- 16 Input
- 8 input, 8 output
- 16 outputs

Selectable by configuration variables, or start with any of these and roll your own

The Arduino Integrated Development Environment (IDE) is free and can downloaded at http://arduino.cc/en/Main/Software It is assumed the user will use this software and a USB cable to configure cpNodes

Deployment Strategy

- Fairly sparse use of address space (take SMINI philosophy another step)
- With 128 node addresses we're unlikely run out: allows for 64 controlled sidings with nodes at each end
- Mix and match with existing nodes
- High density nodes like toggle-style CTC boards or large interlockings could use cpNodes with IOX or SUSIC nodes.

Arduino Configuration

- Base CMRI compatible configuration (e.g. N = 2 for 3 bytes of input and 6 bytes of output)
- JMRI doesn't care, give it any "N" value you like and it will adjust, where N is number of input bytes
- Configurable as SUSIC: any combination of D[IN|OUT][24|32] you like*
- Mapping option for I2C expansion shields to help manage sinking current (logical ports do not have to be in physical order)*

* Under development

Arduino Sketches to implement CMRI Node functionality

- Standard Sketches for Control Point Node
- Jacobsen – minimal framework, you do your own mapping
- Witt – implements a lot of functionality, 2 wire signals, local flashing, etc.*
- A menu or interview based script which generates a configuration sketch for the less-technical user wanting a non-standard configuration*

* Under development

Enhancements to CMRI standard

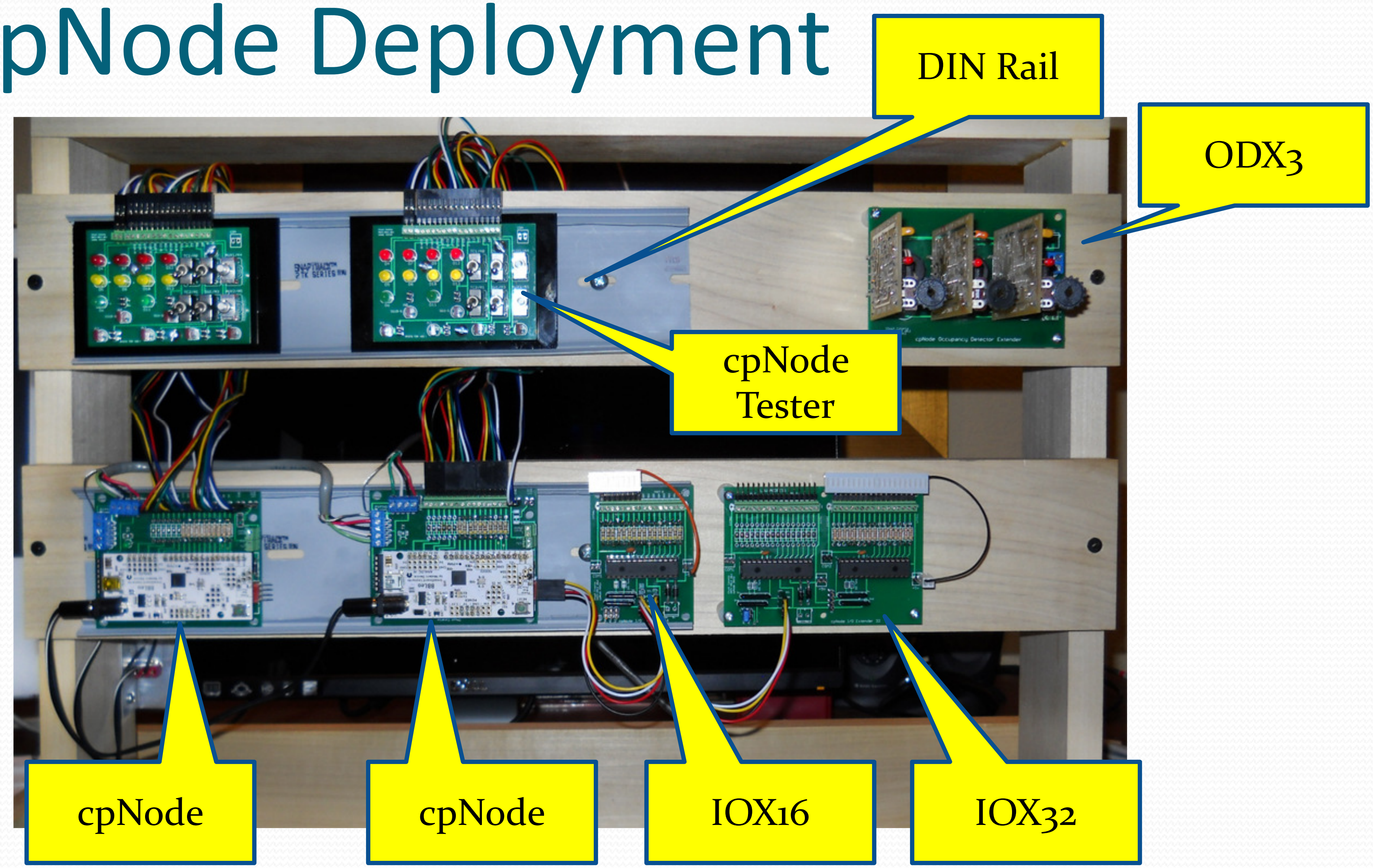
- Break outs with 0.100 headers or screw terms on 3 and 4 position Detector mother boards ODX3, ODX4
- Break outs with 0.100 headers on switch motor driver boards
- More mixing of various board types (more efficient use of i/o based on byte boundaries)
- More efficient use of CMRI Net bandwidth*
  - "no inputs changed" ack
- New Node type for cpNode with card size of 2 bytes*

* In discussion with JMRI developers

“The New Normal”

- 3 Light Emitting Diode Signals at 5V
- $2.00 servos for turnout control, may also use isolated relay boards ($1.50/ segment) for frog power
- High current output for use where needed (< 25% of total) and for backwards compatibility
- Most cpNodes will be used in new installs or extensions as Chubb’s hardware is very robust and users won’t replace just to go to newer hardware so conversion issues should be minimal

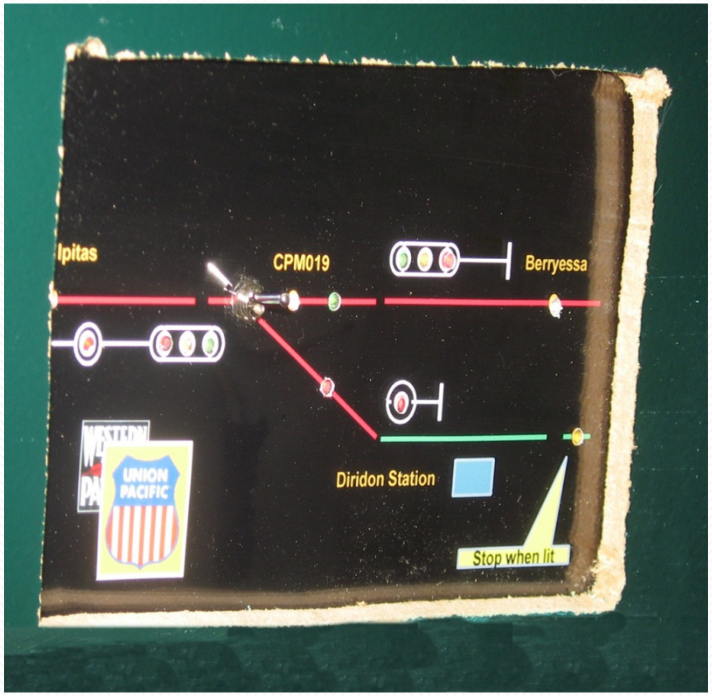
cpNode Deployment



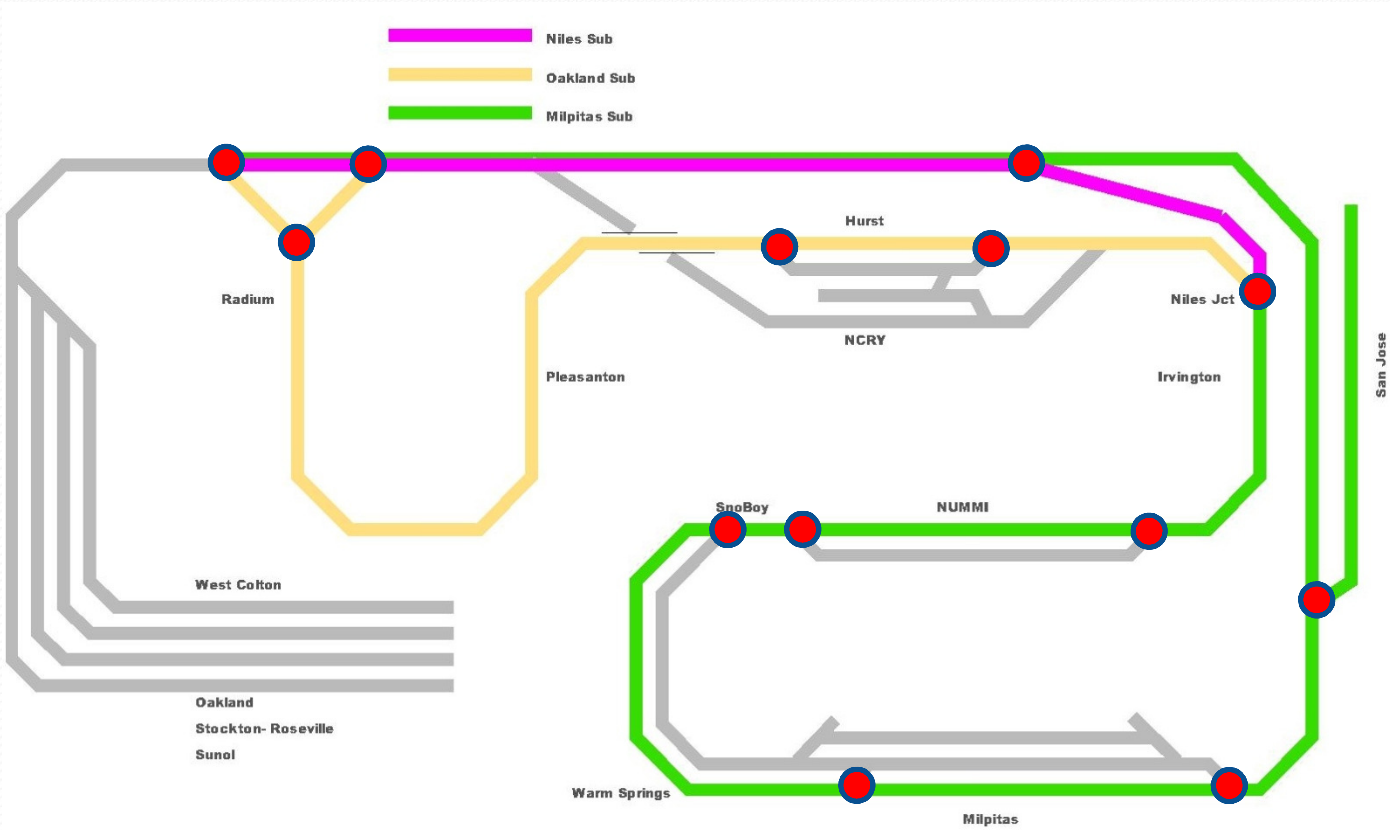
A cpNode at work

Diridon Station control panel on Seth's layout

- 14 outputs – signal repeater, occupancy, end of track
- 1 input – local switch
- 3 lines spare
- all of the inputs driving the LED outputs are on other (SMINI) nodes in the system
- This node eliminated the need to string about 150 feet of CAT5 from two backboards
- I have a clinic on how to make these panels at http://www.pcrnmra.org/pcr/clinics/ControlPanelsRdr7up.pdf
- Fascia work not complete in this photo



Example based on Seth's UP in Niles Canyon



13 Control Points

Example does not cover staging control, control panels

Relative Costs: SMINI v. cpNode

Not Including 39 occupancy detectors which are the same in all configurations

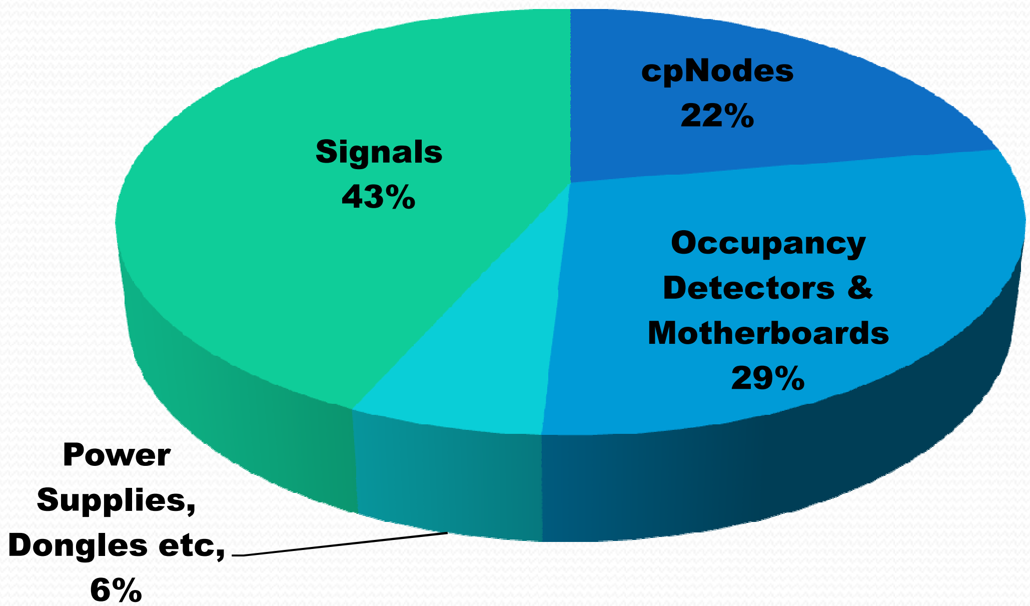
Architecture	Nodes	Electronics	Interconnects	Total	% SMINI
SMINI	4	$ 1,180.00	$ 228.32	$ 1,408.32	
Centralized cpNode	2	$ 706.79	$ 228.32	$ 935.11	66%
Distributed cpNode	13	$ 972.87	$ 15.60	$ 988.47	70%

- Costs based on assembled and tested boards in quantities suitable for this layout
- No power supplies, USB dongles, mounting hardware etc considered here
- Design uses 39 DCC_OD occupancy detectors @ $20 ea = $780 in all cases, may be a little less as most model railroads only have one block between control points

Other Deployment Cost Considerations

- Alternate Signals may be as low as $12 for single head, $20 for Double, *BUT* more exotic signals, such as B&O Color Position Lights may be more
- We feel the DCC_OD is the gold standard, but less expensive compatible detectors exist such as NCE BD20
- While we did not consider switch machines in this example, switching to Servos at $2.00 ea (eBay in 20s) and using Seeed relay boards for frog switching (at $1.50/ segment) you can save over Tortii. You can also omit the stall motor chips from the cpNode. A bracket is required for the servo: Tam Valley Depot makes a laser-cut bracket for $3.95 ea. in 12s. (He also sells servos and kits)
- Sparing should be less expensive as a single inexpensive spare will protect a large number of nodes, also IOX16, 32 are relatively inexpensive

Signaling System Cost Elements



The majority of system costs are in the Signals, followed by Detectors

Resources

- Arduini list on Yahoo Groups
- CMRI_users list on Yahoo Groups
- Jmriusers list on Yahoo Groups
- Arduino home page http://arduino.cc/
- Dr. Chubb's documentation available at JLC Enterprises http://www.jlcenterprises.net/Index.htm
- Handy servo hardware at Tam Valley Depot http://www.tamvalleydepot.com/products/servosaccessories.html
- For those who attend the Digitrax church: http://www.scuba.net/wiki/index.php/Arduino_Loconet

Backup

SMINI Case

	Case 1 - SMINI				
Backboard 1 - Radum					
Control Points	7		Unit	Ext'd	
Input lines	28	3 DCCOD + 1 fascia switch per CP			
Output lines	77	10 LEDs per CP + 1 switch motor			
SMINI	2		$ 190.00	$ 380.00	
DCC_OD	21		$ 20.00	$ 420.00	
ODMB	2		$ 40.00	$ 80.00	
SMC12	1		$ 65.00	$ 65.00	
R12TERM	7		$ 10.00	$ 70.00	$ 1,015.00
Punch Block + 89B	3		$ 20.22	$ 60.66	
Feet of CAT5	525	3 per: 2 signals and Tortoise	$ 0.10	$ 52.50	
Radio Shack Spade lugs	49		$ 0.10	$ 4.90	$ 118.06
				$ 1,133.06	
Backboard 2 - Milpitas					
Control Points	6				
Input lines	24	3 DCCOD + 1 fascia switch per CP			
Output lines	66	10 LEDs per CP + 1 switch motor			
SMINI	2		$ 190.00	$ 380.00	
DCC_OD	18		$ 20.00	$ 360.00	
ODMB	2		$ 40.00	$ 80.00	
SMC12	1		$ 65.00	$ 65.00	
R12TERM	6		$ 10.00	$ 60.00	$ 945.00
Punch Block + 89B	3		$ 20.22	$ 60.66	
Feet of CAT5	450	3 per: 2 signals and Tortoise	$ 0.10	$ 45.00	
Radio Shack lugs	46		$ 0.10	$ 4.60	$ 110.26
				$ 1,055.26	
total				$ 2,188.32	

Centralized cpNode

Backboard 1 - Radum					
Control Points	7		Unit	Ext'd	
Input lines	28				
Output lines	77				
cpNode(H)	1		$ 59.25	$ 59.25	
DCC_OD	21		$ 20.00	$ 420.00	
ODMB	2		$ 40.00	$ 80.00	
SMC12	1		$ 65.00	$ 65.00	
R12TERM	7		$ 10.00	$ 70.00	$ 778.40
Punch Block + 89B	3		$ 20.22	$ 60.66	
Feet of CAT5	525		$ 0.10	$ 52.50	
Radio Shack Spade lugs	49		$ 0.10	$ 4.90	$ 118.06
IOX32(H)	3		$ 28.05	$ 84.14	
				$ 896.46	
Backboard 2 - Milpitas					
Control Points	6				
Input lines	24	3 DCCOD + 1 fascia switch per CP			
Output lines	66	10 LEDs per CP + 1 switch motor			
cpNode(H)	1		$ 59.25	$ 59.25	
DCC_OD	18		$ 20.00	$ 360.00	
ODMB	2		$ 40.00	$ 80.00	
SMC12	1		$ 65.00	$ 65.00	
R12TERM	6		$ 10.00	$ 60.00	$ 708.40
Punch Block + 89B	3		$ 20.22	$ 60.66	
Feet of CAT5	450		$ 0.10	$ 45.00	
Radio Shack lugs	46		$ 0.10	$ 4.60	$ 110.26
IOX32(H)	3		$ 28.05	$ 84.14	
				$ 818.66	
total				$ 1,715.11	
		electronics		$ 1,486.79	
		connectivity		$ 228.32	

Distributed cpNode

Case 3- Distributed cpNodes								
Control Points (Each)	13		Unit		Ext'd			
Inputs per Node	4							
outputs per Node	12							
cpNode(S)	13		$	59.25	$	770.28		
DCC_OD	39		$	20.00	$	780.00		
ODX-4	13		$	15.58	$	202.59	$	1,752.87
ODX4 Jumpers	13		$	0.50	$	6.50		
Shell and Pin kits for serial	13		$	0.70	$	9.10	$	15.60
total					$	1,768.47		
		electronics			$	1,752.87		
		connectivity			$	15.60		

Switch Motor Cost Comparison

	Device	Driver	Bracket	Contacts	Total
Stall - SMINI	$ 17.00	$ 5.42			$ 22.42
Stall - cpNode	$ 17.00	Incl.			$ 17.00
2 Coil (PL10)	$ 10.00	$ 30.00		$ 7.00	$ 47.00
Servo (cpNode)	$ 2.00	Incl.	$ 4.75	$ 1.50	$ 8.25
Servo SMINI	$ 4.00	$ 12.76	$ 4.75	$ 6.00	$ 27.51

For these examples I used Tortoise from Circuitron for the stall motor and the Peco PL-10 as a twin coil machine. For driver boards I used CMRI SM1 and SM2 Twin coil machines and Tam Valley Singlets for servos. TamValley sells the servo, Bracket and singlet as a kit