Designing a Signaling System with cpNode

Seth Neumann –
seth@modelrailroadcontrolsystems.com

Chuck Catania –

chuck@modelrailroadcontrolsystems.com

http://www.modelrailroadcontrolsystems.com/

Assumptions:

- NOT an introductory class on CMRI

- This clinic is focused on implementing a signaling system using cpNodes, CMRInet, and available software support.

- You know what you want to model

- You are generally familiar with principles of Railroad Signaling

- You know something about JMRI or CATS and will be using a computer to control signaling on your railroad

- "Hard" CTC machines can be done easily with cpNode but we do not recommend going to the considerable effort and expense of building a hard panel until after the design is proven on a "glass" panel

Agenda

- Control Point Layout
- Establishing blocks & detection
- Fascia switches/control panels
- Switch motor control
- CMRInet Configuration and Topology
- Configuration examples and worksheets

Control Point layout - 1

West Main OS Section

Main

OS Section East Main

Control Point or "Triad"

Siding
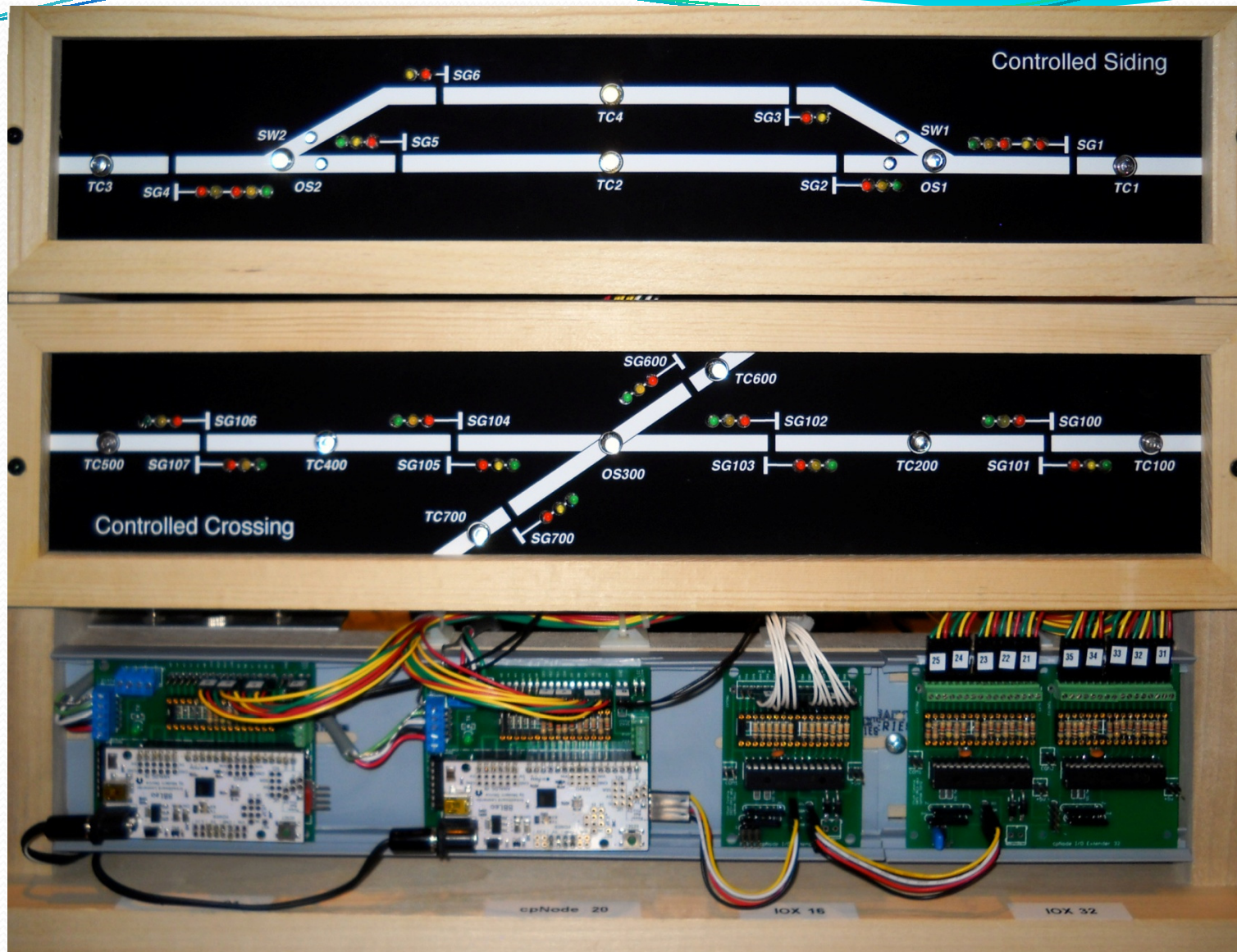
Control Point or "Triad"
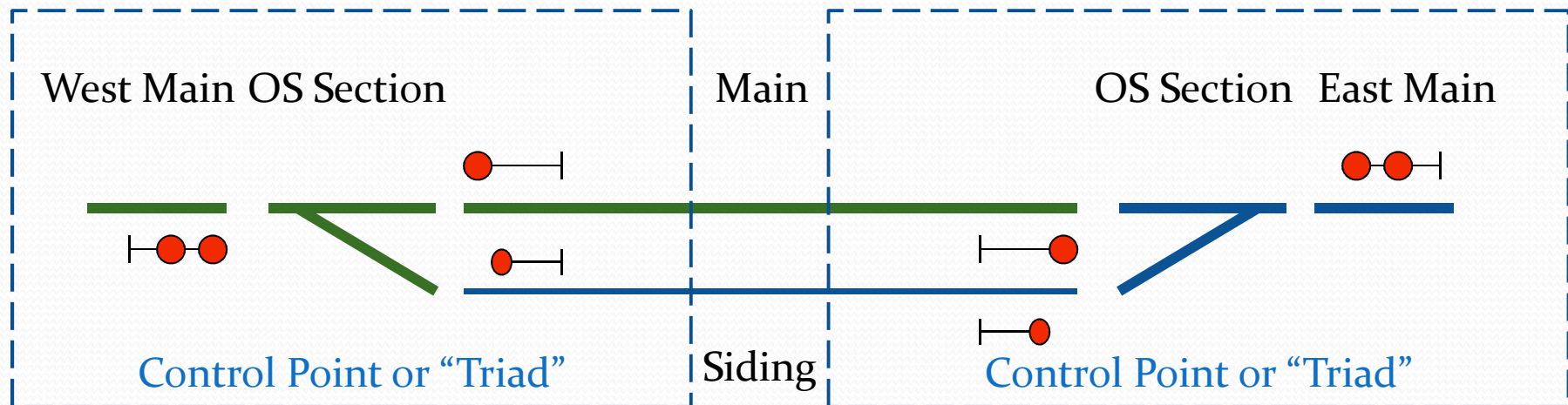
Whole Siding (30 i/o)
- Inputs: (8)
    - 6 Detection Blocks
    - 2 Fascia switches
- Outputs: (22)
    - 2 double high signals (@ 5 = 10)
    - 2 high signals (@3 = 6)
    - 2 low signals = (@2 = 4)
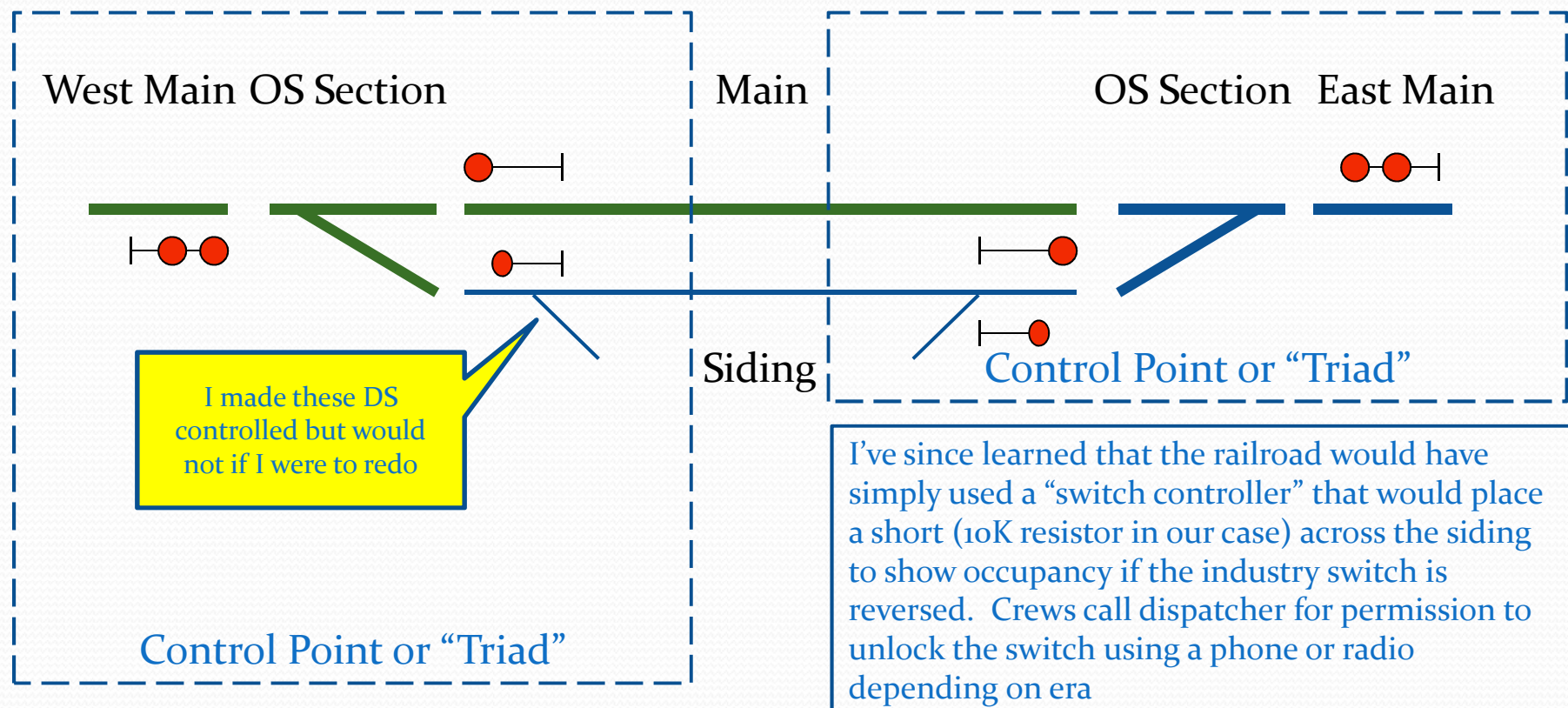   - 2 switch motor lines (@1 = 2)

Control Point (15 i/o)
- Inputs: (4)
    - 3 Detection Blocks
    - 1 Fascia switch
- Outputs: (11)
    - 1 double high signal (@5)
    - 1 high signal (@3)
    - 1 low signal = (@2)
    - 1 switch motor line (@1)

Designing with CMRI and cpNode

Control Point layout - 2

- Siding with industry switches
- Switching signal – no change in hardware
- Possible locks? – add an input or do locally

West Main OS Section

Main

OS Section East Main

I made these DS controlled but would not if I were to redo

Siding

Control Point or "Triad"

Control Point or "Triad"

I've since learned that the railroad would have simply used a "switch controller" that would place a short (10K resistor in our case) across the siding to show occupancy if the industry switch is reversed. Crews call dispatcher for permission to unlock the switch using a phone or radio depending on era

Control Point layout - 3

- **cpNode per control point**
  - Each cpNode has 16 i/o lines and can be expanded to a total of 144 in groups 16 or 32 (IOX 16/32)
  - A standard control point requires 15 lines, or a single cpNode.

- **cpNode per Siding**
  - A simple siding requires 30 lines and can be implemented with a cpNode and a single IOX16

- **cpNode per Interlocking**
  - More complicated control points – such as interlockings – may be achieved by adding more i/o to the node. At 144 i/o lines, a fully expanded cpNode can handle almost any interlocking used on a model railroad

Disclaimer: Chuck and Seth's secret plan for *world domination*:

- We want to offer the cpNode with a standard sketch that does ABS/APB with local switch control when no "code line" is present

- All "vital logic" is on the node (just like the prototype)

- When CMRInet "Code Line" is active the vital logic will accept commands from the CTC machine and execute them IF and ONLY IF the vital logic determines it is safe to do so.

- John Plocher has developed a subset of the ATCS commands used by prototype CTC machines and Code Lines.

-

- The ability to replicate the prototype's control architecture is an additional reason for using the node per control point approach

Powering Signals -1

- We assume you are using modern 3-LED signals that will operate from the local 5 volt supply. A modern LED will light acceptably at 5-10mA current, so a whole siding with 20 heads, assuming all LEDs came on at startup, will draw 200mA.

- 200mA for LEDs can be supplied by the onboard regulator of the BB-Leo (Arduino) on the cpNode. If you need more current, consider an external 5 V supply and be sure to tie the ground side back to the cpNode ground. We like 3 LED common anode signals (such as those from BLMA) but common cathode and two LED signals may be used.

Color	Resistor for 10mA @ 5V	Watts
Green	270 ohm	1/8 or greater
Yellow	220 ohm	1/8 or greater
Red	330 ohm	1/8 or greater
Lunar	6,000 ohm	1/8 or greater

- These values yield a pleasing balance of colors, but YMMV as 20% of males have some degree of diminished color vision. Pads for limiting resistors are provided on the cpNode and IOX16/32 boards.

Powering Signals -2

If you need to drive loads with higher voltage or if you need to exceed 25mA per line or a total of more than 160mA per device, use our CSNK, which can sink up to 500mA at 60V. CSNK connects to cpNode and IOX on the 0.100 pads. CSNK provides compatibility with older 12 volt systems and high current devices such as incandescent lamps or relays.
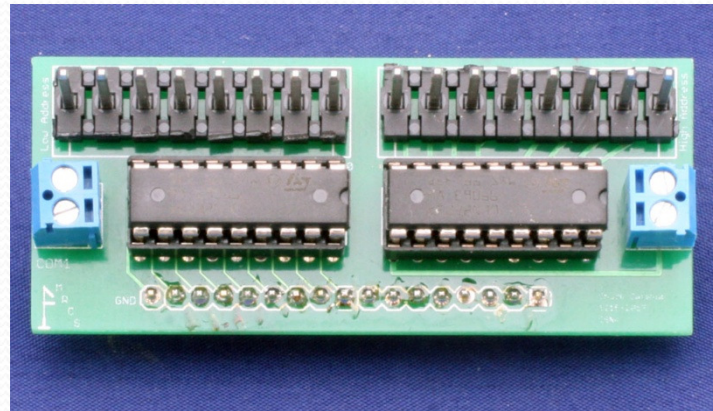
Distance – the LEDs are driven by DC levels, so the limiting factor is resistance of the wire. We use 24 gauge CAT5 cable (each one supports 2 heads) with a resistance of ~ 275 ohms per loop mile. Typical limiting resistor values at 5V are 220-330 Ohms, so keeping the wire at 10% of the resistance yields a limit of about 600ft: unlikely to be an issue on a model railroad
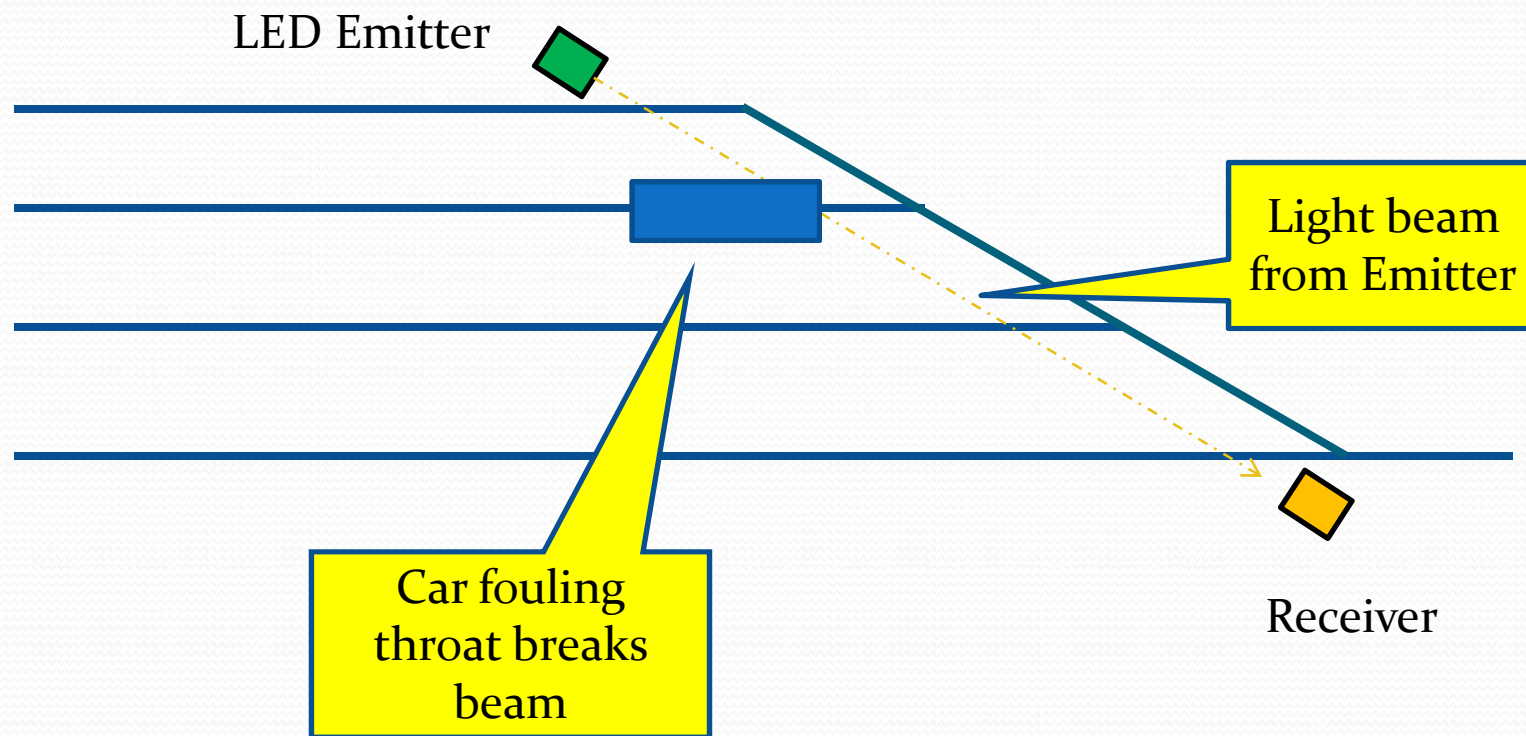
Blocks

- Each block (main, siding, OS, some auxiliary track such as staging) must be detected. Blocks are typically 1.25 – 2.0 train lengths except for OS sections and interlockings

  - **Current Sensing Detectors**
    - Best overall performance
    - $6 -$18 per block
    - Require resistor wheel sets on each car for best performance
    - Generally considered the gold standard for reliability

  - **Optical Detectors**
    - Good for point detection – some people prefer them for OS sections
    - $3-$20 per detector but may need more than one
    - Inexpensive optos are sensitive to ambient light and require some fiddling to get calibrated
    - Good for stopping blocks, impingement detectors

Detector types

- **Current Sense Detectors** – Assembled and Tested
  - cpOD (MRCS) $12 per (in 10s)
  - DCCOD (JLC/SLIQ) $17 per (also available as kits)
  - BOD-8 RR-Cirkits $ 6.25 in 8s
  - CKT BD1 $16 (single) $12.50/channel in 4 (Iowa Scaled)

- **Optical Detectors** –
  - Paisley - $3 in 8s
  - IRDOT –Heathcote (UK) $17 per
  - Nightscope - Boulder Creek $20 per
  - Asian Cheapies - $1- $3 per but are not designed or promoted for model RR use, so they're "Craftsman kits"

Optical Detection for a Throat

LED Emitter

Light beam from Emitter

Car fouling throat breaks beam

Receiver

Current Detector Plans -1

Two approaches but you can mix and match:

Centralized –

- We co-located a cpNode and IOX32 with power distribution for a client.

- Power distribution panel on each wall of a 50' x 15' room. Each wall has about 48 blocks. (48 i/o and 48 detectors)

- Favors larger motherboards such as Chubb's ODMB with DCCOD or cpOD or RR-Cirkits BOD-8

- Longer 12 AWG runs from panel to the blocks. Runs should be limited to about 50'
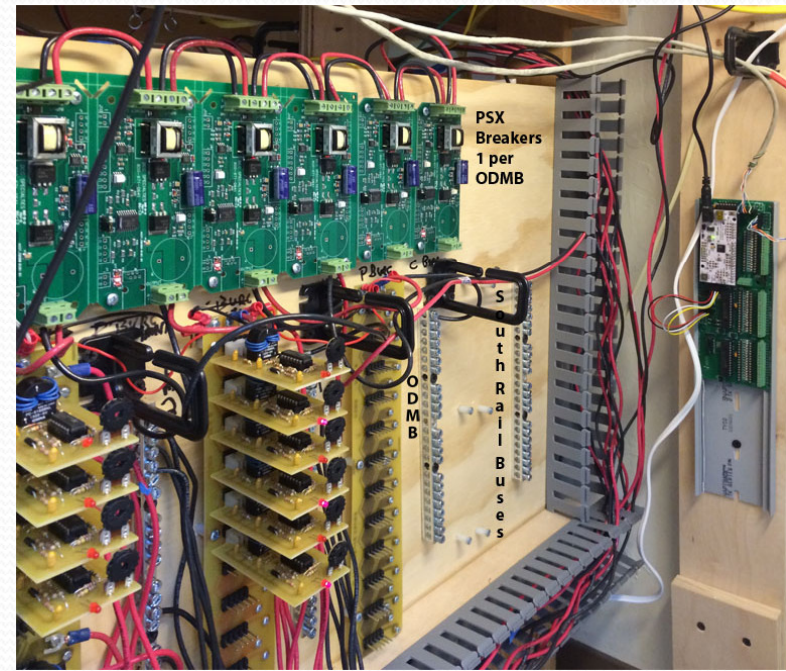
South Wall Power Panel at Ted Stephens' OL&K

Current Detector Plans -2

Distributed -

- Distributed detectors with the control point.

- For control points with 3 blocks we like cpOD on an ODX4 motherboard, for a siding per node model either two ODX4s or a BOD-8 (a couple of detector segments won't be used) will work well. You can also use individual detectors wired into the feeders.
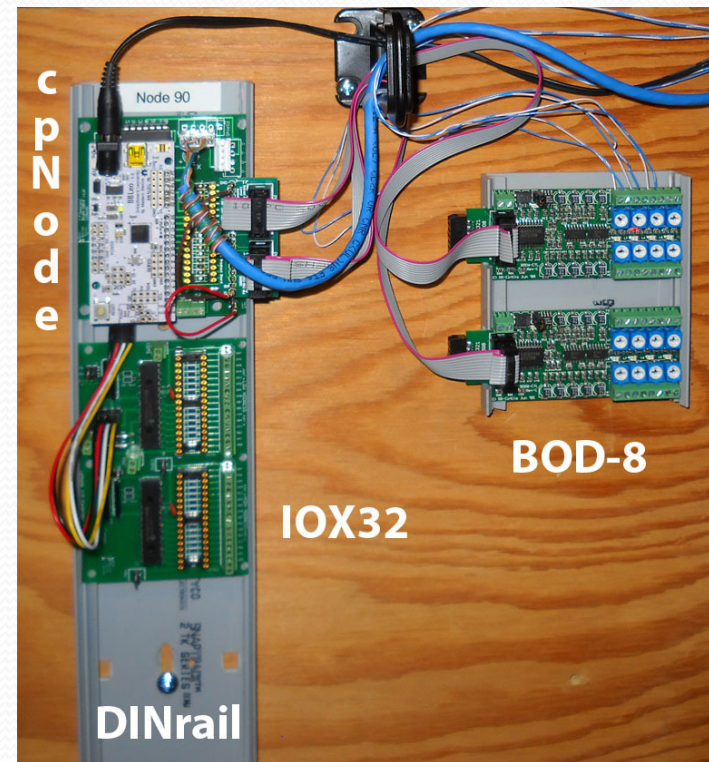
Node 90 at Walt Schedler's Shasta Division – under Dunsmuir
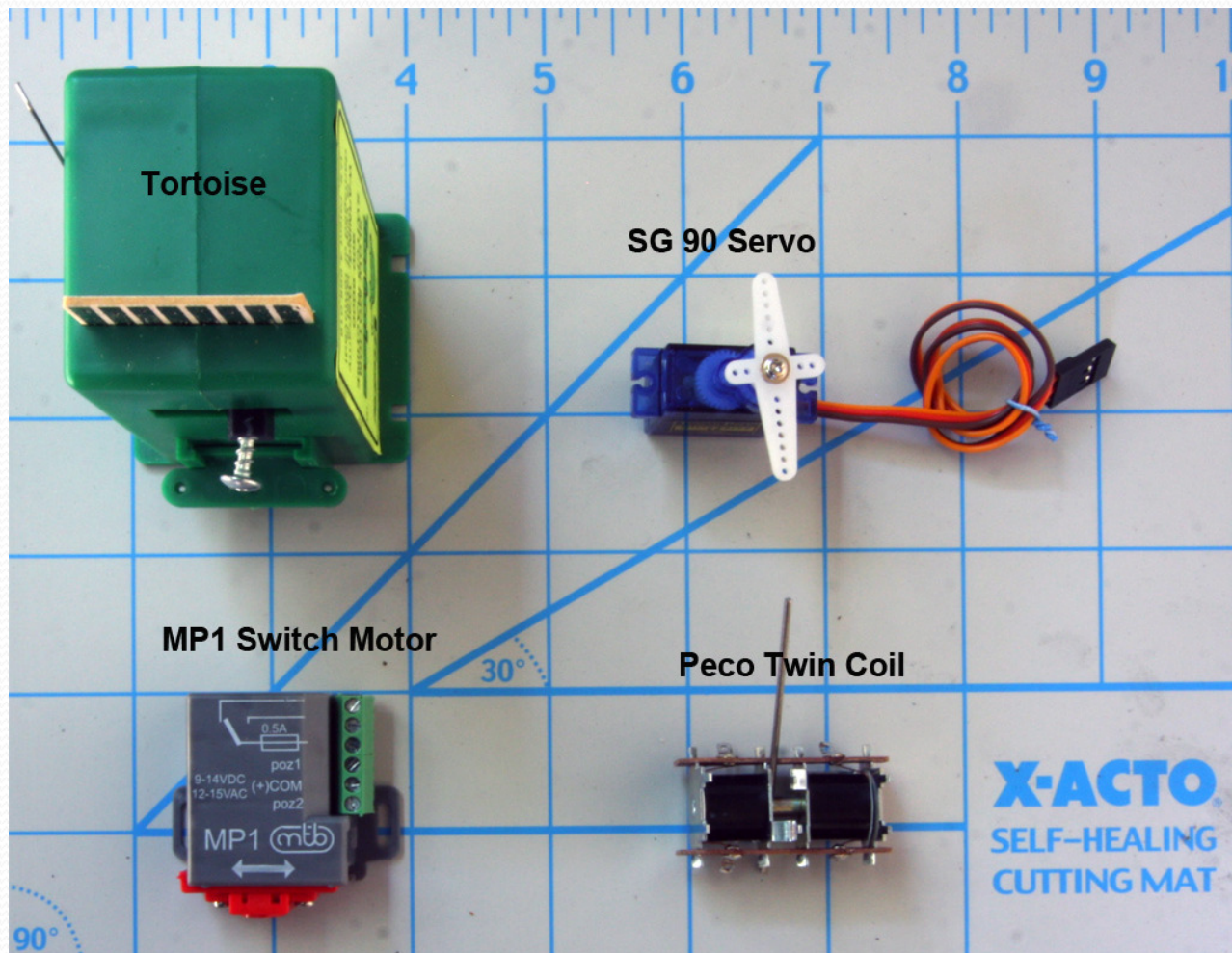
Detectors: to Motherboard or....

Some current detectors plug into motherboards, others have you install the coils on the feeder

- **OD Motherboards**:
  - Let you do the power wiring once and you can swap detectors in and out for trouble shooting
  - Motherboards can be centralized for easier adjustment and to see local occupancy lights
  - Add cost and connections (points of failure)
  - Chubb style motherboards (for DCCOD and cpOD) come in 12 (ODMB) and 4 position (ODX4, Dr Chubb's new design)
  - Detector outputs are usually open collector or open drain (and resist noise) and don't change quickly so you can use the 600' limit above although shorter is better. If you remote mount the "tombstone" transformers try to keep them to 25' from the main detector

## We like motherboards!

Switch Machines - 1

Switch Machines - 2

|	Stall Motor	Servo	MP1	Twin Coil
Market Position	Most common	Challenger	Challenger	Less popular but still used: Kato, Atlas
Power	12V @ 20mA, constant	5V @ 150mA while moving, can shut off	9-15 VDC, 125mA when moving (3S)	12V @ .5A pulse, must turn off
Controller	JLC: SMC12 MRCS: RSMC RR-Cirkits: SMD-8	Tam Valley, Arduino (Sketches on Arduini)	RSMC, CSNK, "Arduino Relay", SMINI, DOUT	JLC: SM1, SM2 RR-Cirkits
Distance from controller	600'	40'	600'	As short as possible
Pressure on points	Constant	Constant or momentary	Constant	Momentary
Frog Polarity Switch	Included in Tortoise	External relay or Micro Switch	1 DPDT included	External Relay or optional contacts
Street price including controller and frog switch	$28	$12 (using an Arduino controller), $ 22 with our kit $25 with Tam Valley	$16	$25

Switch Controls 3 – Stall Motor

- Stall Motor:
  - SMC-12

Image Courtesy of SLIQ Electronics

  - RSMC
    - Free standing
    - Stuff option for one RSMC on cpNode

  - SMD 8 (not shown)
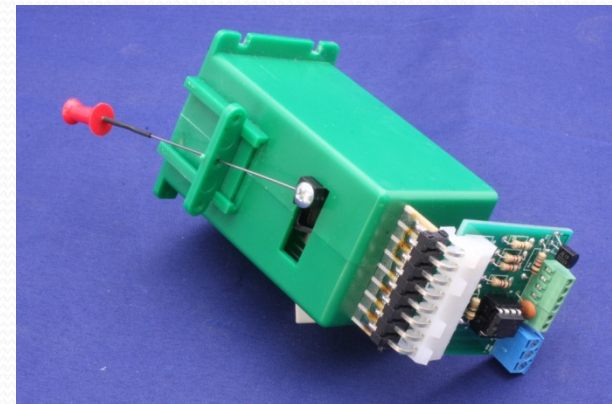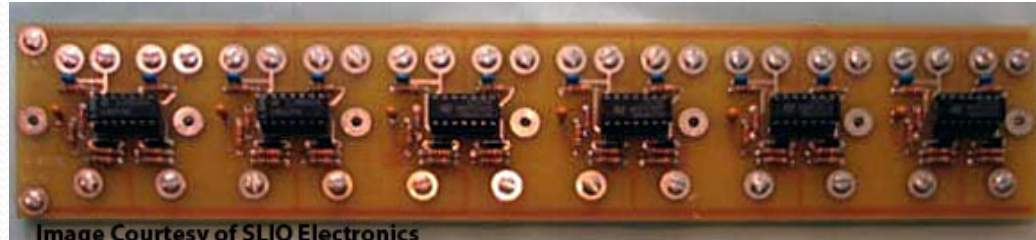
Switch Controls 4 - Servo

- Our Servo Controller

- TAM Valley Depot (TV)

- Various Arduini Sketches including, use any handy Arduino

- Write your own Sketch that combines node and servo timing and use cpNode hardware

- Mounting:
  - TAM Valley servo mount
  - Brunel servo mount (MRCS)
  - Iowa Scaled
  - Others, DIY

Brunel Servo Mount

TAM VALLEY Switchwright
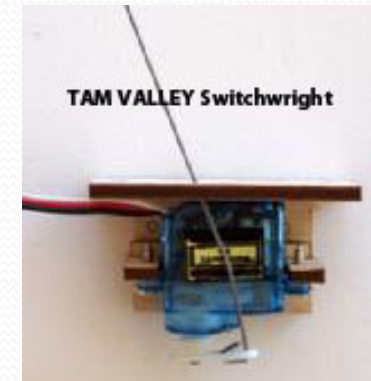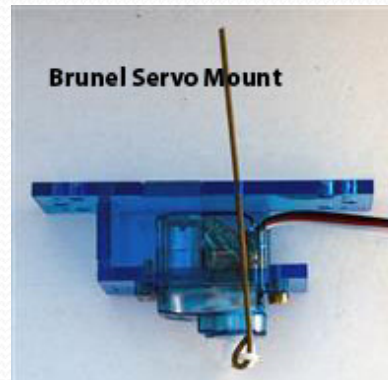
- SG90 Servos do not have internal contacts to switch frog polarity so you'll need an external relay or a micro switch mounted on the bracket (Brunel, TV) or a frog juicer if you want to switch frog polarity

- Servos draw about 150mA while moving, so for most applications you'll want an external 5V supply (ground side tied to logic ground)

Fascia/Panel Controls

Use any type of switch you like – I like Rick Fortin's slide switch recessed behind the fascia – doesn't snag or break off. Keeps the fascia clean.

East Milpitas XO CP M010

Slide Switch
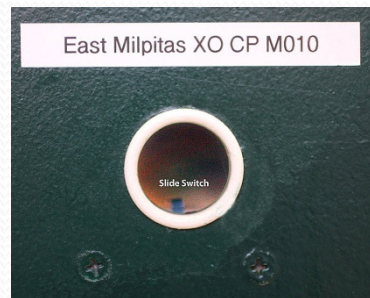
- Switch can be wired directly to cpNode input but requires that computer be on.

- Local panel to provide local control when no computer, for example Dennis Drury designed a switch panel using an RSMC that looks for a 5V line from the computer power supply, if 5V isn't present, the switch panel is in local control.

- Usually one input line per Control Point, but a second line can be used for a switch lock. The lock can also be wired in series with the switch so the switch can't get to the input unless the lock is unlocked (with Dispatcher permission)

CMRInet Node Configuration

- Use standard JMRI or QBASIC or VBASIC configuration tools
- Rule of thumb for setting JMRI Node Type for cpNode + IOXs. Provide enough data cards for the total number of input and output bytes.

Inputs	Outputs	JMRI Node Type
<= 3	<=6	SMINI
> 3	> 6	USIC/SUSIC w/24 bit or 32 bit cards

- Need to have at least one input (sensor) defined for JMRI to poll the node.
- When JMRI is launched, an Init message is sent for the number of defined output bytes.

CMRInet – C/MRI Communication Protocol

- Designed by Bruce Chubb in 1985 to be a simple, easy to implement, serial data messaging system.

- Robust, industrial grade network technology for moving data between a host (master) and node (slave) in a connected network.

- CMRInet is NMRA Layout Control Specification LCS-9.10.

- "Owned" by NMRA - CMRI Special Interest Group (SIG) established 2015.

CMRInet Connection

Master (Host)
Computer

Note:
Host Transmit (Tx) connects to Node Receive (Rx)
Host Receive (Rx) connects to Node Transmit (Tx)

USB or
RS-232
Serial

RS-485 Tx
Card   Rx

"Dongle"

CMRInet Network Connection
serial, 4-wire, half-duplex, daisy-chain

To Other Nodes

Tx Rx | Tx Rx
In | Out

SMINI
SUSIC
cpNode

I/O Ports

Tx Rx | Tx Rx
In | Out

SMINI
SUSIC
cpNode

I/O Ports

Tx Rx | Tx Rx
In | Out

SMINI
SUSIC
cpNode

I/O Ports

The serial communication connection to all C/MRI network nodes is through a four-wire cable. One pair of wires is for transmission, the other pair for receive.   The network is defined as half-duplex, RS-422/485, Master/Slave.

The connection from the control computer (Host) to the C/MRI network is through an interface device which converts USB or RS-232 signals to RS-422/RS-485.

Nodes in a C/MRI network are connected daisy chain fashion, node to node.

CMRInet Topology

- Bruce Chubb assumed the network started at the host computer and worked linearly out to the furthest node, his RS232/485 converter includes a terminator at the computer and the user terminates the bus at the far end.

- RS485 does not allow branches (not to say that modelers don't cheat <g>), so best practice is to have a single CMRInet snaking around your layout with no taps or branches

- Install a terminator at the far end.

- More modern practice is to use an RS-485 USB dongle at the computer. Use a terminator at the computer as well as the far end. This is standard RS-485. The Computer does not have to be at one end, but if not, ensure that the ends (only) are terminated.

- We recommend CAT5 or better data cable rather than shielded 2 pair as the performance is comparable, the price is lower and you don't need to worry about shielding (which is best left to experts)

CMRInet Timing

- Most Classic CMRI installations have a few large nodes and run at 9600 bps. Each node requires about 30mS to respond so a 10 node system has a poll cycle time of about 300mS (or 3 polls per second). This is plenty fast for our purposes.

- We recommend running faster, 28,800 or greater, to keep the poll cycle in the 300mS range with a larger number of nodes. The CMRInet RS485 bus will run as fast as 115Kbps.

- There is no problem with mixing and matching cpNode and Classic nodes as long as they are set to the same speed – the Classic nodes can also work up to 115K

Use My Layout as a Configuration Example

- Main line ~ 100'

- Switches
    - 12 mainline switches (dispatcher controlled)
    - 6 controlled switches connecting to sidings
    - 6 industry spurs connect to the main

- Signals – All high signals are BLMA US&S H2 Searchlights
    - 14 double head (but 3 not visible so they have repeaters only)
    - 14 single head high (but 3 not visible so they have repeaters only)
    - 10 low(but 2 not visible so it they have repeaters only)
    - 10 dwarf (some used in place of low signals in yards, industry areas)
- 3 Sidings, 1 Wye, crossover in the middle of the loop

- Blocks (35):
    - 12 OS (main line switches)
    - 3 main with sidings
    - 3 sidings, 1 main in cross over, 3 Wye sections, 4 staging
   - 10 Main line

My Track Plan
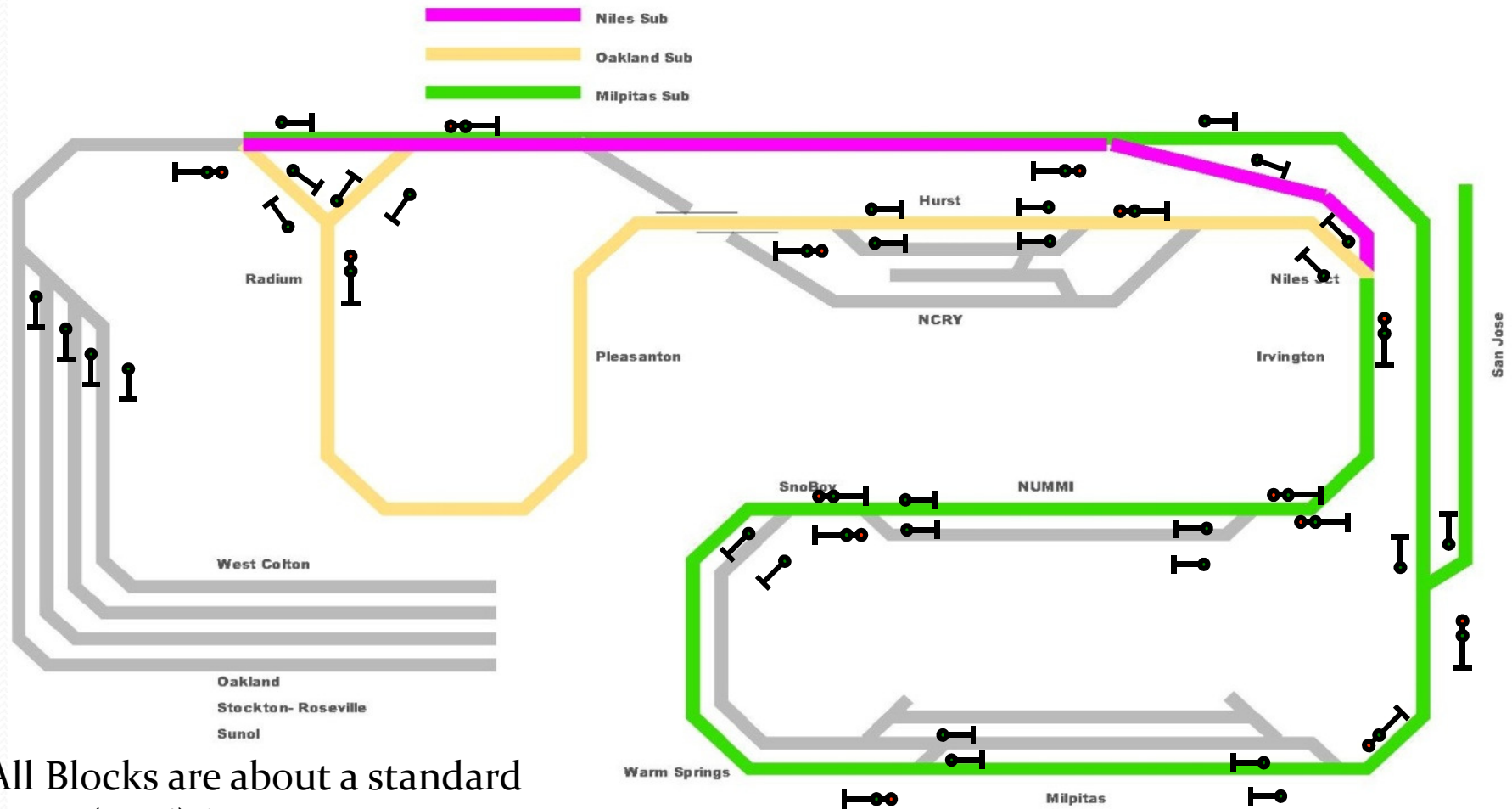
All Blocks are about a standard Train (~ 10') long except Pleasanton and the hidden Back track, so not much point In intermediate signals

Layout example

- UP (ex-WP) used 3 block route signaling, note the real WP did not "bond" the sidings so the most favorable indication into the siding was "Restricting" – I use "Approach"

- 3 sidings + staging

- All of the sidings are connected to industry tracks or a yard

- No intermediate signals (uncommon in the prototype but very common in the model world)
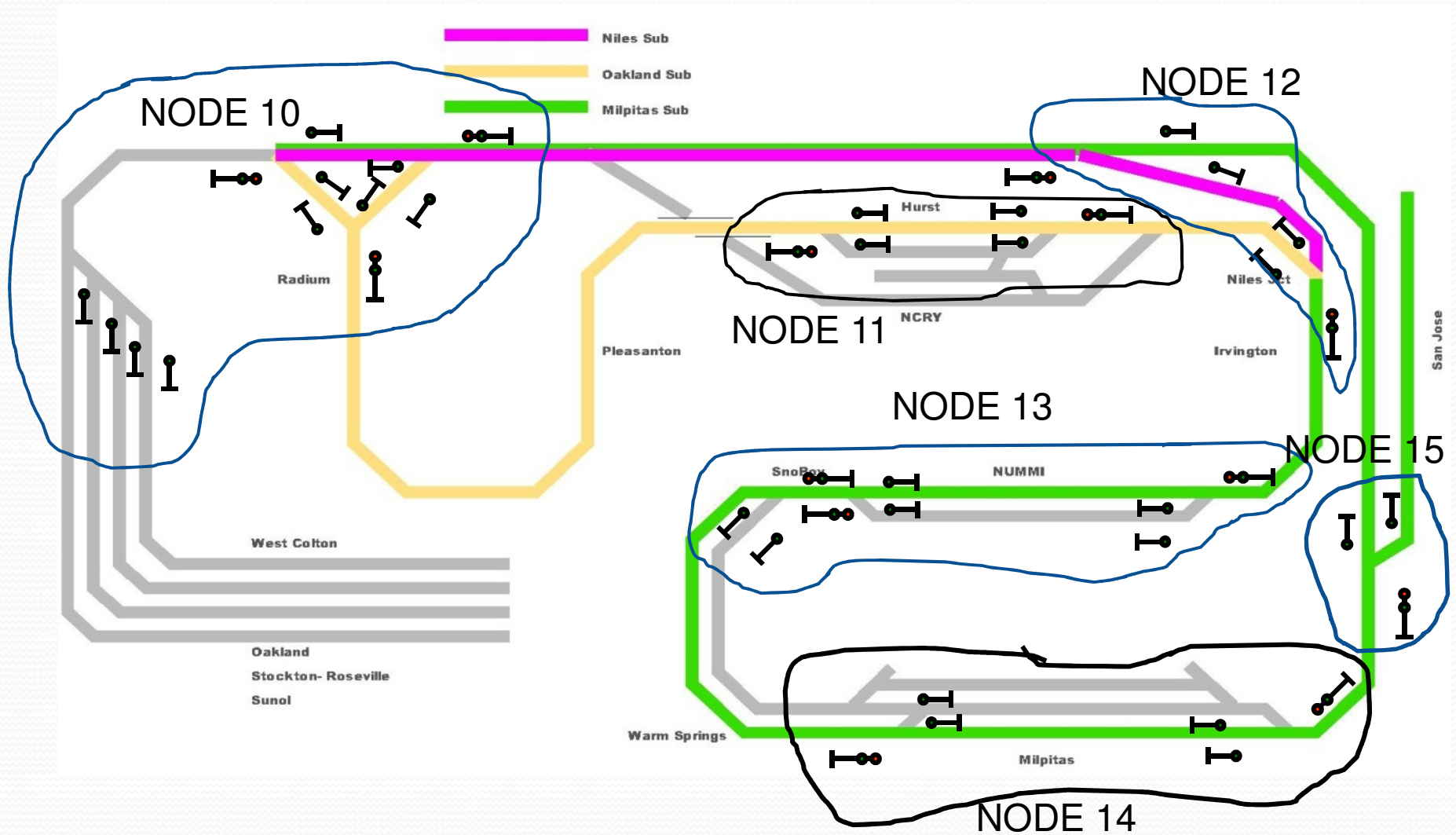
Example – control point per node
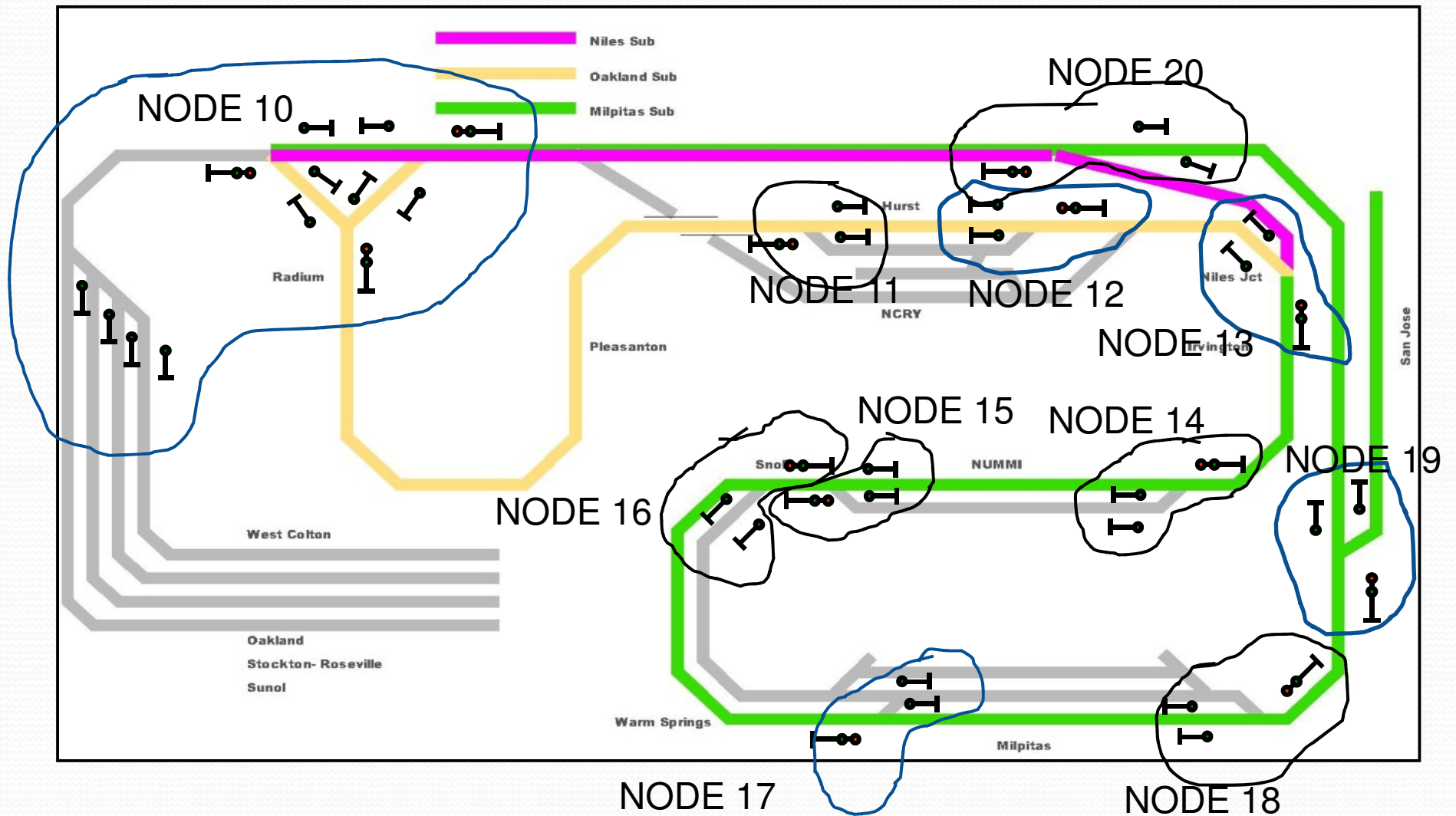
Bill of Materials:
cpNode per Control Point

Node		Milepost	Inputs		Outputs		total i/o	cpNode	IOX16	cpOD(M)	ODX4	RSMC	Dongle
			fascia	Blocks	Switch	Signal Lines							
10	Staging + Wye	F044	7	10	7	40	64	1	3	10	3	6	
11	E Hearst	F039	1	3	1	10	15	1	0	3	1	0	
12	W Hearst	F038	1	3	1	10	15	1	0	3	1	0	
13	Niles JCT	F030	1	3	1	11	16	1	0	3	1	0	
14	E NUMMI	M004	1	2	1	10	14	1	0	2	1	0	
15	W NUMMI	M005	1	2	1	10	14	1	0	2	1	0	
16	Yard Lead	M009	1	3	1	8	13	1	0	3	1	0	
17	E Milpitas	M010	2	2	2	11	17	1	1	2	1	1	
18	W Milpitas	M012	1	3	1	9	14	1	0	3	1	0	
19	Diridon	M019	1	3	1	8	13	1	0	3	1	0	
20	Niles Back	NI010	1	2	1	12	16	1	0	2	1	0	
	Computer												1
	needed							11	4	36	13	7	1
	10% Sparing							2	1	4	1	1	1
	total order						**211**	**13**	**5**	**40**	**14**	**8**	**2**

Example – cpNode Per Siding

Bill of Material: cpNode per Siding

Node		Milepost		Inputs		Outputs		total i/o	cpNode	IOX16	cpOD(M)	ODX4	RSMC	Dongle
				fascia	Blocks	Switch	Signal Lines							
10	Staging + Wye	F044	F043	7	10	7	40	64	1	3	10	3	6	
11	Hearst	F039	F038	2	6	2	20	30	1	1	6	2	1	
12	Niles Cutoff	F030	NI010	2	5	2	23	32	1	1	5	2	1	
13	E NUMMI	M004	M005	3	7	3	28	41	1	2	7	2	2	
14	E Milpitas	M010		3	5	3	20	31	1	1	5	2	2	
15	Diridon	M019		1	3	1	8	13	1	0	3	1	0	
	Computer													1
	needed								6	8	36	12	12	1
	10% Sparing								1	1	4	1	2	1
	total order								**7**	**9**	**40**	**13**	**14**	**2**

Opportunistic Clusters
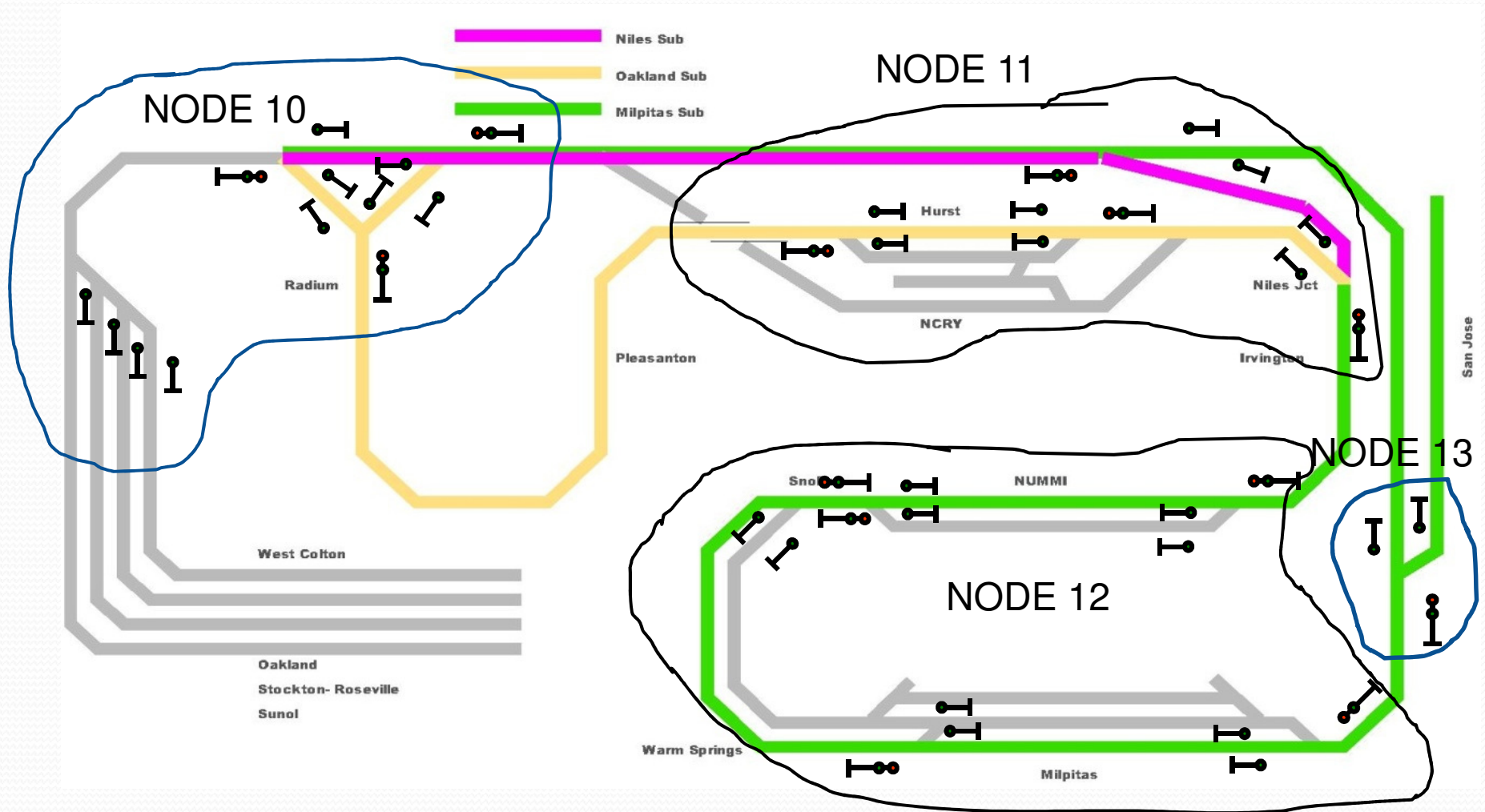
Bill of Materials:
Opportunistic Clusters

Node		Milepost		Inputs fascia	Blocks	Outputs Switch	Signal Lines	total i/o	cpNode	IOX16	cpOD(M)	ODX4	RSMC	Dongle
10	Staging + Wye	F044	F043	7	10	7	40	64	1	3	10	3	6	
11	Hearst	F039	NI010	4	11	4	20	62	1	3	11	3	3	
13	E NUMMI	M004	M005	6	12	6	48	72	1	4	12	3	5	
13	Diridon	M019		1	3	1	8	13	1	0	3	1	0	
	Computer													1
	needed								4	10	36	10	14	1
	10% Sparing								1	1	4	1	2	1
	total order							**211**	**5**	**11**	**40**	**11**	**16**	**2**

Example – SMINI Replacement

My Layout actually has 3 SMINI under Radum, 2 under Milpitas and an Intelligent (cpNode) Control panel for Diridon
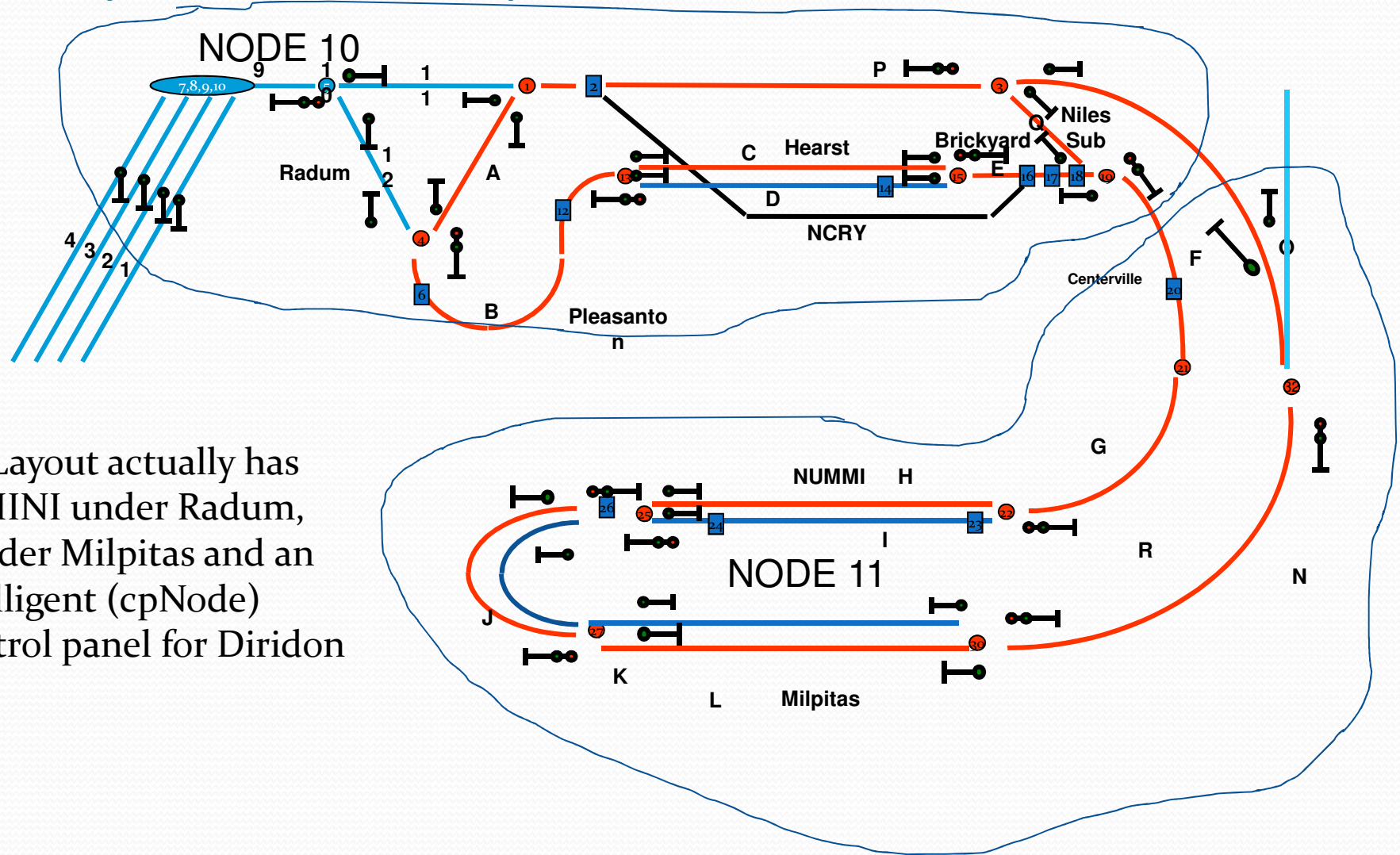
Bill of Materials:
SMINI Replacement

| Node | | Milepost | | Inputs | | Outputs | | total i/o | cpNode | IOX16 | cpOD(M) | ODX4 | RSMC | Dongle |
				fascia	Blocks	Switch	Signal Lines							
10	Radum Side	F044	NI010	11	21	11	84	126	1	7	21	6	10	
11	Milpitas Side	M004	M005	7	15	7	56	85	1	5	15	4	6	
	Computer													1
	needed								2	12	36	10	16	1
	10% Sparing								1	2	4	1	2	1
	total order							**211**	**3**	**14**	**40**	**11**	**18**	**2**

Configuration Summary

- You can mix and match cpNodes from as small as a single control panel to 144 ports (= 2 SMINI)

- You can mix and match cpNodes with Classic SUSIC or SMINI nodes to extend existing CMRI installations

- The cpNode design philosophy is to use a larger number of smaller nodes which are physically co-located with the controlled devices to minimize wiring and follow prototype practice: this enables on board logic on modules and things like intelligent control panels

- Ultimately we want to provide basic "vital logic" functionality even in the absence of the CMRInet "code line"

- Using an on board micro-controller opens the possibility of integrated servo control and other applications requiring real time control and A/D and D/A conversion at the node
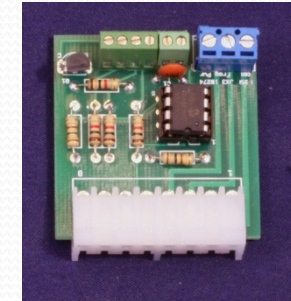
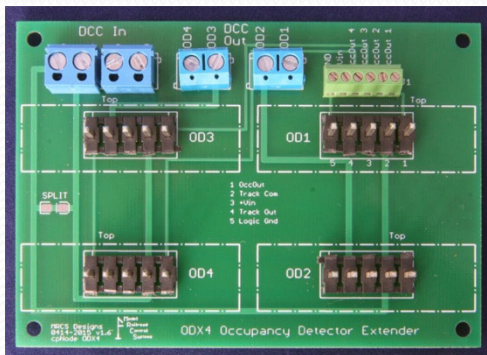# Appendix – the cpNode family
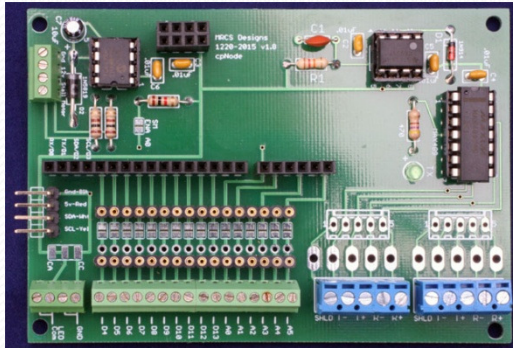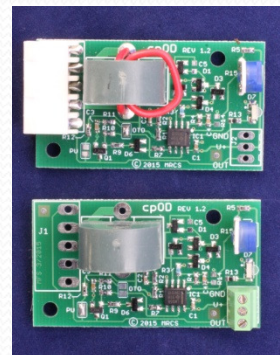

cpNode v2.0
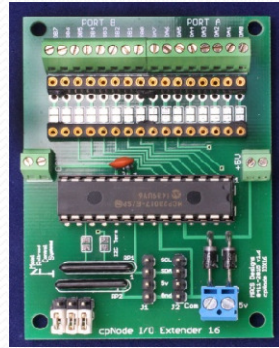
IOX16 v2.0
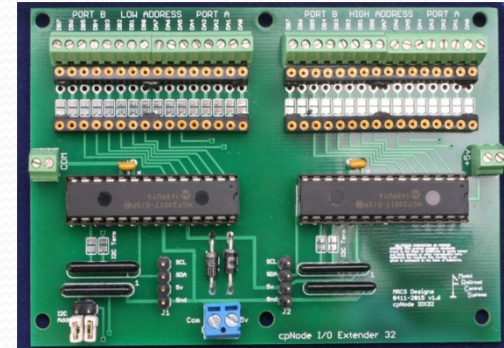
IOX32 v.02

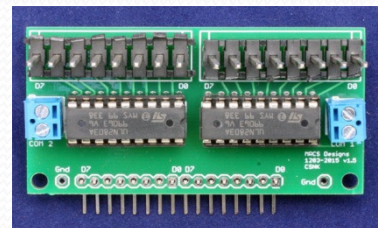RSMC
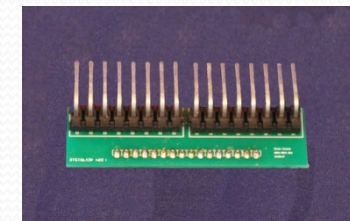

ODX4 v2.0

cpOD

CSNK v2.0

MOLEX

Visit us at www.modelrailroadcontrolsystems.com

References:

- Our (MRCS) website http://www.modelrailroadcontrolsystems.com/

- Bruce Chubb's excellent manuals at http://www.jlcenterprises.net/Products.htm#Manual

- Texas Instruments RS485 Application Note http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&cad=rja&uact=8&ved=0CCcQFjAB&url=http%3A%2F%2Fwww.ti.com%2Flit%2Fan%2Fslla272b%2Fslla272b.pdf&ei=UCFQVcCgIMWz0QTF80HQDQ&usg=AFQjCNGfNyOdKHc1uZHfxBvNlognOeiC0g&sig2=PlID20JIA4kyFDee1J-leA&bvm=bv

- Other Vendors – see our resource section: http://www.modelrailroadcontrolsystems.com/information/