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

- **cpNode**
- **SMINI**
- **IOX32**

- 48 Ports Set in 8 Port groups
- 24 in 48 out
## Comparative I/O And Costs

<table>
<thead>
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<th>SMINI</th>
<th>cpNode</th>
<th>cpNode Max</th>
<th>SUSIC MAX</th>
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<td>72</td>
<td>18</td>
<td>144</td>
<td>480</td>
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<td>$60</td>
<td>$160</td>
<td>$1,485</td>
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<td>Both</td>
<td>5V *</td>
<td>5V *</td>
<td>Both</td>
</tr>
<tr>
<td>Cost per line</td>
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<td>$ 3.33</td>
<td>$ 1.11</td>
<td>$ 3.09</td>
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<tr>
<td>Best For</td>
<td>Larger Areas distributed</td>
<td>Small distributed nodes</td>
<td>Interlockings, yard throats, cpNode Expansion</td>
<td>Larger centralized installs and CTC Machines</td>
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</table>

* 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
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)
- 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
• 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 be 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

- DIN Rail
- ODX3
- cpNode Tester
- cpNode
- cpNode
- IOX16
- IOX32

12/10/2013
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

<table>
<thead>
<tr>
<th>Architecture</th>
<th>Nodes</th>
<th>Electronics</th>
<th>Interconnects</th>
<th>Total</th>
<th>% SMINI</th>
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<td>$1,408.32</td>
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<td>$935.11</td>
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<td>$972.87</td>
<td>$15.60</td>
<td>$988.47</td>
<td>70%</td>
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</table>

- 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.
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
- Dr. Chubb’s documentation available at JLC Enterprises [http://www.jlcenterprises.net/Index.htm](http://www.jlcenterprises.net/Index.htm)
Backup
# SMINI Case

## Case 1 - SMINI

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<tr>
<th>Element</th>
<th>Control Points</th>
<th>Input lines</th>
<th>Output lines</th>
<th>SMINI</th>
<th>DCC_OD</th>
<th>ODMB</th>
<th>SMC12</th>
<th>R12TERM</th>
<th>Punch Block + 89B</th>
<th>Feet of CATS</th>
<th>Radio Shack Spade lugs</th>
<th>Total</th>
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<tr>
<td>Backboard 1 - Radum</td>
<td>7</td>
<td>283 DCCOD + 1 fascia switch per CP</td>
<td>7710 LEDs per CP + 1 switch motor</td>
<td>2</td>
<td>21</td>
<td>2</td>
<td>1</td>
<td>7</td>
<td>3</td>
<td>5253 per: 2 signals and Tortoise</td>
<td>49</td>
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## Backboard 2 - Milpitas

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<th>Output lines</th>
<th>SMINI</th>
<th>DCC_OD</th>
<th>ODMB</th>
<th>SMC12</th>
<th>R12TERM</th>
<th>Punch Block + 89B</th>
<th>Feet of CATS</th>
<th>Radio Shack Spade lugs</th>
<th>Total</th>
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<td></td>
<td>6</td>
<td>243 DCCOD + 1 fascia switch per CP</td>
<td>6610 LEDs per CP + 1 switch motor</td>
<td>2</td>
<td>18</td>
<td>2</td>
<td>1</td>
<td>6</td>
<td>3</td>
<td>4503 per: 2 signals and Tortoise</td>
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12/10/2013
## Centralized cpNode

### Backboard 1 - Radum

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<th>Unit</th>
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<td>ODMB</td>
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<td>SMC12</td>
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<td>R12TERM</td>
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<td>$70.00</td>
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$ 896.46

### Backboard 2 - Milpitas

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<td>Output lines</td>
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<td>10 LEDs per CP + 1 switch motor</td>
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$ 818.66

**total**

$ 1,715.11

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12/10/2013
## Distributed cpNode

### Case 3- Distributed cpNodes

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<th>Item</th>
<th>Quantity</th>
<th>Unit</th>
<th>Ext'd</th>
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<td>Unit</td>
<td>Ext'd</td>
</tr>
<tr>
<td>Inputs per Node</td>
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<td></td>
</tr>
<tr>
<td>Outputs per Node</td>
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</tr>
<tr>
<td>cpNode(S)</td>
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<td>$</td>
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<tr>
<td>DCC_OD</td>
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<td>$</td>
<td>$</td>
</tr>
<tr>
<td>ODX-4</td>
<td>13</td>
<td>$</td>
<td>$</td>
</tr>
<tr>
<td>ODX4 Jumpers</td>
<td>13</td>
<td>$</td>
<td>$</td>
</tr>
<tr>
<td>Shell and Pin kits for serial</td>
<td>13</td>
<td>$</td>
<td>$</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>$ 1,768.47</strong></td>
<td><strong>$ 1,752.87</strong></td>
</tr>
<tr>
<td><strong>Electronics</strong></td>
<td></td>
<td><strong>$ 1,752.87</strong></td>
<td><strong>$ 15.60</strong></td>
</tr>
<tr>
<td><strong>Connectivity</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

12/10/2013
## Switch Motor Cost Comparison

<table>
<thead>
<tr>
<th>Device</th>
<th>Driver</th>
<th>Bracket</th>
<th>Contacts</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stall - SMINI</td>
<td>$17.00</td>
<td></td>
<td></td>
<td>$22.42</td>
</tr>
<tr>
<td>Stall - cpNode</td>
<td>$17.00</td>
<td></td>
<td></td>
<td>$17.00</td>
</tr>
<tr>
<td>2 Coil (PL10)</td>
<td>$10.00</td>
<td>$30.00</td>
<td>$7.00</td>
<td>$47.00</td>
</tr>
<tr>
<td>Servo (cpNode)</td>
<td>$2.00</td>
<td></td>
<td>$4.75</td>
<td>$8.25</td>
</tr>
<tr>
<td>Servo SMINI</td>
<td>$4.00</td>
<td>$12.76</td>
<td>$4.75</td>
<td>$27.51</td>
</tr>
</tbody>
</table>

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.