Safety Chain Control System

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2015
Overview

• Background
  • Chain Control Operations
  • Operational need for change

• Design
  • Initial Design
  • Final Design

• Controlling Electronics
  • Hardware
  • Software

• Deployment

• Functional Testing

• Operational Status

• Lessons Learned

• Questions
Chain Control Operations

• Manually turned chain control signs
Chain Control Operations

- Manually turned chain control signs
- Worker Hazards
  - Traffic
Chain Control Operations

• Manually turned chain control signs
• Worker Hazards
  • Traffic
  • Limited visibility
Chain Control Operations

• Manually turned chain control signs
• Worker Hazards
  • Traffic
  • Limited visibility
  • Severe weather
Chain Control Operations

• Manually turned chain control signs
• Worker Hazards
  • Traffic
  • Limited visibility
  • Severe weather
  • Icy Roadways
Chain Control Operations

• Manually turned chain control signs
• Worker Hazards
  • Traffic
  • Limited visibility
  • Severe weather
  • Icy Roadways
  • Workers on foot
Operational Need for Change
Existing Chain Control System (Anderson Grade Pass)

- Anderson Grade Summit, 3067’
- Western State Forum
- Chain Control Location 1, Yreka, CA
Operational Need for Change
Existing Chain Control System (Anderson Grade Pass)

Chain Control Location 2, Hornbrook, CA

Anderson Grade Summit, 3067’
Operational Need for Change
Existing Installation for Multilane Highways

- Each sign must be manually turned
Operational Need for Change
Existing Installation for Multilane Highways

- Each sign must be manually turned
- Requires workers to be on foot in poor conditions
Operational Need for Change
Existing Installation for Multilane Highways

• Turn 1st set of signs
• Traverse highway twice
Operational Need for Change
Existing Installation for Multilane Highways

- Turn 1\textsuperscript{st} set of signs
  - Traverse highway twice
- Turn 2\textsuperscript{nd} set of signs
  - Traverse highway twice
Operational Need for Change
Existing Installation for Multilane Highways

- Turn 1\textsuperscript{st} set of signs
  - Traverse highway twice
- Turn 2\textsuperscript{nd} set of signs
  - Traverse highway twice
- Turn 3\textsuperscript{rd} set of signs
  - Traverse highway twice
Operational Need for Change

Existing Installation for Multilane Highways

- Turn 1\textsuperscript{st} set of signs
  - Traverse highway twice
- Turn 2\textsuperscript{nd} set of signs
  - Traverse highway twice
- Turn 3\textsuperscript{rd} set of signs
  - Traverse highway twice
- Turn 4\textsuperscript{th} set of signs
  - Traverse highway twice
Operational Need for Change

Existing Installation for Multilane Highways

- Turn 1\textsuperscript{st} set of signs
  - Traverse highway twice
- Turn 2\textsuperscript{nd} set of signs
  - Traverse highway twice
- Turn 3\textsuperscript{rd} set of signs
  - Traverse highway twice
- Turn 4\textsuperscript{th} set of signs
  - Traverse highway twice

Worker must traverse the highway 8 times!
Initial Design

• Develop two independent systems that allow maintenance crews *remotely* turn on chain control signs via telephone.
  • One located in Yreka, CA
  • One located in Hornbrook, CA

• Each system would consist of signage and controlling electronics.

• Each system would have a single controlling cabinet.
Initial Design
Small Changeable Message Sign vs Static Signs

- Small Changeable Message Sign
  - 3 lines, 8 characters per line
Initial Design
Small Changeable Message Sign vs Static Signs

• Small Changeable Message Sign
  • 3 lines, 8 characters per line
  • R1 Modified would require 3 panels

R1 Modified
“CHAINS REQUIRED ON SINGLE AXLE DRIVE VEHICLE WITH TRAILER”
Initial Design
Small Changeable Message Sign vs Static Signs

• Small Changeable Message Sign
  • 3 lines, 8 characters per line
  • R1 Modified would require 3 panels

R1 Modified Example
Initial Design
Small Changeable Message Sign vs Static Signs

• Small Changeable Message Sign
  • 3 lines, 8 characters per line
  • R1 Modified would require 3 panels

R1 Modified Example
Initial Design
Small Changeable Message Sign vs Static Signs

• Small Changeable Message Sign
  • 3 lines, 8 characters per line
  • R1 Modified would require 3 panels

R1 Modified Example

VEHICLE
WITH
TRAILER
Initial Design
Small Changeable Message Sign vs Static Signs

• Small Changeable Message Sign
  • 3 lines, 8 characters per line
  • R1 Modified would require 3 panels
  • R1 would require 4 panels

R1
“CHAINS REQUIRED AUTOS & PICKUPS SNOW TIRES OK – CARRY CHAINS”
Initial Design
Small Changeable Message Sign vs Static Signs

- Small Changeable Message Sign
  - 3 lines, 8 characters per line
  - R1 Modified would require 3 panels
  - R1 would require 4 panels
Initial Design
Small Changeable Message Sign vs Static Signs

- Small Changeable Message Sign
  - 3 lines, 8 characters per line
  - R1 Modified would require 3 panels
  - R1 would require 4 panels
Initial Design
Small Changeable Message Sign vs Static Signs

- Small Changeable Message Sign
  - 3 lines, 8 characters per line
  - R1 Modified would require 3 panels
  - R1 would require 4 panels
Initial Design
Small Changeable Message Sign vs Static Signs

- Small Changeable Message Sign
  - 3 lines, 8 characters per line
  - R1 Modified would require 3 panels
  - R1 would require 4 panels
Initial Design
Small Changeable Message Sign vs Static Signs

• Small Changeable Message Sign
  • 3 lines, 8 characters per line
  • R1 Modified would require 3 panels
  • R1 would require 4 panels
  • R2 would require 4 panels

R2
“CHAINS REQUIRED 4-W DRIVE WITH SNOW TIRES OK – CARRY CHAINS”
Initial Design
Small Changeable Message Sign vs Static Signs

- Small Changeable Message Sign
  - 3 lines, 8 characters per line
  - R1 Modified would require 3 panels
  - R1 would require 4 panels
  - R2

![Example of Small Changeable Message Sign]

R2 Example
Initial Design
Small Changeable Message Sign vs Static Signs

- Small Changeable Message Sign
  - 3 lines, 8 characters per line
  - R1 Modified would require 3 panels
  - R1 would require 4 panels
  - R2 would require 4 panels

![R2 Example]
Initial Design
Small Changeable Message Sign vs Static Signs

- Small Changeable Message Sign
  - 3 lines, 8 characters per line
  - R1 Modified would require 3 panels
  - R1 would require 4 panels
  - R2 Example
Initial Design
Small Changeable Message Sign vs Static Signs

• Small Changeable Message Sign
  • 3 lines, 8 characters per line
  • R1 Modified would require 3 panels
  • R1 would require 4 panels
  • R2

[Image of a display panel with the text "CARRY CHAINS" displayed]
Initial Design
Small Changeable Message Sign vs Static Signs

- Small Changeable Message Sign
  - 3 lines, 8 characters per line
  - R1 Modified would require 3 panels
  - R1 would require 4 panels
  - R2 would require 4 panels

Maximum of two panels are allowed on a CMS.

“Each message shall consist of no more than two phases. A phase shall consist of no more than three lines of text. Each phase shall be understood by itself regardless of the sequence in which it is read…”

California Manual on Uniform Traffic Control Devices (CA MUTCD) Section 2L.05.04
Initial Design
Small Changeable Message Sign vs Static Signs

- Static Signs
  - Existing Standard Signs
Initial Design
Small Changeable Message Sign vs Static Signs

• Static Signs
  • Existing Standard Signs
Initial Design
Small Changeable Message Sign vs Static Signs

• Static Signs
  • Existing Standard Signs
Initial Design

Small Changeable Message Sign vs Static Signs

• Use Static Signs based on Standard Signs

CHAINS REQUIRED
Initial Design
Small Changeable Message Sign vs Static Signs

- Use Static Signs based on Standard Signs
Initial Design
Small Changeable Message Sign vs Static Signs

• Use Static Signs based on Standard Signs
Initial Design
Small Changeable Message Sign vs Static Signs

• Use Static Signs based on Standard Signs

CHAINS REQUIRED
ON SINGLE AXLE DRIVE
AUTOS & PICKUPS SNOW
4x4 DRIVE WITH SNOW
TIRES OK - CARRY CHAINS
Initial Design
Sign Layout

- Flashing Beacon Control Signs with Variable Speed Limit Signs.
- Advanced Flashing Beacon
Advanced Flashing Beacon

Flashing Beacon Control Signs with Variable Speed Limit Signs.
Initial Design
Sign Structure (Initial Variants)

September 2010

September 2011
Initial Design
Speed Limit Sign

- Display enforceable speed limit sign
  - Foldable Sign (Fixed Sign)
Initial Design
Speed Limit Sign

- Display enforceable speed limit sign
  - Foldable Sign (Fixed Sign)
  - Extinguishable Message Sign (EMS)
Initial Design
Speed Limit Sign

• Display enforceable speed limit sign
  • Foldable Sign (Fixed Sign)
  • Extinguishable Message Sign (EMS)
  • Variable Speed Limit Sign (VSLS)
Initial Design
Controller Cabinet

- All controlling electrons will be located in a District 2 ITS Flashing Beacon Controller cabinet
  - Custom 332/334 Controller Cabinet
Final Design
Sign Layout

- Flashing Beacon Control Signs with Variable Speed Limit Signs.
- Advanced Flashing Beacon
Final Design
Sign Structure

Advanced Flashing Beacon

Flashing Beacon Control Signs with Variable Speed Limit Signs.
Final Design
Speed Limit Sign

- Information Display
  - Company SpeedCheck
  - VSL-18
    - Meets MUTCD
    - 18” LED display
    - Enforceable
Final Design
Controller Cabinet

• District 2 ITS Flashing Beacon Controller cabinet
Controlling Electronics
Hardware

- Schneider Electric Zelio Logic Smart Relay (SR2 B121BD)
  - Number or control scheme lines
    - 120 Ladder Logic Lines (LD)
    - $\leq 200$ with Function Block Diagram (FBD)
  - Inputs
    - 4 Discrete (24 V DC)
    - 4 Discrete or Analog (0-24 V DC)
  - Outputs
    - 4 normally open relay outputs
      - 5-30 V DC
      - 24-250 V AC
  - Power Requirements
    - 24 V DC at 100mA
Controlling Electronics

Hardware

- CircuitWerkes DR-10 Dial-up Remote Control
  - DTMF microprocessor based remote control
    - Allows for system control by telephone
  - Easily programmable
  - Relays
    - 8 Normally Open contacts rated at 10 VA
Controlling Electronics

Hardware

- Police Panel Push Button Controls
  - Custom Placard
  - Backlit LED momentary push buttons
Controlling Electronics

Hardware

LED Driver Board
Controlling Electronics
Custom Electronics

LED Driver Board
Controlling Electronics
Custom Electronics Box
Controlling Electronics
Custom Electronics Box

LED Driver Board
Modified Housing
Connectors
Controlling Electronics
Custom Electronics Box

- Modified Housing
- LED Driver Board
- Connectors
Controlling Electronics
System Schematic
Controlling Electronics
Custom Mounting Plate

- Zelio Smart Relay
- Terminal Blocks
- Custom Mounting Plate
- Circuit Breaker
- Test Switch
- Solid State Relay
Controlling Electronics
Terminal Block Wiring Diagram
Controlling Electronics
Cabinet Wiring Diagram
Battery Backup System
Battery Backup System
Inverter

• Alpha FXM 1100
  • Battery String Voltage: 48 V DC
  • Nominal Voltage: 120 V AC
  • Input
    • Voltage Range: 85-175 V AC
    • Current: 9.8 A
    • Frequency: 60/50 Hz
  • Output
    • Pure Sine
    • Voltage: 120 V AC
    • Frequency: Same as Input
    • Power: 1100 W
Battery Backup System

Batteries

- C&D Technologies Dynasty UPS12-300MR
  - Voltage: 12 V DC
  - Amp Hours: 78.6 AH
  - Absorbed Glass Mat (AGM)
  - Can be operated in any orientation
Battery Backup System
Battery Tray

• Custom designed battery tray
  • Holds 4 batteries
  • Holds up to 350 lbs
  • Slides out for ease of changing/testing batteries
  • Acid resistant powder coating
Flashing Beacon Controller Cabinet

- DTMF Remote Control
- Flashing Beacon Controller Assembly
- Inverter
- District 2 ITS Node PDA
- Batteries and Tray
Software
ZelioSoft Programming

• Functional Block Diagram
  • Graphical programming based on predefined function blocks
  • Easy to understand without needing to know detailed programming language
Software
ZelioSoft Programming

• Simulation/Testing functionality is limited in programming suite
  • Cannot step through program
  • Cannot mimic real time inputs
Software
ZelioSoft Programming

• Inputs
  • Discrete (DISCR) Inputs
  • Filtered Discrete Input
  • Analog Input
  • Filtered Analog Input
  • Integer Input
  • Special Inputs in FBD Language
  • 10-Bit Integer Input
Software
ZelioSoft Programming

• Standard Functions
  • BOOLEAN Equation (Boolean function)
  • SET and RESET Function (RS switching)
  • PRESET COUNT Up/Down Counter
  • H-SPEED COUNT (Fast Counter)
  • UP/DOWN COUNT (Up/Down Counter)
  • TIMER A/C (Timer)
  • TIMER BW (Pulses on Edges)
  • TIMER Li (Cyclic Timing)
  • TIMER B/H (Time out)
  • COMP IN ZONE Comparison
  • PRESET H-METER (Preset Hour Counter)
  • TRIGGER (Schmitt Trigger)
  • COMP IN ZONE (Comparison of two values)
  • GAIN Function
  • DISPLAY (LCD Screen display)
Software
ZelioSoft Programming

- Standard Functions (Cont)
  - TEXT
  - TIME PROG (Daily, weekly, yearly programmer)
  - BISTABLE (Impulse Relay)
  - MUX (Multiplexing)
  - ADD/SUB (ADD/SUB Arithmetic Function)
  - MUL/DIV (MUL/DIV Arithmetic Function)
  - CAM BLOCK (Cam Programmer)
  - ARCHIVE
  - STATUS (Module Status)
  - CNA (Bit to Word Conversion)
  - CAN (Word to Bit Conversion)
  - SLIn (Serial Port Input)
  - SLOut (Serial Port Output)
  - COM (Message)
  - Sunrise/Sunset
  - Suntrack
Software
ZelioSoft Programming

• Sequential Function Charts Functions
  • Initial Step
  • Resettable initial step
  • Step
  • Divergence to AND
  • Convergence to AND
  • Divergence to OR
  • Convergence to OR
Software
ZelioSoft Programming

• Logic Functions
  • NO (NOT)
  • AND
  • OR
  • NO AND (NAND)
  • NO OR (NOR)
  • EXCLUSIVE OR
Software
ZelioSoft Programming

• Output Functions
  • Discrete (DISCR) Output
  • Integer Output
  • LCD Screen Backlighting Output
Software
ZelioSoft Programming

Inputs
Output Logic
LCD Display Objects

Countdown
Reset Timer

Output Relays
Software
ZelioSoft Programming

Momentary Inputs (DTMF Control & Police Panel)
Pulse on Rising Edge

Push Buttons
Software
ZelioSoft Programming

Pulse on Rising Edge

State 1 Logic
State 2 Logic
State 3 Logic
Countdown Timer Reset

Input 1
Input 2
Input 3
Input 4 (Reset)

Output Logic
Software
ZelioSoft Programming

- How Each State’s Logic Works
  - Input State goes “high”
    - Output State turns on
  - Input State goes “low”
    - Output does not change
  - Other States, Reset, or Timer
    - Reset goes “high”
      - Output State turns off

### Truth Table

<table>
<thead>
<tr>
<th>Input</th>
<th>Other State A</th>
<th>Other State B</th>
<th>Reset</th>
<th>Timer Reset</th>
<th>Output</th>
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</table>

![Diagram](image-url)
Software
ZelioSoft Programming

<table>
<thead>
<tr>
<th>Input 1</th>
<th>Input 2</th>
<th>Input 3</th>
<th>Input 4 (Reset)</th>
<th>Timer Reset</th>
<th>Output 1</th>
<th>Output 2</th>
<th>Output 3</th>
<th>Output 4</th>
</tr>
</thead>
<tbody>
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</tbody>
</table>

System Truth Table
Software
ZelioSoft Programming

• How Countdown Timer Reset Works
Software
ZelioSoft Programming

• Custom Logic Blocks
• Second Countdown

- Initialized Seconds (Preset)
- Pulse on Rising Edge
- Second Clock
- Current Second
- Second Reset
- Decrement
- Reset
- Force Preset
- Preset
- Sec < 0
- Reset Value

Initialized Seconds
(Preset)
Software
ZelioSoft Programming

- Custom Logic Blocks (Cont)
  - Minute Countdown

[Diagram with labels: Reset, Second Reset, Current Second, Minute Reset, Increment, Decrement, Reset, Force Preset, Min < 0, Preset, Initialized Seconds (Preset), Pulse on Rising Edge, Reset Value]
• Custom Logic Blocks (Cont)
  • Hour Countdown

- Minute Reset
- Preset Hours
- Reset
- Decrement
- Force Preset
- Preset
- Hour < 0
- Hour Reset
- Current Hour
- Reset Value
Deployment
Cabinet Wiring
Deployment
Cabinet Wiring
Deployment
Cabinet Wiring
Functional Testing

• Steady Lit Condition vs Alternating Flashing Condition
  • Steady Lit does not catch eye
  • Alternating Flashing catches eye
  • Maintenance choose Alternating Flashing
Functional Testing

• Variable Speed Limit Sign has a “start-up” lag
  • Signs take approx. 10 seconds to show visible speed limit after system is turned on
Functional Testing

• Sign Text sizing
  • Feedback from local maintenance crew is that text size is too small
  • Text size is standard size used for chain control signs – 4”
  • Text size is too small for normal freeway speeds in good weather
  • Text is readable at 45-35 mph, typical speed during snowy conditions
Functional Testing

- Sign Lighting
  - Signs were not designed to have lighting
  - Testing at night time revealed the need for sign lighting.
Operational Status

- System has been deployed
- Mild Winter
  - No snow has been present on Anderson Grade Pass to cause chain conditions
  - Could not monitor motorist behavior due to the mild winter
- Operations of Chain Control area has changed
  - Chain Control area is now manned during chain control events
Lessons Learned

• Variable Speed Limit Sign vs Extinguishable Message Sign
  • EMS would be better
    • Maintenance
    • Cost
    • Ease of integration

• Zelio Smart Relay
  • More inputs and outputs
    • More flexibility in adding and changing available conditions

• Add second Flashing Beacon Controller Assembly
  • Adds ability to have 8 controlled states
Lessons Learned

- Sign Lighting
  - Add Sign lighting
- Chain Condition Text Size
  - Increase size of text
Questions?