Practical Computerized Home Automation

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Home automation is computer control of home devices, typically electrical. Using inexpensive hardware and open source software, it is possible to programmatically control many devices in your home, providing ease and enjoyment for your family.

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Last updated: February 2023
1. What is computerized automation?
2. Evaluating technologies
3. Sample deployment
4. Device programming basics
5. What is success?
6. Home automation applications
1. What Is Computerized Automation?
Non-Programmatic Automation

- Timers
- Clapper
- Dawn/Dusk Sensors
- Motion Sensors
Programmatic Automation

- Device behavior can be combined
- No distance limitations
- Activity detection
- Fully programmable / scriptable
- Access to external data
2. Evaluating Technologies: Home Networks

- Wired telephone
- Cordless telephone (900MHz, 2.4GHz, 5.8 GHz, 1.9GHz)
- Wired local area network (Ethernet)
- Wireless local area network (802.11)
- Electrical
- New wireless networks
Home Network Choices

- Power Line Control (PLC)
  - X10: signal transmitted at 60 Hz zero-crossings (120 kHz)
  - Universal Power Bus (UPB): out-of-band signal (4–40 kHz)
- Radio frequency (wireless)
  - Z-Wave: 900 MHz
  - Zigbee: 900 MHz and 2.4GHz (IEEE standard 802.15.4)
- Hybrid
  - Insteon: out-of-band PLC (131 kHz) and radio frequency (900MHz), plus X10 support, https://www.theverge.com/2022/6/9/23161803/insteon-customers-bought-company-restored-service
Choosing a Home Network Technology

- Open source computer control
  - heyu supports X10
  - MisterHouse (Perl-based) supports all listed technologies
- Availability of devices
  - electrical plug control
  - wireless remotes
  - chimes
  - sensors
  - doors, locks
  - thermostats/HVAC
  - 220-volt control
- Signal reliability (X10 is the worst)
- Technology longevity (X10’s future is uncertain)
- Simplicity of device replacement
- Cost
- External/cloud dependency, privacy
3. Sample Deployment: X10, Electrical Signal Basics, 60 Hertz

http://www.pcguide.com/ref/power/ext/basicsACDC-c.html
Adding A Signal

Figure 2

Complementary Pair Data

A binary “1” is a pulse...
...followed by the absence of a pulse.

And a binary “0” is the absence of a pulse...
...followed by a pulse.

http://www.pcguide.com/ref/power/ext/basicsACDC-c.html and following
Immediately after a “Start Code”, a “Letter Code” is sent. (4 cycles)

Figure 3

<table>
<thead>
<tr>
<th>Code</th>
<th>Letter</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0110</td>
</tr>
<tr>
<td>B</td>
<td>1110</td>
</tr>
<tr>
<td>C</td>
<td>0010</td>
</tr>
<tr>
<td>D</td>
<td>1010</td>
</tr>
<tr>
<td>E</td>
<td>0001</td>
</tr>
<tr>
<td>F</td>
<td>1001</td>
</tr>
<tr>
<td>G</td>
<td>0101</td>
</tr>
<tr>
<td>H</td>
<td>1101</td>
</tr>
<tr>
<td>I</td>
<td>0111</td>
</tr>
<tr>
<td>J</td>
<td>1111</td>
</tr>
<tr>
<td>K</td>
<td>0011</td>
</tr>
<tr>
<td>L</td>
<td>1011</td>
</tr>
<tr>
<td>M</td>
<td>0000</td>
</tr>
<tr>
<td>N</td>
<td>1000</td>
</tr>
<tr>
<td>O</td>
<td>0100</td>
</tr>
<tr>
<td>P</td>
<td>1100</td>
</tr>
</tbody>
</table>
Oscilloscope Showing Zero

Figure 4
Oscilloscope Showing One

Figure 5
The X10 Standard

X10 is an international and open industry standard for communication among electronic devices used for home automation.

- Designed in 1975 by Pico Electronics of Glenrothes, Scotland
- Uses a 120 kHz carrier transmitted as bursts during the relatively quiet zero crossings of the 60 Hz AC alternating current waveform
- One bit is transmitted per zero crossing
- 120 bits per second transmission rate
- 256 maximum device codes
- 16 house codes, A–P; 16 devices per house code, 1–16

X10 Protocol

http://www.x10.com/support/technology1.htm and following
### X10 Protocol

<table>
<thead>
<tr>
<th>HOUSE CODES</th>
<th>KEY CODES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>H1</strong></td>
<td><strong>D1</strong></td>
</tr>
<tr>
<td><strong>H2</strong></td>
<td><strong>D2</strong></td>
</tr>
<tr>
<td><strong>H4</strong></td>
<td><strong>D4</strong></td>
</tr>
<tr>
<td><strong>H8</strong></td>
<td><strong>D8</strong></td>
</tr>
<tr>
<td><strong>D16</strong></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>0</td>
</tr>
<tr>
<td>B</td>
<td>1</td>
</tr>
<tr>
<td>C</td>
<td>0</td>
</tr>
<tr>
<td>D</td>
<td>1</td>
</tr>
<tr>
<td>E</td>
<td>0</td>
</tr>
<tr>
<td>F</td>
<td>1</td>
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<tr>
<td>G</td>
<td>0</td>
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<tr>
<td>H</td>
<td>1</td>
</tr>
<tr>
<td>I</td>
<td>0</td>
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<tr>
<td>J</td>
<td>1</td>
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<tr>
<td>K</td>
<td>0</td>
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<tr>
<td>L</td>
<td>1</td>
</tr>
<tr>
<td>M</td>
<td>0</td>
</tr>
<tr>
<td>N</td>
<td>1</td>
</tr>
<tr>
<td>O</td>
<td>0</td>
</tr>
<tr>
<td>P</td>
<td>1</td>
</tr>
</tbody>
</table>

**Figure 4**

- **All Units Off**: 0 0 0 0 1 1
- **All Lights On**: 0 0 0 1 1
- **On**: 0 0 1 0 1
- **Off**: 0 0 1 1 1
- **Dim**: 0 1 0 0 1
- **Bright**: 0 1 0 1 1
- **All Lights Off**: 0 1 1 0 1
- **Extended Code**: 0 1 1 1 1
- **Hail Request**: 1 0 0 0 1
- **Hail Acknowledge**: 1 0 0 1 1
- **Pre-Set Dim**: 1 0 1 X 1
- **Extended Data [analog]**: 1 1 0 0 1
- **Status-On**: 1 1 1 1 1
- **Status-Off**: 1 1 1 0 1
- **Status Request**: 1 1 1 1 1
X10 Limitations

- Requires 0.75 seconds to transmit a command
- Poor propagation in split-phase electricity distribution
- Affected by line noise from other devices
- Affected by X10 signals from other buildings
The Split-Phase Electricity Distribution Problem

Figure 3-2. Circuit balancing

Allowing Split-Phase Electricity Distribution Propagation, With Amplification
Phase Coupling

Reducing Line Noise

I need to use this because my UPS dampens X10 signals. You also might want to block X10 signals from coming into your house, or you can use unique house codes.
Wall Switch
Flat Switch
Three-way switches are difficult to install because the X10 detection module must be on the *power* side of the switch, not the ground side; see [http://www.hometoys.com/htinews/dec97/articles/kingery/kingery6.htm](http://www.hometoys.com/htinews/dec97/articles/kingery/kingery6.htm).
Wireless Wall Switch
Wireless Receiver
Wireless Remote
Wireless Remote
Lamp/Appliance Control
The pool pump runs longer when the weather is warmer. The server gets the outside air temperature from a weather web site and turns the pool pump on and off at the proper times.
NAME
heyu - control program for the X10 CM11A serial interface

SYNOPSIS
heyu address unit-specifier
heyu date
heyu erase
heyu function unit-specifier state
heyu info
heyu help
heyu monitor
heyu preset unit-specifier preset-dim
heyu reset [housecode]
heyu setclock
heyu status [unit-specifier]
heyu stop
heyu turn unit-specifier state [amount]
heyu upload [check]
heyu version
Computer/Power Line Interface
7/6 at 05:40:49 address unit 8 : housecode d (entrymotion_dusk)
7/6 at 05:40:49 function Off : housecode d unit 8 (entrymotion_dusk)
7/6 at 20:35:57 address unit 8 : housecode d (entrymotion_dusk)
7/6 at 20:35:57 function On : housecode d unit 8 (entrymotion_dusk)
7/6 at 22:05:46 address unit 3 : housecode f (catherine)
7/6 at 22:05:46 function Off : housecode f unit 3 (catherine)
7/5 at 23:18:20 address unit 13 : housecode i (remotebed2)
7/5 at 23:18:21 function Off : housecode i unit 13 (remotebed2)
```bash
x10 monitor | while read LINE
do
  echo "$LINE" >/var/log/x10
  case "$LINE" in
    *" Off : "*"(remotebed)"*
      x10off $(x10group 1 | egrep -v '^entrytable$')
    ;;
    # is it dusk?
    *" On : "*"(entrymotion_dusk)"*
      if [ -f /u/x10/wait_for_dusk ];
      then rm /u/x10/wait_for_dusk
         x10on 1
         echo "x10on masterbath laundry" | at now +45 minutes
      fi
    ;;
    *" On : "*"(kitchen_chime"*"")"*
      say "We are ready to eat."
      daemon -cf sbplay bell.wav 50
      sleep 2
    ;;
  esac
done
```
4. Device Programming Basics: Software Control
Inputs

- User commands
- Clock/Timer
- Dawn/Dusk sensors
- Wireless remotes
- Caller Id
- Telephone Dialing
- Web sites, e.g., outside temperature
Outputs

- Lights
- Motors
- Appliances, e.g., coffee maker
- Sounds
- Network broadcast messages
- Slideshow
Sample Application: Dusk

X10 switch, which allows manual or remote operation, turns on lights (45 minutes later)

Bridge to other circuit

Receive signal and turn on interior lights

Receive wireless signal and transmit across circuit

Turn on interior lights and set cron to turn on outside lights in 45 minutes

Send signal to turn on lights

Read signal and send to computer

Sense sunset (wireless)
5. What Is Success?

- Adding home automation changes your family’s home environment
- Start slow; make incremental changes
- Accept that some home automation tasks are impossible
- You have succeeded when a family member asks for a home automation addition

Challenges

- Change
- Reliable operation
- Device longevity
- Maintenance
- Cost, coordination server
- Security/privacy

6. Home Automation Applications: Telephone Interface
Telephone Logging

AT#CID=1

Wed Jul 8 21:34:00 EDT 2009 DATE = 0708
Wed Jul 8 21:34:00 EDT 2009 TIME = 2134
Wed Jul 8 21:34:00 EDT 2009 NMBR = 6107429657
Wed Jul 8 21:34:00 EDT 2009 NAME = PENNSYLVANIA

Lookup phone number in contact directory.

Wed Jul 8 21:34:04 EDT 2009 Bruce and Christine Momjian
from Bruce's cell phone (610) 742-9657

Optionally sound X10 chime if phone call is from an important phone number.
Dial phone number from contact directory:

ATDT16107429657

Tue Apr  7 14:57:26 EDT 2009  16107429657  Bruce and Christine Momjian to Bruce's cell phone

This can also be used to automatically dial recently received calls using the log.
Telephone Notification

caller_id daemon

Call Chime (optional)

Numbers/Names from Contact Directory

Logfile

Broadcast Message

Caller ID (via modem)
Outgoing Calls

User Command → dial script → Outgoing Call

Numbers/Names from Telephone Directory
Home Application: Second Floor

- Wireless Remote
- Chime
- Pool Pump (outside)
- Bedroom
- Hallway
- Bedroom
- Bedroom
- Play
- Light
Heyu

X10 devices are controlled and monitored using the X10 CM11a computer interface device and the open source heyu control software. For heyu information, see [http://www.heyu.org/](http://www.heyu.org/). Heyu can be customized by defining devices in ~/.x10config:

```plaintext
remotebed I 1  # downstairs remote allof
entrytable I 2
bookcase I 3
couch I 4
tiffany I 5
schoolroom I 6
fireplace I 7
laundry I 8
wireless I 9  # wireless outlet, makes click noise
masterbed I 10
...
```
Heyu Wrapper Script

Instead of:

$ heyu turn couch on

a script can be created:

$ x10on couch

The script can handle multiple devices:

$ x10on tiffany bookcase

and groups of devices can be defined:

$ x10off video
Simple Time-Based Activity

cron

Time → cron → Output
Crontab Scheduler

0 7 * * * root x10on slideshow
0 11 * * * root x10on decor
0 12 * * * root touch /u/x10/wait_for_dusk
0 14 * * * root x10on bathroom
30 20 * * * root x10on boyscolor catherine

# fade
30 21 * * * root x10dim entrytable decor bathroom

# off
0 21 * * * root x10off bookcase
0 23 * * * root frontlights off; x10off decor tiffany
0 0 * * * root x10off `x10group 1 | egrep -v '^entrytable$'`
0 0 * * * root touch /u/x10/wait_for_dawn
59 0 * * * root x10dimoff_slow laundry
59 1 * * * root ! is_tz_fallback && x10alloff
Dawn/Dusk Activity

Dawn/Dusk Sensor (via X10) → x10monitor daemon → Inside Lights On

Outside Lights On → +30 minutes
Acting on Events (Dusk)

x10 monitor | while read LINE
do
  echo "$LINE" >>/var/log/x10
  case "$LINE" in
    # is it dusk?
    *" On : "*((entrymotion_dusk))"*)
      if [-f /u/x10/wait_for_dusk ]
        then rm /u/x10/wait_for_dusk
          x10on 1
            echo "heyu turn masterbath on; heyu turn laundry on" | at now +45 minutes
        fi
  esac
;;
X10 Already Supports Wireless Remotes
Coffee Maker
Coffee Maker Timer

Wireless Remote (via X10) → x10monitor → Coffee Maker Off

*" On : "*(coffeepot"*)"*)
    echo "heyu turn coffeepot off" | at now +15 minutes
    ;;
Implementing Smartphone Coffee Control

1. Install an SSH client on the smartphone (VX Connectbot)
2. Setup an SSH key to avoid password prompting
3. Use *post-log automation* to issue the *heyu* shell command to turn on the coffee, and logout
A script allows scheduled pump control with manual override.
Screen is shown on a dummy display and also on laptops throughout the house. Source available at http://code.google.com/p/infodisp.
Time to Eat

Wireless Remote (via X10) → x10monitor daemon

"Eat" Chime
Broadcast Message
Activity Screen Off (for 50 minutes)
Garage Entry Detection

- Light
- Motion
- Distance
- Garage door activation
- Garage door position
Detection Challenges

- Taking out the trash
- Leaving vs. arriving
Garage Door Position Detection
Garage Door Position Detection
Garage Door Position Detection
Garage Door Closed
Garage Door Open
Distance Detection

Distance Sensor → Arduino → X10 → Server
Arduino Distance Detection: Ping Ultrasonic Range Finder
The Solution
Arrival Reporting

- Turn on outside lights
- Issue message that someone has arrived
- Report who was in the car (what MAC address disappeared when the car left)
- Van has returned with Christine
Conclusion

moore's law, let me show you it.

Another presentation: http://www.ushomeautomation.com/Presentations/TCF2011

https://momjian.us/presentations