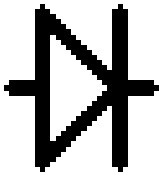
Secure Data Export and Auditing using Data Diodes



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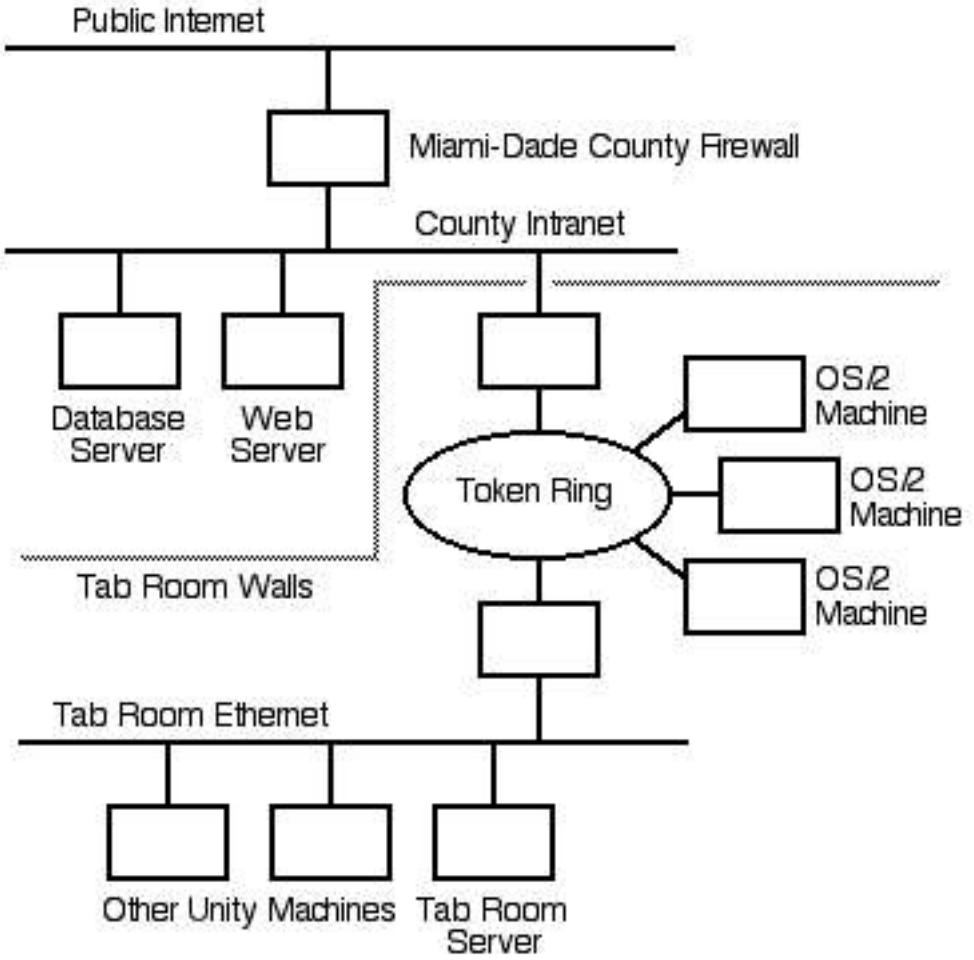
http://www.cs.uiowa.edu/~jones/voting/diode/

The Problem

- Election result must be put on the net.
- Election database must be protected.
- Conflict resolved by:
  - Sneakernet or
  - Even odder solutions

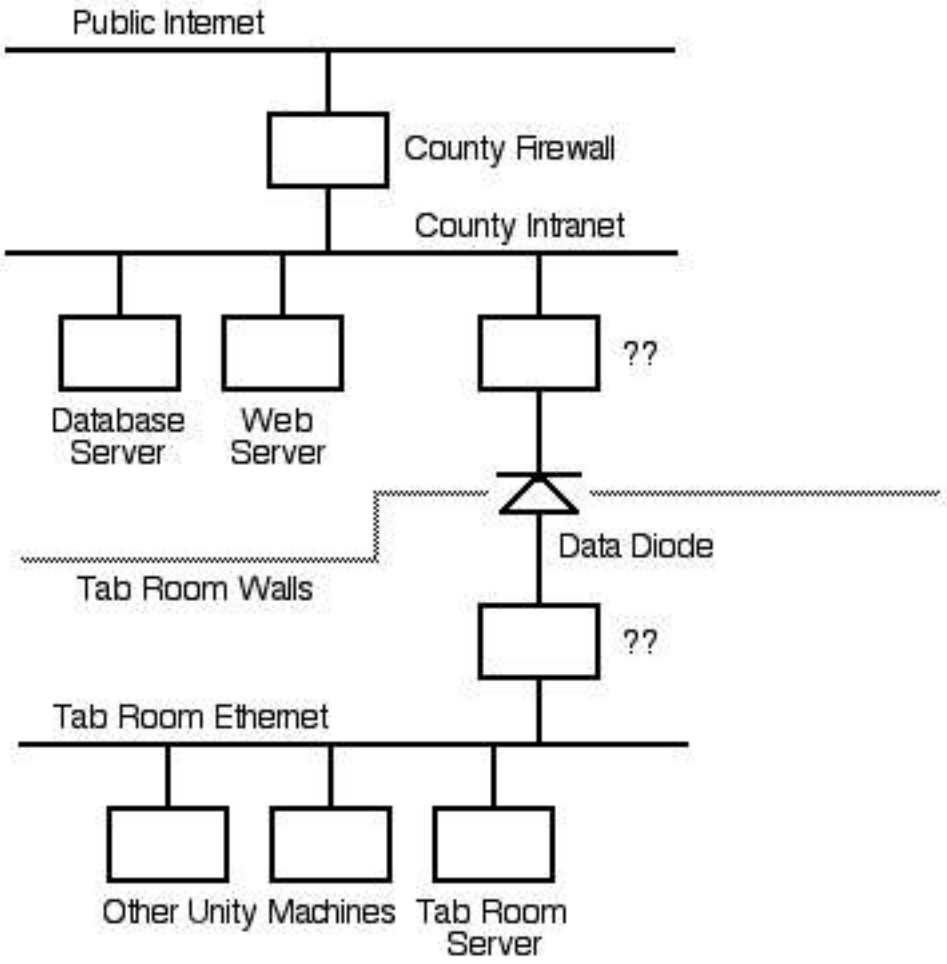


Miami Dade County Solution
Security through obscurity

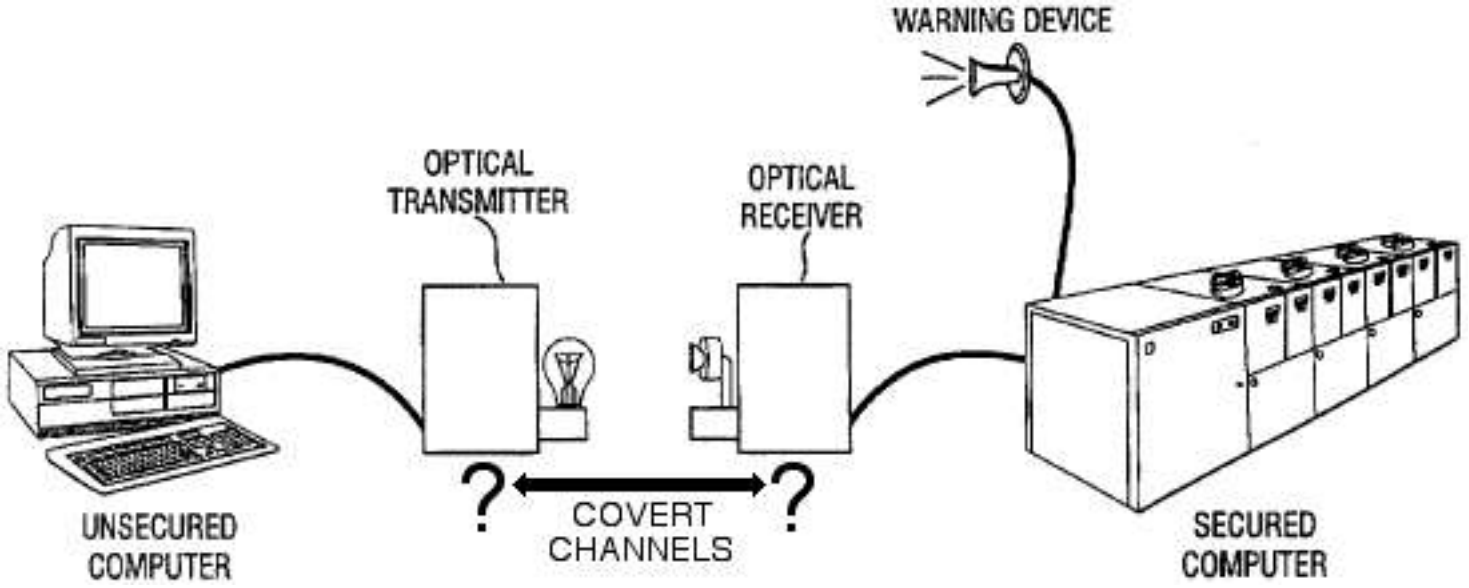
What we need

A data diode

- Allow data export
- Prevent data import
- Design understood by
  - Election observers
  - Election officials
  - Losing candidates



US Patent 5,703,562

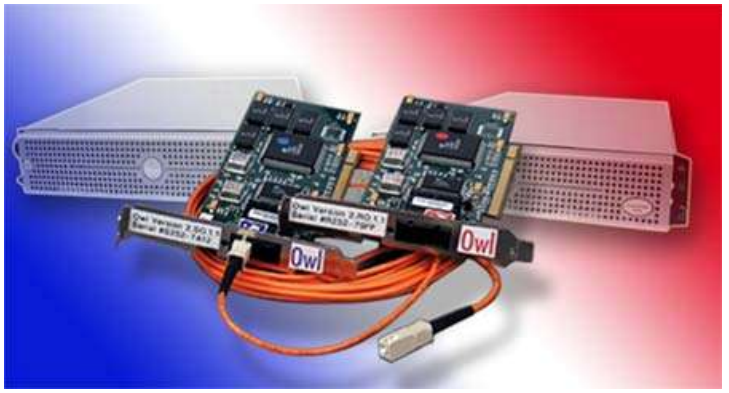


- Claims limited to up-hierarchy transmission
- Example given for RS-232 implementation
  - Transmit: 1 IC + 8 components + 5 volt supply
  - Receive: 1 IC + 4 components + 5 volt supply
- Explain this to a naïve suspicious observer!

Commercial Data Diodes

Owl Computing Technologies

www.owlcti.com



Tenix DATAGATE

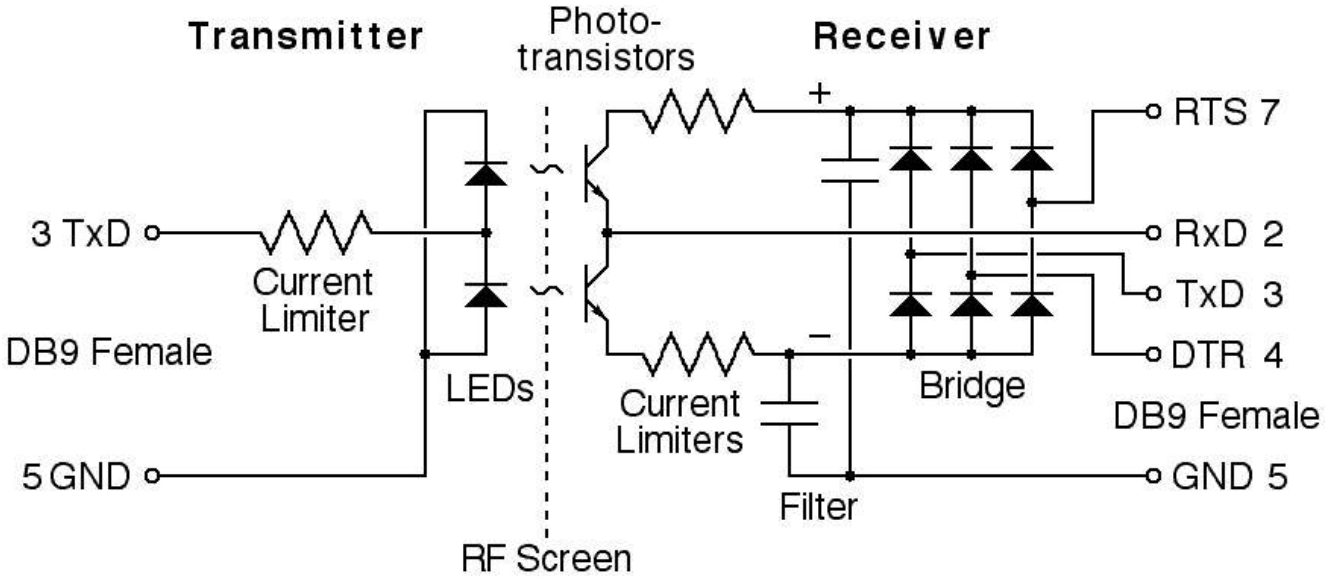
www.tenix.com

- Both based on fiber-optic technology
- Tenix Data Diode certified to EAL 7 under Common Criteria

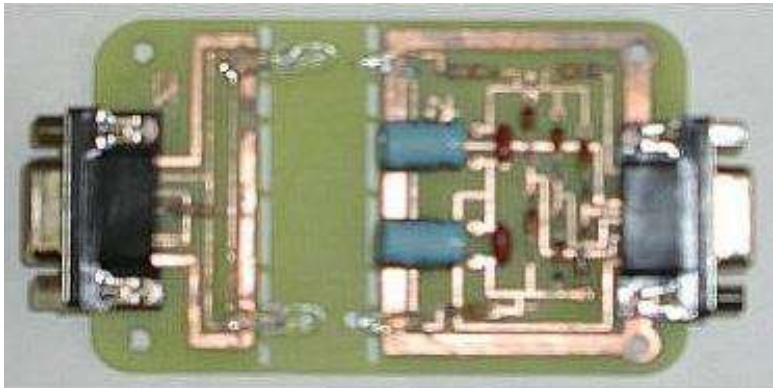
Design Transparency

- EAL 7 certification
  - Insufficient if the certifying agency is not trusted
  - What if the vendor cheats after certification?
- Therefore, we need
  - Complete design transparency
  - Open documentation
  - Rights of observers to inspect entire mechanism
  - Minimal complexity

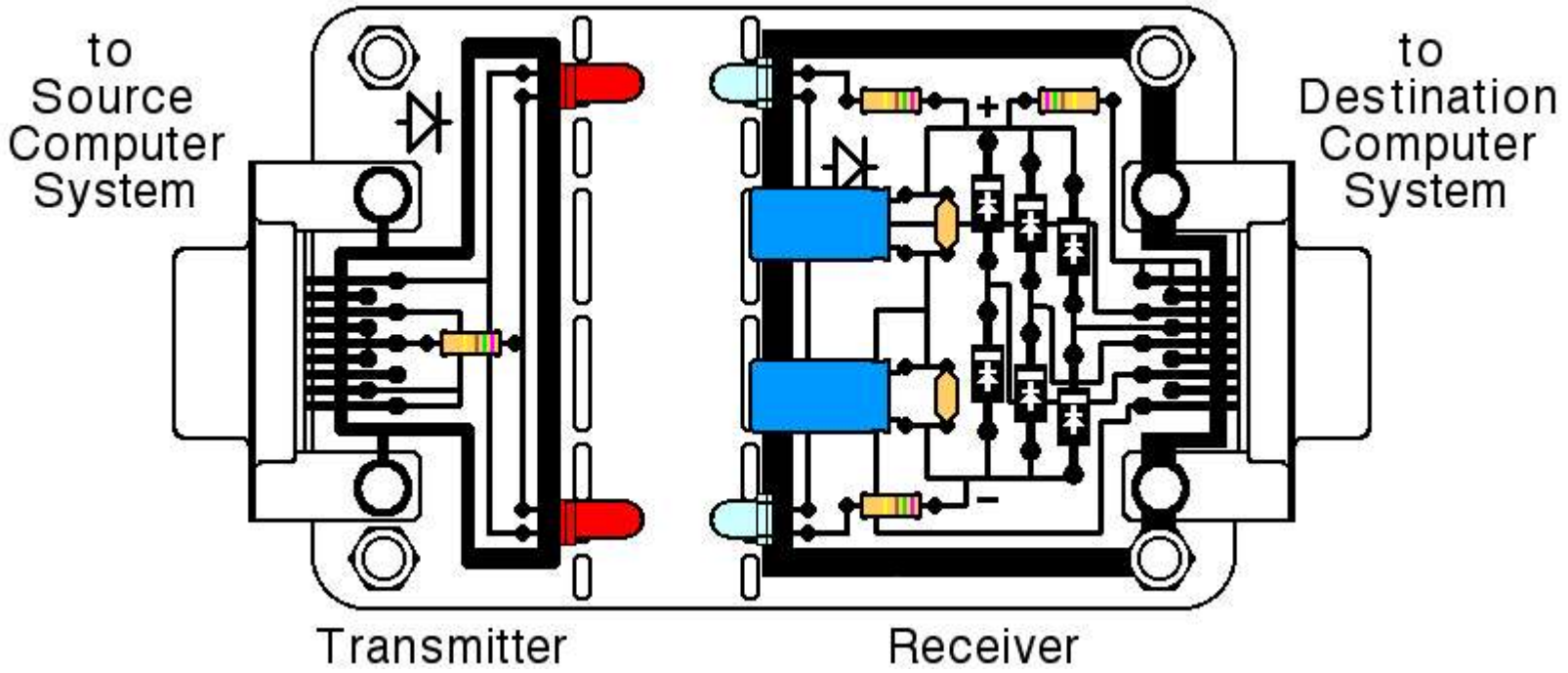
Our Design



- Avoid all black boxes
  - no 3-terminal devices
  - No ICs
- Extreme simplicity
  - Use RS-232



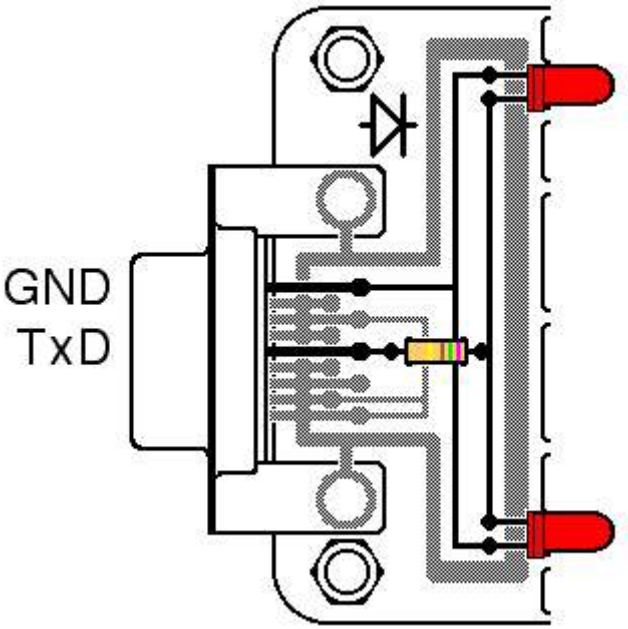
Explaining the circuit board



- Must explain function of
  - Every circuit trace
  - Every component

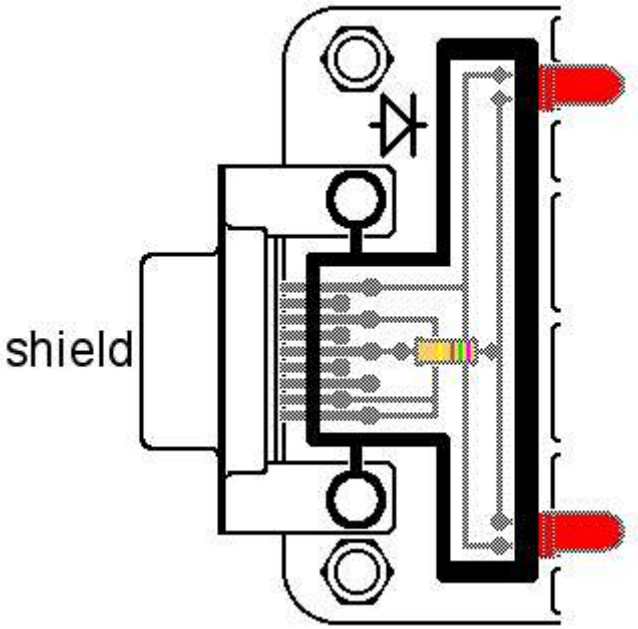
Explaining the Transmitter

- GND: signal ground
- TxD: transmit data
- When TxD is positive
  - Top LED lights
- When TxD is negative
  - Bottom LED lights
- Resistor needed as
  - Current limiter



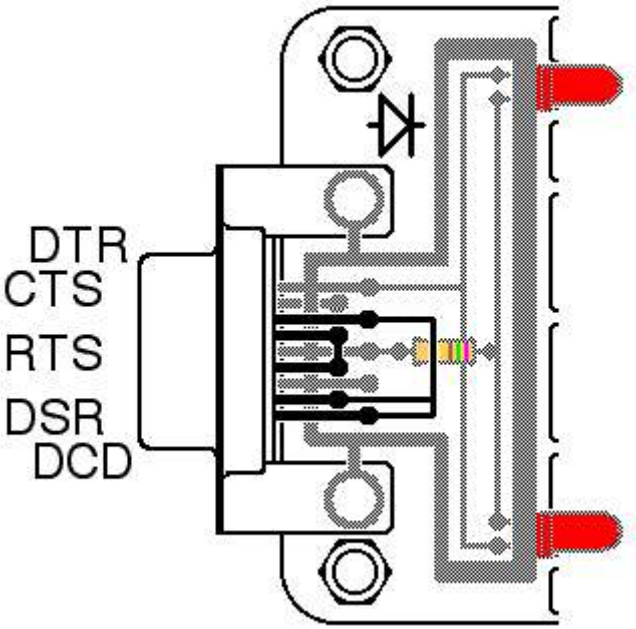
Explaining the Transmitter

- The shield pin in the cable
  - Connects to metallic sheath
- The shield pin on the board
  - Connects to trace that surrounds the electronics
- Together
  - These make it difficult to use conductors inside the shield as radio antennas



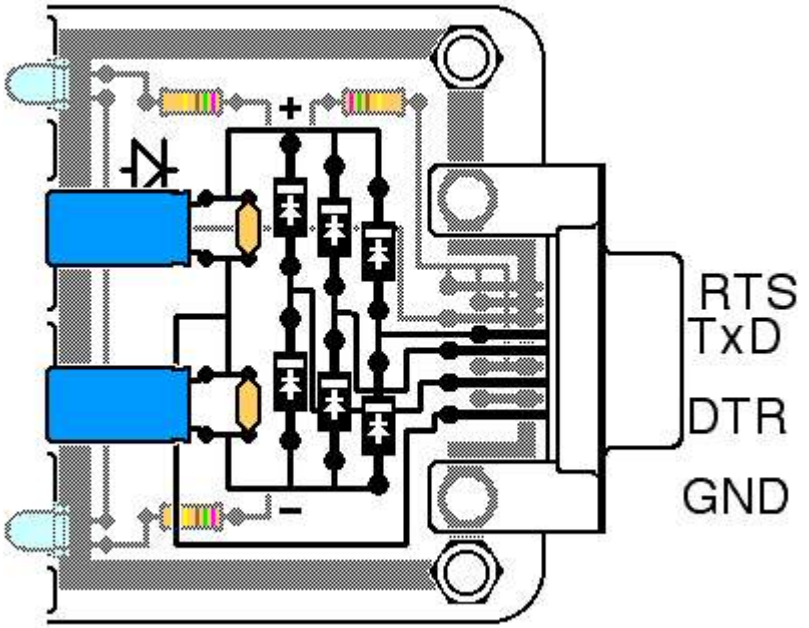
Explaining the Transmitter

- The loopback connections
  - Tell computer we're ready
- RTS to CTS
  - Request To Send (input)
  - Clear To Send (output)
- DTR to DSR and DCD
  - Data Terminal Ready (input)
  - Data Set Ready (output)
  - Data Carrier Detect (output)



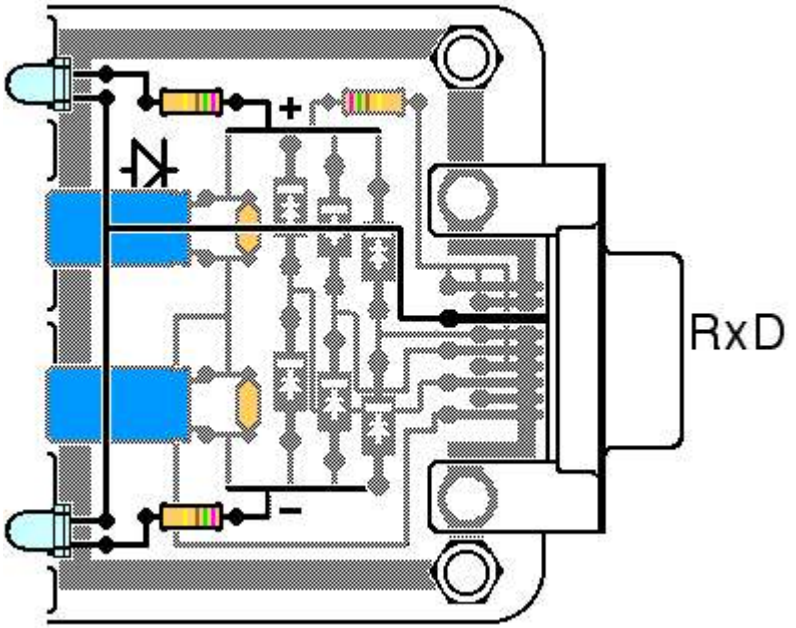
Explaining the Receiver

- The power supply
  - Uses RTS TxD and DTR
- Power from Serial cable
- Power from special cable
  - 2 batteries
  - AC power from wall outlet
- Capacitors and Diodes
  - Permit 60Hz operation



Explaining the Receiver

- The Receiver itself
  - Uses the power supply
  - Transmits to RxD output
- Top photodiode
  - Pulls RxD positive
- Bottom photodiode
  - Pulls RxD negative
- Resistors needed as
  - Current limiters



Using the Data Diode

- No reverse channel (almost)
  - Must rely entirely on forward error correction
  - Checksums (or better) to reject bad data
  - Redundancy to provide for correction
  - Operational status determined from downstream
- Sending from high to low security domain
  - Covert content in data is a big issue
  - Unlike most low to high transmission

Auditors and Wiretaps

- Data exported from EMS is public
- Observers should not trust the web server
- So, observers should be allowed wiretaps
  - Directly observe data-flow to server
  - Directly verify that data conforms to spec
- Free air (as opposed to fiber optic) optical data diodes offer excellent access to the data stream by observers!

Exporting Election Results

Using relational database terminology election results are a single relation over:

- Precinct (or split, for split precincts)
- Race (or contest)
- Candidate (or position with respect to contest)
- Votes for that candidate in that race in that precinct

What we need to do is export this entire relation

OASIS EML, A Bad Idea

- Requires header
  - Data diode invites an infinite stream
- Verbose
  - human audit difficult
- Covert channels
  - Complex rules for canonical form
- Difficult to checksum

```
#-- EML-20081104-US-CA-Santa_Clara_County-2216-1274.xml --#
<?xml version="1.0" encoding="UTF-8"?>
<CastVote xmlns="440-castvote.xsd">
<ElectionEvent>
  <Event>
    <EventName Id="n1274s213">
      Santa Clara County, CA, USA (2008-11-04)
    </EventName>
    <EventQualifier>Precint 2216</EventQualifier>
  </Event>
  <Election>
    <ElectionName>Presidency</ElectionName>
    <Contest>
      <ContestName>President</ContestName>
      <Selection>
        <Option>
          <OptionName>V. I. Lenin</OptionName>
        </Option>
      </Selection>
    </Contest>
  </Election>
  <Election>
    <ElectionName>Presidency</ElectionName>
    <Contest>
      <ContestName>Vice-President</ContestName>
      <Selection>
        <Option>
          <OptionName>Karl Marx</OptionName>
        </Option>
      </Selection>
    </Contest>
  </Election>
  <Election>
    <ElectionName>Senate</ElectionName>
    <Contest>
      <ContestName>Senator</ContestName>
      <Selection>
        <Option>
          <OptionName>William Lloyd Garrison</OptionName>
        </Option>
```

Reasonable Data Formats

- A repeating stream of checksummed records
- Tab separated fields?

```
IC15 President Lincoln 25   16384
CV06 Mayor     Thomas  42   32768
```

- XMLish but not really XML

```
<ITEM PRECINCT="IC15" RACE="President"
CANDIDATE="Lincoln" VOTES="25" />53895

<ITEM PRECINCT="CV06" RACE="mayor"
CANDIDATE="Thomas" VOTES="42" />41274
```

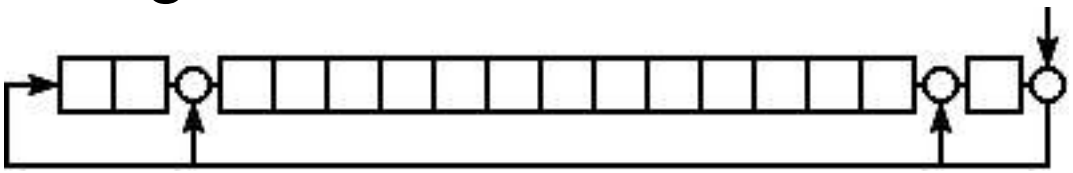
- We opt (on weak grounds) for XMLish

Covert Channels

- The Risk
  - Covert export of security keys from EMS
- The Defense
  - Rigid format constraints on data
    - No optional, permutable, or alternate elements
    - No free use of whitespace or line ends
  - Code audit on real-time checks in transmit code
    - No non-constant time delays allowed in transmitter

Transparent Checksums

- We have a transparent data diode design
- We have a transparent data format
- We need a transparent checksum algorithm
  - Understandable using highschool math
  - Easy to code in a bad programming language
- CRC-16 is not transparent!
  - Try explaining this: $X^{16} + X^{15} + X^2 + 1$
  - Or this:



Transparent Checksums

- A classic transparent but weak checksum
  - $S_0 = 0$; $S_{i+1} = (S_i + C_i) \bmod 256$
- A modest proposal
  - $S_0 = 0$; $S_{i+1} = (5S_i + C_i) \bmod 65536$
  - Akin to multiplicitative congruence PRNG
- What multipliers and moduli are best
- Is there a cryptographically secure hash code that meets our transparency goals?

Code to checksum data stream

```
#include <stdio.h>
/* filter to checksum each block of angle-bracketed text
   Reads from stdin and copies to stdout.
   Appends decimal checksum to each closing angle bracket.
   Angle brackets are included in the checksum.
   NOTE:  This code is dumb, bracket nesting is ignored and
   bracked imbalance is not checked.                          */
main ()
{
        int ch;
        unsigned int sum = 0;
        while ((ch = getchar()) != EOF) {
                putchar( ch );
                sum = (sum * 5 + ch) % 66636; /*accumulate*/
                if (ch == '<') {
                        sum = '<';            /*initialize*/
                } else if (ch == '>') {
                        printf("%1u",sum);
}       }       }
```

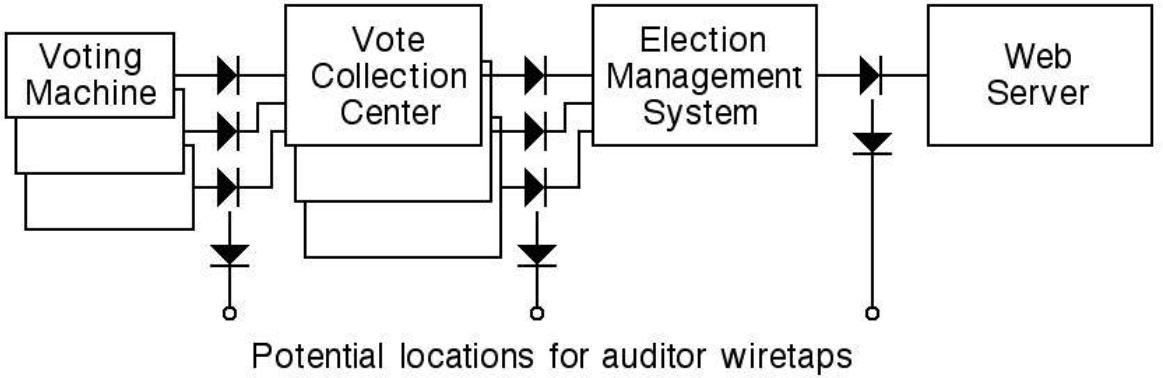
Even this is hard to explain, but it's in reach of a student who only has a semester of programming, perhaps in VB or worse

A Prototype Application

- Scaffolding
  - Extract results from example county data
  - Inject in model EMS database
- Demo code
  - Cyclically scan EMS database
  - Export through data diode
- Decent quality prototype application code
  - Receive data from data diode to mirror database
  - Server-side web application for results

Other Applications

- Upstream



- In voting machine