Noise Isolation: Keeping the Gremlins Out!

Gabriel Hugh Elkaim
Fall 2015
How noise gets into your circuits

Figure 1-11. Before noise can be a problem, there must be a noise source, a receptor that is susceptible to the noise, and a coupling channel that transmits the noise to the receptor.
Key Characteristics of the noise source

• Voltage
  - high voltage
  - $\frac{dV}{dt}$
  - Strong electric field - capacitance coupling

• Current
  - high current
  - Strong magnetic field - inductance coupling

• Frequency
  - High Frequency
  - Radiation/Radiation Conducted
  $0 \leq \text{Distance} \leq \text{wavelength}$

• Distance from the victim
  - $= \Phi$
  - Direct contact conductive coupling
What is the most likely coupling mechanism for:

- Florescent Light noise
  - 1000s of volts, capacitive coupling

- Arc Welding Noise
  - Inductive - High current 100s of Amps

- Digital Clock Noise
  - Capacitive noise
  \[ \frac{dv}{dt} = 80 \text{ Volts/second} \]
Conductive coupling (1.2)

Diagram showing conductive coupling with a power supply, common line impedances, a motor, and a sensor.
Conductive coupling (2.2)

+12V

CIRCUIT 1

GROUND VOLTAGE CIRCUIT 1

GROUND CURRENT 1

GROUND CURRENT 2

COMMON GROUND IMPEDANCE

GROUND VOLTAGE CIRCUIT 2

+5V
How should I wire these up?

(1) Avoid ground loops

(2) Low resistance path to ground
Which waveform **must** be conductively coupled?

Why?

1

2

DC component

DC ≠ φ
Identifying Characteristics of Conductive Coupling

1) Metallic contact is required
2) Unaffected by people or cable movement
3) Non-zero DC value on its waveform

Break the conductive contact
- Restore wires (power/ground) back to battery
- Use a strong beam
Capacitively coupled noise

Coupling capacitance

Simplified circuit
Physical Representation of capacitively coupled noise

[Diagram of a circuit with labeled components: noise source, conductors, and capacitances.]
Equivalent circuit for capacitively coupled noise

\[ V_N = \frac{j\omega[C_{12} / (C_{12} + C_{2G})]}{j\omega + 1 / R(C_{12} + C_{2G})} V_1 \]

If \( R \gg \frac{1}{j\omega(C_{12} + C_{2G})} \)

\[ V_N = \frac{C_{12}}{(C_{12} + C_{2G})} V_1 \]

If \( R \ll \frac{1}{j\omega(C_{12} + C_{2G})} \)

\[ V_N = j\omega RC_{12} V_1 \]
Reducing Capacitively Coupled Noise

Position shield do intercept noise
Summary of capacitive noise reduction techniques

1. Reduce capacitive coupling

2. Use a shield, ground only one side

3. Reduce circuit impedance
Isolation

Split my circuits so there are no common paths.
Isolation via magnetic coupling
PCB mount miniature relays
Reed Relay construction

Axial leads allow various mounting configurations.

Nickel plated steel jacket provides magnetic shields.

Coil windings on reed switch for increased electrical efficiencies.

Ends epoxy sealed to provide environmental protection.

End flange for coil winding retainer.
Optical Isolation
**GENERAL PURPOSE 6-PIN PHOTOTRANSISTOR OPTOCOUPLERS**

<table>
<thead>
<tr>
<th></th>
<th>4N25</th>
<th>4N26</th>
<th>4N27</th>
<th>4N28</th>
<th>4N35</th>
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<tr>
<td></td>
<td>H11A1</td>
<td>H11A2</td>
<td>H11A3</td>
<td>H11A4</td>
<td>H11A5</td>
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</tr>
</tbody>
</table>

**WHITE PACKAGE (-M SUFFIX)**

![White Package Diagram]

**BLACK PACKAGE (NO -M SUFFIX)**

![Black Package Diagram]

**SCHEMATIC**

PIN 1. ANODE  
2. CATHODE  
3. NO CONNECTION  
4. EMITTER  
5. COLLECTOR  
6. BASE
# Electrical Characteristics

$T_A = 25^\circ C$ unless otherwise specified

## Individual Component Characteristics

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Test Conditions</th>
<th>Symbol</th>
<th>Min</th>
<th>Typ*</th>
<th>Max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Emitter</strong></td>
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<tr>
<td>Input Forward Voltage</td>
<td>($I_F = 10 \text{ mA}$)</td>
<td>$V_F$</td>
<td>1.18</td>
<td>1.50</td>
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<td>V</td>
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<tr>
<td>Reverse Leakage Current</td>
<td>($V_R = 6.0 \text{ V}$)</td>
<td>$I_R$</td>
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<td><strong>Detector</strong></td>
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<tr>
<td>Collector-Emitter Breakdown Voltage</td>
<td>($I_C = 1.0 \text{ mA}$, $I_F = 0$)</td>
<td>$BV_{CEO}$</td>
<td>30</td>
<td>100</td>
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<td>V</td>
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<tr>
<td>Collector-Base Breakdown Voltage</td>
<td>($I_C = 100 \text{ $\mu$A}$, $I_F = 0$)</td>
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<tr>
<td>Emitter-Collector Breakdown Voltage</td>
<td>($I_E = 100 \text{ $\mu$A}$, $I_F = 0$)</td>
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<td>Collector-Emitter Dark Current</td>
<td>($V_{CE} = 10 \text{ V}$, $I_F = 0$)</td>
<td>$I_{CEO}$</td>
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<td>($V_{CB} = 10 \text{ V}$)</td>
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<td>Capacitance</td>
<td>($V_{CE} = 0 \text{ V}$, $f = 1 \text{ MHz}$)</td>
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<td>pF</td>
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<td>DC Characteristic</td>
<td>Test Conditions</td>
<td>Symbol</td>
<td>Device</td>
<td>Min</td>
<td>Typ*</td>
<td>Max</td>
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<td>4N37</td>
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</table>

*Current Transfer Ratio, Collector to Emitter*
<table>
<thead>
<tr>
<th>Collector-Emitter Saturation Voltage</th>
<th>( V_{CE,\text{SAT}} )</th>
<th>( I_C )</th>
<th>( I_F )</th>
<th>( V )</th>
</tr>
</thead>
<tbody>
<tr>
<td>((I_C = 2 , \text{mA}, , I_F = 50 , \text{mA}))</td>
<td>4N25, 4N26, 4N27, 4N28</td>
<td>0.5</td>
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<td></td>
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<tr>
<td>((I_C = 0.5 , \text{mA}, , I_F = 10 , \text{mA}))</td>
<td>4N35, 4N36, 4N37</td>
<td>0.3</td>
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</tbody>
</table>

| AC Characteristic | \( T_{ON} \) | \( I_F = 10 \, \text{mA}, \, V_{CC} = 10 \, \text{V}, \, R_L = 100\Omega \) (Fig.20) | \( H11A1, \, H11A2, \, H11A3, \, H11A4, \, H11A5 \) | 2 | \( \mu s \) |

| Non-Saturated Turn-on Time | \( T_{ON} \) | \( I_C = 2 \, \text{mA}, \, V_{CC} = 10 \, \text{V}, \, R_L = 100\Omega \) (Fig.20) | \( 4N35, \, 4N36, \, 4N37 \) | 2 | 10 | \( \mu s \) |
AC INPUT/PHOTOTRANSISTOR OPTOCOUPLERS

DESCRIPTION
The H11AAX series consists of two gallium-arsenide infrared emitting diodes connected in inverse parallel driving a single silicon phototransistor output.

FEATURES
- Bi-polar emitter input
- Built-in reverse polarity input protection
- Underwriters Laboratory (UL) recognized — File #E90700
- VDE approved — File #E94766 (ordering option ‘300’)

APPLICATIONS
- AC line monitor
- Unknown polarity DC sensor
- Telephone line interface

CMPE 118/218 – Intro. to Mechatronics
PHOTODARLINGTON OPTOCOUPLERS

DESCRIPTION
The CNX48U, H11BX, MOC8080 and TIL113 have a gallium arsenide infrared emitter optically coupled to a silicon planar photodarlington.

FEATURES
- High sensitivity to low input drive current
- Meets or exceeds all JEDEC Registered Specifications
- VDE 0884 approval available as a test option
  - add option .300. (e.g., H11B1.300)

APPLICATIONS
- Low power logic circuits
- Telecommunications equipment
- Portable electronics
- Solid state relays
- Interfacing coupling systems of different potentials and impedances.
### AC Characteristics

<table>
<thead>
<tr>
<th>Switching Times</th>
<th>$t_{on}$</th>
<th>$t_{off}$</th>
<th>$t_{on}$</th>
<th>$t_{off}$</th>
<th>$t_{on}$</th>
<th>$t_{off}$</th>
<th>$t_{on}$</th>
<th>$t_{off}$</th>
<th>$t_{on}$</th>
<th>$t_{off}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>($I_C = 10$ mA, $V_{CE} = 10$ V) ($R_L = 100$ $\Omega$) (Fig.7)</td>
<td>H11B1</td>
<td>H11B2</td>
<td>H11B255</td>
<td>H11B3</td>
<td>25</td>
<td>18</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>($I_F = 10$ mA, $V_{CC} = 5$ V) ($R_E = 100$ $\Omega$), ($R_{BE} = 1M\Omega$) (Fig. 8)</td>
<td>$t_{on}$</td>
<td>$t_{off}$</td>
<td>CNX48U</td>
<td></td>
<td>3.5</td>
<td>36</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>($I_F = 1$ mA, $V_{CC} = 5$ V) ($R_E = 1k\Omega$), ($R_{BE} = 10M\Omega$) (Fig. 8)</td>
<td>$t_{on}$</td>
<td>$t_{off}$</td>
<td>MOC8080</td>
<td></td>
<td>70</td>
<td>190</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>($I_F = 5$ mA, $V_{CC} = 10$ V) ($R_L = 100$ $\Omega$) (Fig.7)</td>
<td>$t_{on}$</td>
<td>$t_{off}$</td>
<td>TIL113</td>
<td></td>
<td>3.5</td>
<td>25</td>
<td></td>
<td></td>
<td></td>
<td>0.35</td>
</tr>
<tr>
<td>($I_F = 200$ mA, $I_C = 50$ mA) ($V_{CC} = 10$ V) ($R_L = 100$ $\Omega$) (Fig.7)</td>
<td>$t_{on}$</td>
<td>$t_{off}$</td>
<td></td>
<td></td>
<td>0.35</td>
<td>5</td>
<td>100</td>
<td></td>
<td></td>
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</tbody>
</table>
6-Pin DIP Optoisolators

Logic Output

The H11L1 and H11L2 have a gallium arsenide IRED optically coupled to a high-speed integrated detector with Schmitt trigger output. Designed for applications requiring electrical isolation, fast response time, noise immunity and digital logic compatibility.

- Guaranteed Switching Times — \( t_{\text{on}}, t_{\text{off}} < 4 \, \mu s \)
- Built-in On/Off Threshold Hysteresis
- High Data Rate, 1 MHz Typical (NRZ)
- Wide Supply Voltage Capability
- Microprocessor Compatible Drive
- *To order devices that are tested and marked per VDE 0884 requirements, the suffix "V" must be included at end of part number. VDE 0884 is a test option.*

Applications

- Interfacing Computer Terminals to Peripheral Equipment
- Digital Control of Power Supplies
- Line Receiver — Eliminates Noise
- Digital Control of Motors and Other Servo Machine Applications
- Logic to Logic Isolator
- Logic Level Shifter — Couples TTL to CMOS

MAXIMUM RATINGS (\( T_A = 25^\circ C \) unless otherwise noted)
# H11L1 H11L2

## ELECTRICAL CHARACTERISTICS ($T_A = 25^\circ C$ unless otherwise noted)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Symbol</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>INPUT LED</strong></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Reverse Leakage Current ($V_R = 3 \text{ V}, R_L = 1 \text{ M\Omega}$)</td>
<td>$I_R$</td>
<td>—</td>
<td>0.05</td>
<td>10</td>
<td>$\mu\text{A}$</td>
</tr>
<tr>
<td>Forward Voltage ($I_F = 10 \text{ mA}$)</td>
<td>$V_F$</td>
<td>0.75</td>
<td>1.2</td>
<td>1.5</td>
<td>Volts</td>
</tr>
<tr>
<td>($I_F = 0.3 \text{ mA}$)</td>
<td></td>
<td>0.95</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capacitance ($V_R = 0 \text{ V}, f = 1 \text{ MHz}$)</td>
<td>$C$</td>
<td>—</td>
<td>18</td>
<td>—</td>
<td>pF</td>
</tr>
<tr>
<td><strong>OUTPUT DETECTOR</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operating Voltage</td>
<td>$V_{CC}$</td>
<td>—</td>
<td>3</td>
<td>15</td>
<td>Volts</td>
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<tr>
<td>Supply Current ($I_F = 0, V_{CC} = 5 \text{ V}$)</td>
<td>$I_{CC,(\text{off})}$</td>
<td>—</td>
<td>1</td>
<td>5</td>
<td>mA</td>
</tr>
<tr>
<td>Output Current, High ($I_F = 0, V_{CC} = V_O = 15 \text{ V}$)</td>
<td>$I_{OH}$</td>
<td>—</td>
<td>100</td>
<td>—</td>
<td>$\mu\text{A}$</td>
</tr>
<tr>
<td><strong>COUPLED</strong></td>
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<td></td>
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<tr>
<td>Supply Current ($I_F = I_F,(\text{on}), V_{CC} = 5 \text{ V}$)</td>
<td>$I_{CC,(\text{on})}$</td>
<td>—</td>
<td>1.6</td>
<td>5</td>
<td>mA</td>
</tr>
<tr>
<td>Output Voltage, Low ($R_L = 270 \text{ \Omega}, V_{CC} = 5 \text{ V}, I_F = I_F,(\text{on})$)</td>
<td>$V_{OL}$</td>
<td>—</td>
<td>0.2</td>
<td>0.4</td>
<td>Volts</td>
</tr>
<tr>
<td>Threshold Current, ON ($R_L = 270 \text{ \Omega}, V_{CC} = 5 \text{ V}$)</td>
<td>$I_F,(\text{on})$</td>
<td>—</td>
<td>1.2</td>
<td>1.6</td>
<td>mA</td>
</tr>
<tr>
<td>($R_L = 270 \text{ \Omega}, V_{CC} = 5 \text{ V}$)</td>
<td>$H11L1$</td>
<td>—</td>
<td>—</td>
<td>10</td>
<td>mA</td>
</tr>
</tbody>
</table>

| Threshold Current, OFF ($R_L = 270 \text{ \Omega}, V_{CC} = 5 \text{ V}$) | $I_F\,(\text{off})$ | 0.3 | 0.75 | —   | mA   |
| ($R_L = 270 \text{ \Omega}, V_{CC} = 5 \text{ V}$) | $H11L2$ | 0.3 | — | — | mA |

| Hysteresis Ratio ($R_L = 270 \text{ \Omega}, V_{CC} = 5 \text{ V}$) | $I_F\,(\text{off})$ | 0.5 | 0.75 | 0.9 | mA |
| ($R_L = 270 \text{ \Omega}, V_{CC} = 5 \text{ V}$) | $I_F\,(\text{on})$ | 0.3 | — | — | mA |
| Isolation Voltage ($V_{ISO}$) ($2^\text{nd}$ 60 Hz, AC Peak, 1 second, $T_A = 25^\circ C$) | $7500$ | — | — | — | Vac(pk) |
| Turn–On Time ($R_L = 270 \text{ \Omega}$) | $t_{on}$ | — | 1.2 | 4 | $\mu\text{s}$ |
| Fall Time ($R_L = 270 \text{ \Omega}$) | $t_f$ | — | 0.1 | — |      |
| Turn–Off Time ($R_L = 270 \text{ \Omega}$) | $t_{off}$ | — | 1.2 | 4 |      |
| Rise Time ($R_L = 270 \text{ \Omega}$) | $t_r$ | — | 0.1 | — |      |

---

1. Always design to the specified minimum/maximum electrical limits (where applicable).
2. For this test, IRED Pins 1 and 2 are common and Output Gate Pins 4, 5, 6 are common.
3. $R_L$ value effect on switching time is negligible.
Create a design to connect

+3.3

UNO 32

PS 2501
Opto-Isolator

V_{BATT}

SSK4

H-Bridge
Questions?
Announcements

(1) T- Sharks

(2) Parker Vulnerable (Train Wreck)

(3) Midterm grades — Tuesday

(4) Field is up — Robotics still need work
   Nothing so bad on Field. $1/penny talks

(5) Beer Challenge — 5-6 pm on Tuesday