Noise Isolation
Keeping the Gremlins Out!

Cyrus Bazeghi
Winter 2010
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, electric field
  - \( J = \frac{\text{d}V}{\text{d}t} \)

- Current
  - High Current, magnetic field
  - \( \text{Inductive coupling} \)

- Frequency
  - High Frequency
  - \( \text{Radiation} \)
  - \( \text{R.F. coupling} \)

- Distance from the victim
  - \( 0 < \text{Distance Chip length} \)
  - \( \text{R.F. coupling} \)
  - \( 0 = \text{Distance, direct contact} \)
  - \( \text{Conductive direct coupling} \)
What is the most likely coupling mechanism for:

- Florescent Light noise
  - High $\frac{du}{dt}$ “Capacitive Coupling”

- Arc Welding Noise
  - High current 100s of Amps
    “Inductive Coupling”

- Digital Clock Noise
  - Low $\frac{du}{dt}$ “Capacitive Coupling”
Conductive coupling (1.2)

Diagram:
- POWER SUPPLY
- COMMON LINE IMPEDANCES
- SOURCE IMPEDANCE
- Motor
- Sensor

Equation:
\[ i_1 + i_2 \]
Conductive coupling (2.2)

+12V

CIRCUIT 1

GROUND VOLTAGE CIRCUIT 1

GROUND CURRENT 1

GROUND IMPEDANCE

COMMON GROUND

+5V

CIRCUIT 2

GROUND CURRENT 2

GROUND VOLTAGE CIRCUIT 2

Sensor
How should I wire these up?

HC12

Motor

Sensor

5V

12V
Avoid Ground Loops

HC12

5V

+ G

Sensor

Motor

12V

+ G

Am Ant
Which waveform **must** be conductively coupled?

Why?
Identifying Characteristics of Conductive Coupling

- Metallic contact is required
- Unaffected by people or cable movement
- Non-zero average value for waveform

Break contact
- Separate wires back to power supply
- Use filtering

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Capacitively coupled noise

Simplified circuit

Coupling capacitance

NOISE VOLTAGE SOURCE

V

C

Z

SIGNAL CIRCUIT IMPEDANCE

Coupling capacitance

Simplified circuit
Physical Representation of capacitively coupled noise
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 \( R >> \frac{1}{j \omega (C_{12} + C_{2G})} \)

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

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

\[ V_N = j \omega R C_{12} V_1 \]
Reducing Capacitively Coupled Noise
Summary of capacitive noise reduction techniques

1) Reduce capacitive noise by:
   1) Reduce capacitive coupling
   2) Increase circuit impedance
   3) Use shielding
      - Proper shield location
      - i.e. signals
      - Connect shield to ground in one place only
Isolation

Why do we need it?
- Conductive noise
- Large voltage differentials
- Fault isolation
- Minimize leakage currents

How do we do it?
- Optical
- Magnetic
Isolation via magnetic coupling

Diagram of magnetic coupling system:
- **Input Current ($i_1$)**: Input current to the armature coil.
- **Armature**: The movable part of the device connected to the input current.
- **Spring**: A spring mechanism that helps in isolating the system.
- **Contact**: A contact mechanism that is electrically isolated from the armature.
- **Coil**: The coil where the output current ($i_2$) is generated.
- **Core**: The core of the coil which is electrically and magnetically isolated from the armature.

Note: The diagram shows a mechanism where the input is electrically not connected to the armature, resembling a mechanical isolation method.
PCB mount miniature relays

[Images of PCB mount miniature relays]
Reed Relay construction

- **Axial leads** allow various mounting configurations.
- **Ends** epoxy sealed to provide environmental protection.
- **End flange** for coil winding retainer.
- **Coil windings** on reed switch for increased electrical efficiencies.
- **Nickel plated steel jacket** provides magnetic shields.
Optical Isolation

- No contact
- No common
- No level difference
- Don't near cut
# FAIRCHILD SEMICONDUCTOR

## GENERAL PURPOSE 6-PIN PHOTOTRANSISTOR OPTOCOUPLEERS

<table>
<thead>
<tr>
<th></th>
<th>4N25</th>
<th>4N26</th>
<th>4N27</th>
<th>4N28</th>
<th>4N35</th>
<th>4N36</th>
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<tbody>
<tr>
<td>Package</td>
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</tr>
<tr>
<td>WHITE</td>
<td>4N37</td>
<td>H11A1</td>
<td>H11A2</td>
<td>H11A3</td>
<td>H11A4</td>
<td>H11A5</td>
</tr>
<tr>
<td>BLACK</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

### WHITE PACKAGE (-M SUFFIX)

![White Package Diagram]

### BLACK PACKAGE (NO -M SUFFIX)

![Black Package Diagram]

### SCHEMATIC

- **PIN 1**: ANODE
- **PIN 2**: CATHODE
- **PIN 3**: NO CONNECTION
- **PIN 4**: EMITTER
- **PIN 5**: COLLECTOR
- **PIN 6**: BASE

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### ELECTRICAL CHARACTERISTICS ($T_A = 25^\circ\text{C unless otherwise specified}$)

### 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>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<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>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Reverse Leakage Current</td>
<td>($V_R = 6.0 \text{ V}$)</td>
<td>$I_R$</td>
<td>0.001</td>
<td>10</td>
<td>$\mu\text{A}$</td>
<td></td>
</tr>
<tr>
<td><strong>DETECTOR</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<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>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Collector-Base Breakdown Voltage</td>
<td>($I_C = 100 \text{ $\mu$A}, I_F = 0$)</td>
<td>$BV_{CBO}$</td>
<td>70</td>
<td>120</td>
<td>V</td>
<td></td>
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<tr>
<td>Emitter-Collector Breakdown Voltage</td>
<td>($I_E = 100 \text{ $\mu$A}, I_F = 0$)</td>
<td>$BV_{EBO}$</td>
<td>7</td>
<td>10</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Collector-Emitter Dark Current</td>
<td>($V_{CE} = 10 \text{ V}, I_F = 0$)</td>
<td>$I_{CEO}$</td>
<td>1</td>
<td>50</td>
<td>$\text{nA}$</td>
<td></td>
</tr>
<tr>
<td>Collector-Base Dark Current</td>
<td>($V_{CB} = 10 \text{ V}$)</td>
<td>$I_{CBO}$</td>
<td>20</td>
<td>nA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capacitance</td>
<td>($V_{CE} = 0 \text{ V}, f = 1 \text{ MHz}$)</td>
<td>$C_{CE}$</td>
<td>8</td>
<td></td>
<td></td>
<td>$\text{pF}$</td>
</tr>
</tbody>
</table>

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## Transfer Characteristics

\( (T_A = 25^\circ C \text{ Unless otherwise specified.}) \)

<table>
<thead>
<tr>
<th>DC Characteristic</th>
<th>Test Conditions</th>
<th>Symbol</th>
<th>Device</th>
<th>Min</th>
<th>Typ*</th>
<th>Max</th>
<th>Unit</th>
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<td>4N35</td>
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<td>4N36</td>
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<td>4N37</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>((I_F = 10 \text{ mA, } V_{CE} = 10 \text{ V}))</td>
<td>H11A1</td>
<td>50</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>H11A5</td>
<td>30</td>
<td></td>
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</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4N25</td>
<td>20</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>4N26</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4N27</td>
<td></td>
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</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4N28</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>H11A2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>H11A3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>((I_F = 10 \text{ mA, } V_{CE} = 10 \text{ V, } T_A = -55^\circ C))</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>((I_F = 10 \text{ mA, } V_{CE} = 10 \text{ V, } T_A = +100^\circ C))</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Current Transfer Ratio, Collector to Emitter

\( \% \)
<table>
<thead>
<tr>
<th>Collector-Emitter Saturation Voltage</th>
<th>( V_{CE(SAT)} )</th>
<th>4N25</th>
<th>4N26</th>
<th>4N27</th>
<th>4N28</th>
<th>( V )</th>
<th>0.3</th>
<th>0.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>( I_C = 0.5 \text{ mA}, I_F = 10 \text{ mA} )</td>
<td></td>
<td>4N35</td>
<td>4N36</td>
<td>4N37</td>
<td>H11A1</td>
<td>H11A2</td>
<td>0.4</td>
<td></td>
</tr>
<tr>
<td>( I_C = 2 \text{ mA}, I_F = 50 \text{ mA} )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>H11A3</td>
<td>H11A4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AC Characteristic</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>H11A5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-Saturated Turn-on Time</td>
<td>( T_{ON} )</td>
<td>4N25</td>
<td>4N26</td>
<td>4N27</td>
<td>4N28</td>
<td>H11A1</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>( I_F = 10 \text{ mA}, V_{CC} = 10 \text{ V}, R_L = 100 \Omega ) (Fig.20)</td>
<td></td>
<td>H11A2</td>
<td>H11A3</td>
<td>H11A4</td>
<td>H11A5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-Saturated Turn-on Time</td>
<td>( T_{ON} )</td>
<td>4N35</td>
<td>4N36</td>
<td>4N37</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# AC INPUT/PHTOTRANSISTOR OPTOCOUPLERS

<table>
<thead>
<tr>
<th>H11AA1</th>
<th>H11AA3</th>
<th>H11AA2</th>
<th>H11AA4</th>
</tr>
</thead>
</table>

## 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

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Schematic of the optocoupler showing connections and symbols.

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- Switch replacement
- Inexpensive to polarity
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.

Higher current transfer ratio (CTR) ~ 100%
### AC Characteristics

<table>
<thead>
<tr>
<th>Conditions</th>
<th>$t_{on}$</th>
<th>$t_{off}$</th>
<th>$H11B1$</th>
<th>$H11B2$</th>
<th>$H11B255$</th>
<th>$H11B3$</th>
<th>$\mu s$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$(I_C = 10 \text{ mA}, V_{CE} = 10 \text{ V})$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>25</td>
</tr>
<tr>
<td>$(R_L = 100 \Omega)$ (Fig.7)</td>
<td>$t_{on}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$t_{off}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>18</td>
</tr>
<tr>
<td>$(I_F = 10 \text{ mA}, V_{CC} = 5 \text{ V})$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.5</td>
</tr>
<tr>
<td>$(R_E = 100 \Omega), (R_{BE} = 1M\Omega)$</td>
<td>$t_{on}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Fig. 8)</td>
<td>$t_{off}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>36</td>
</tr>
<tr>
<td>$(I_F = 1 \text{ mA}, V_{CC} = 5 \text{ V})$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>70</td>
</tr>
<tr>
<td>$(R_E = 1k\Omega), (R_{BE} = 10M\Omega)$</td>
<td>$t_{on}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Fig. 8)</td>
<td>$t_{off}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>190</td>
</tr>
<tr>
<td>$(I_F = 5 \text{ mA}, V_{CC} = 10 \text{ V})$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.5</td>
</tr>
<tr>
<td>$(R_L = 100 \Omega)$ (Fig.7)</td>
<td>$t_{on}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$t_{off}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>25</td>
</tr>
<tr>
<td>$(I_F = 200 \text{ mA}, I_C = 50 \text{ mA})$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.35</td>
</tr>
<tr>
<td>$(V_{CC} = 10 \text{ V}) (R_L = 100 \Omega)$</td>
<td>$t_{on}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>(Fig.7)</td>
<td>$t_{off}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>55</td>
</tr>
</tbody>
</table>

### Switching Times

- **Input Signal**: 2.5 $\mu s$
- **Output Signal**: 16 $\mu s$
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 — $t_{on}, t_{off} < 4 \mu s$
- 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)
### ELECTRICAL CHARACTERISTICS (\(T_A = 25^\circ C\) unless otherwise noted)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Symbol</th>
<th>Min</th>
<th>Typ(^{(1)})</th>
<th>Max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>INPUT LED</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reverse Leakage Current ((V_R = 3) (V), (R_L = 1) (M\Omega))</td>
<td>(I_R)</td>
<td>—</td>
<td>0.05</td>
<td>10</td>
<td>(\mu A)</td>
</tr>
<tr>
<td>Forward Voltage ((I_F = 10) (mA)) (&lt;) (I_F = 0.3) (mA))</td>
<td>(V_F)</td>
<td>0.75</td>
<td>0.95</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Capacitance ((V_R = 0) (V), (f = 1) MHz)</td>
<td>(C)</td>
<td>—</td>
<td>18</td>
<td>—</td>
<td>(pF)</td>
</tr>
<tr>
<td><strong>OUTPUT DETECTOR</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operating Voltage</td>
<td>(V_{CC})</td>
<td>3</td>
<td>—</td>
<td>15</td>
<td>(Volts)</td>
</tr>
<tr>
<td>Supply Current ((I_F = 0), (V_{CC} = 5) (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) (V))</td>
<td>(I_{OH})</td>
<td>—</td>
<td>—</td>
<td>100</td>
<td>(\mu A)</td>
</tr>
<tr>
<td><strong>COUPLED</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supply Current ((I_F(\text{on})), (V_{CC} = 5) (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) (\Omega), (V_{CC} = 5) (V))</td>
<td>(V_{OL})</td>
<td>—</td>
<td>0.2</td>
<td>0.4</td>
<td>(Volts)</td>
</tr>
<tr>
<td>Threshold Current, ON (&lt;) (H11L1), (H11L2)  (R_L = 270) (\Omega), (V_{CC} = 5) (V))</td>
<td>(I_{F(\text{on})})</td>
<td>—</td>
<td>1.2</td>
<td>1.6</td>
<td>(mA)</td>
</tr>
<tr>
<td>Threshold Current, OFF (&lt;) (H11L1), (H11L2) (R_L = 270) (\Omega), (V_{CC} = 5) (V))</td>
<td>(I_{F(\text{off})})</td>
<td>0.3</td>
<td>0.75</td>
<td>—</td>
<td>(mA)</td>
</tr>
<tr>
<td>Hysteresis Ratio ((R_L = 270) (\Omega), (V_{CC} = 5) (V))</td>
<td>(\frac{I_{F(\text{off})}}{I_{F(\text{on})}})</td>
<td>0.5</td>
<td>0.75</td>
<td>0.9</td>
<td>—</td>
</tr>
<tr>
<td>Isolation Voltage(^{(2)}) 60 Hz, AC Peak, 1 second, (T_A = 25^\circ C)</td>
<td>(V_{ISO})</td>
<td>7500</td>
<td>—</td>
<td>—</td>
<td>(Vac(pk))</td>
</tr>
<tr>
<td>Turn–On Time (&lt;) (R_L = 270) (\Omega) (R_L = 270) (\Omega) (V_{CC} = 5) (V), (V_{CC} = 5) (V), (I_F = I_F(\text{on}))</td>
<td>(t_{on})</td>
<td>—</td>
<td>1.2</td>
<td>4</td>
<td>(\mu s)</td>
</tr>
<tr>
<td>Fall Time (&lt;) (V_{CC} = 5) (V), (I_F = I_F(\text{on}))</td>
<td>(t_f)</td>
<td>—</td>
<td>0.1</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Turn–Off Time (&lt;) (I_F = I_F(\text{on})) (&lt;) (T_A = 25^\circ C)</td>
<td>(t_{off})</td>
<td>—</td>
<td>1.2</td>
<td>4</td>
<td>—</td>
</tr>
<tr>
<td>Rise Time (&lt;) (I_F = I_F(\text{on})) (&lt;) (T_A = 25^\circ C)</td>
<td>(t_r)</td>
<td>—</td>
<td>0.1</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

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

HC12

PS2501 Opto-Isolator

L-298 H-Bridge
Voltage Regulator

2805 5V Regulator

\[ U_{out} = 5V \]

\begin{align*}
&\text{if} U_{in} \geq U_{max} \\
&U_{in} < U_{max}
\end{align*}

5V

12V input ~ 5% 
12V output 
200mA 
\( P = (2 \times 1.2) = 1.44 \)
Questions?