LOW AIR PRESSURE REGULATOR

A thesis submitted to the
Faculty of the Electrical Engineering Technology Program
Of the University of Cincinnati
in partial fulfillment of the
requirements for the degree of

Bachelor of Science

in Electrical Engineering Technology
at the College of Engineering & Applied Science

by

DUNG NGUYEN

Bachelor of Science University of Cincinnati

May 2011

Faculty Advisor: MAX RABIEE
Introduction

During my career at L-3 Fuzing and Ordnance Systems, I have built the low air pressure regulator tester which is used to simulate one of the environments for our product. By manually adjust the pressure valve; the high air pressure from the main line is reduced from 120 psi to a range from 0 to 2.5 psi, with a resolution of .0046 psi per degree (15 turn’s resolution of the valve). Then the output pressure is connected to a pressure calibrator to monitor current pressure, also connected to a pressure sensor which converts from the pressure to voltage ranges from 0 to 4.5 vdc that use for environment sensing. After built and tested the pressure box, I found some areas can be improved to make it easier for our current and future testing. I decided to automate the pressure box and make it as my senior design project. This report summarizes the works that have been done for the Low Air Pressure Regulator project.

Acknowledgment

I would like to thanks to Professor Max Rabiee for being my advisor, and Professor Zhou Zuefu who directs me through series of senior design classes, also to Professors at CAES who have been shared their great experiences with me.

I would like to thanks to my co-worker at L-3 Fuzing and Ordnance System for their supporting and encouragement. To my wife and family who support my interest.
Content

I. Objective .................................................................3
II. Problem .................................................................3
III. Solution .................................................................3
IV. Methodology ..........................................................3
V. Schematic ..............................................................5
VI. Sensor testing ........................................................6
VII. Future Work .........................................................10
VIII. Part list ..............................................................12
IX. Conclusion ..........................................................13
X. Appendix ..............................................................14

Data sheet:
1. EPC Valve .............................................................14

2. Pressure sensor ......................................................16

3. Power FET ...........................................................19

4. Labview DAQ .........................................................22
I. Objective:

The objective of this project is automating the manual pressure regulator by using the labview, data acquisition and microcontroller. This report will be focus on the method and the testing using labview and data acquisition. The future work of microcontroller will be completed at L-3 Fuzing and Ordnance Systems.

II. Problem:

Need an air pressure regulator in a range from 0 to 1 PSI, use for environments testing. The problems with manual air pressure regulator are: slowly response to the set points, can’t control series of pressure points and future automate d testing incompatible.

III. Solution:
Automate the pressure box, and control the electronic valve to desire pressure set points by using: labview- DAQ or microcontroller circuit board. 
The benefit of automating the pressure box is:
* Can be used in automatic tester
* Applied electronic control valve to reduce space and devices
* Increase accuracy and testing time.

IV. Methodology:
Apply the feed back control theory to reduce the main air input to a small range (from 0 to 1 psi) then continue to activate the control loop to maintain the output at set point. The bock diagram in figure 1 described the operation of the control loop which applied to the control using labview or microcontroller.
Beside the control loop there are 3 devices to sense and control the air that include: electronic proportional control valve (EPC), which is the solenoid that control the main air pressure; Relieve switch which is the solenoid that relief the air pressure build-up when necessarily; Pressure sensor which send the voltage back to the control according to the current pressure.
The set voltage which also represent for the pressure set will be compare with the feed back voltage from the pressure sensor. The difference voltage will be integrate and add to the proportional voltage control to maintain the air pressure. The digital output signal from the PI control will be converted to an analog signal to feed to a power FET which drives the EPC valve. Other digital signal out from PI control will go to power FET drive the quick pressure relief switch, when the control need to reduce the pressure. After setting properly, the pressure output should maintain at setting level with acceptable oscillation.
Mathematic expression: \[ V_{out} = P*(V_{set}-V_{sensor}) + I\int(V_{set}-V_{sensor}) \]
Figure 1: Control loop block diagram

EPC characteristic:
Coil and connection resistance: 75 - 85 ohms
Coil inductance: 25mH
Opening voltage: 2.5 - 7Vdc
Control range span: 1-2 Vic
Power dissipation: .8 watt
Maximum operating pressure: 200PSIG

Pressure sensor characteristic:
Pressure range: 0 to 0.36 PSI
Supply voltage: 4.75 to 5.25Vdc
Full scale span: 4Vdc

(See appendix for more detail in datasheet)

V. Schematic

By using Labview for the control loop, it is possible to monitor the set voltage, set pressure, voltage sense, difference voltage between set and sense calculation and voltage send out to the main valve. See the figure 2 for Labview front panel view.
Figure 2: Laview front panel testing

Behind the Laview front panel monitor and control is the visual block of setting where it convert from the setting to the machine code. All the setting for data acquisition and calculation are here. See figure 3 for Labview window of block diagram and setting. All data acquisition and simulate signal are set at 2000 sample /second.

Figure 3: Laview block diagram and setting
The DAQ connection
The PC with Labview communicated with DAQ through USB. Other components is wired to the DAQ as shown in Figure 4. The pressure sensor signal connected to the analog input, also it used the power +5Vdc from DAQ. The analog output from DAQ control the main valve EPC and the digital output control the relief solenoid valve. Other external +5Vdc supply is used for EPC and relief solenoid.
After wiring the control and run the labview the control should adjust itself to any setpoint from 0 to .36psi. The response time of the control is not recorded but capable of adjust to the requirement by changing the P and I constant, sampling rate or reduce the diameter of the relieve air valve. See Figure 5 for the whole test setup.

Figure 4: Wiring diagram between Labview, data acquisition and other components.
VI. Pressure sensor testing

Using the industrial calibrator check for the response of the pressure sensor at ambient. There are three pressure sensors have been tested and the result is s
ASDXLYYD4RR Pressure sensor test, \( P_{\text{max}} = 10 \text{H20} = .361 \text{ psi} \), Step = \( .361/30 = .012 \text{ psi/step} \); at ambient

<table>
<thead>
<tr>
<th>Step</th>
<th>Pressure (PSI)</th>
<th>Sensor 1</th>
<th>Sensor 2</th>
<th>Sensor 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.0017</td>
<td>0.49</td>
<td>0.49</td>
<td>0.48</td>
</tr>
<tr>
<td>1</td>
<td>0.0120</td>
<td>0.60</td>
<td>0.59</td>
<td>0.59</td>
</tr>
<tr>
<td>2</td>
<td>0.0240</td>
<td>0.74</td>
<td>0.72</td>
<td>0.73</td>
</tr>
<tr>
<td>3</td>
<td>0.0360</td>
<td>0.88</td>
<td>0.84</td>
<td>0.87</td>
</tr>
<tr>
<td>4</td>
<td>0.0480</td>
<td>1.01</td>
<td>0.96</td>
<td>1.01</td>
</tr>
<tr>
<td>5</td>
<td>0.0600</td>
<td>1.15</td>
<td>1.17</td>
<td>1.13</td>
</tr>
<tr>
<td>6</td>
<td>0.0720</td>
<td>1.27</td>
<td>1.25</td>
<td>1.27</td>
</tr>
<tr>
<td>7</td>
<td>0.0840</td>
<td>1.41</td>
<td>1.37</td>
<td>1.39</td>
</tr>
<tr>
<td>8</td>
<td>0.0960</td>
<td>1.54</td>
<td>1.51</td>
<td>1.52</td>
</tr>
<tr>
<td>9</td>
<td>0.1080</td>
<td>1.68</td>
<td>1.65</td>
<td>1.67</td>
</tr>
<tr>
<td>10</td>
<td>0.1200</td>
<td>1.82</td>
<td>1.88</td>
<td>1.84</td>
</tr>
<tr>
<td>11</td>
<td>0.1320</td>
<td>1.94</td>
<td>1.92</td>
<td>1.92</td>
</tr>
<tr>
<td>12</td>
<td>0.1440</td>
<td>2.07</td>
<td>2.09</td>
<td>2.05</td>
</tr>
<tr>
<td>13</td>
<td>0.1560</td>
<td>2.21</td>
<td>2.17</td>
<td>2.21</td>
</tr>
<tr>
<td>14</td>
<td>0.1680</td>
<td>2.34</td>
<td>2.32</td>
<td>2.34</td>
</tr>
<tr>
<td>15</td>
<td>0.1800</td>
<td>2.50</td>
<td>2.45</td>
<td>2.55</td>
</tr>
<tr>
<td>16</td>
<td>0.1920</td>
<td>2.60</td>
<td>2.59</td>
<td>2.60</td>
</tr>
<tr>
<td>17</td>
<td>0.2040</td>
<td>2.76</td>
<td>2.71</td>
<td>2.75</td>
</tr>
<tr>
<td>18</td>
<td>0.2160</td>
<td>2.89</td>
<td>2.85</td>
<td>2.88</td>
</tr>
<tr>
<td>19</td>
<td>0.2280</td>
<td>3.04</td>
<td>2.98</td>
<td>3.00</td>
</tr>
<tr>
<td>20</td>
<td>0.2400</td>
<td>3.16</td>
<td>3.14</td>
<td>3.16</td>
</tr>
<tr>
<td>21</td>
<td>0.2520</td>
<td>3.30</td>
<td>3.25</td>
<td>3.30</td>
</tr>
<tr>
<td>22</td>
<td>0.2640</td>
<td>3.42</td>
<td>3.38</td>
<td>3.42</td>
</tr>
<tr>
<td>23</td>
<td>0.2760</td>
<td>3.57</td>
<td>3.52</td>
<td>3.55</td>
</tr>
<tr>
<td>24</td>
<td>0.2880</td>
<td>3.68</td>
<td>3.65</td>
<td>3.67</td>
</tr>
<tr>
<td>25</td>
<td>0.3000</td>
<td>3.81</td>
<td>3.83</td>
<td>3.82</td>
</tr>
<tr>
<td>26</td>
<td>0.3120</td>
<td>3.95</td>
<td>3.91</td>
<td>3.95</td>
</tr>
<tr>
<td>27</td>
<td>0.3240</td>
<td>4.07</td>
<td>4.04</td>
<td>4.08</td>
</tr>
<tr>
<td>28</td>
<td>0.3360</td>
<td>4.23</td>
<td>4.18</td>
<td>4.21</td>
</tr>
<tr>
<td>29</td>
<td>0.3480</td>
<td>4.36</td>
<td>4.33</td>
<td>4.35</td>
</tr>
<tr>
<td>30</td>
<td>0.3600</td>
<td>4.49</td>
<td>4.46</td>
<td>4.49</td>
</tr>
<tr>
<td>31</td>
<td>0.3720</td>
<td>4.63</td>
<td>4.59</td>
<td>4.62</td>
</tr>
</tbody>
</table>

**Figure 6:** Three sensors testing for the response
VII. Future Work:

There is some advance to control the air pressure by using the microcontroller, high speed response, compact, can work alone or with PC for more advance feature. The developing the controller board with LCD display, button to set and start the program, PI control implement are under constrution. See Figure 8 for electrical schematic and Figure 9 for PCB lay out. Using the microcontroller PIC 16F877 for the main control, DAC 0808 converter, pressure sensor and using assembly language to program the control loop.
Figure 8: Electrical schematic for microcontroller board

Figure 9: Board layout for microcontroller
VIII. Part list

As current, the project cost $375 for the parts and PCB making. Other equipment and components are available at L-3 FOS. See Figure 10 for the part list.

Figure 10: Part list:
IX. CONCLUSION

A. Challenging:
   Devote more time to understand the sensor and construct the circuit.
   Develop the control loop using microcontroller and assembly language.

B. Benefit:
   There are many benefits to do the senior design project. I have learned to handle a project from the design concept to manage the project on time. Also display, present and answer the question for the final product to others.
   Learn the new tools, Labview and DAQ, and using them to experiment with control loop before implement to the microcontroller.

C. Conclusion
   The important of the complete the project, demonstrated the knowledge have gained during studying in the Electrical Engineering Technology program at CEAS. Help to understand and apply the Electrical Engineering skill to solve the real world problem.
X. Appendix:
1. EPC valve

The Porter Instrument Model EPC Electronic Proportional Control Valve is an electromagnetically-actuated, proportional control valve designed for use in closed loop flow or pressure control systems. When coupled with a flow sensor or pressure transducer and a proportional electronic controller, Model EPC is capable of providing steady and precise control of gas flow rates or pressures. The Model EPC is a DC-driven, normally-closed valve which includes an elastomeric valve seat to provide bubble-tight shut-off. A broad range of flow coefficients ($C_v$'s) is available for either flow or pressure control.

The Model EPC is offered with either integral compression fittings for in-line mounting or as a manifold-mount version. To allow design and user flexibility, custom configurations in OEM-scale quantities are also available.

**Design Features and Benefits**
- LOW COST
- CLEANED FOR USE IN ANALYTICAL INSTRUMENTATION
- GREATER THAN 50:1 DYNAMIC RANGE
- MANY ELECTRICAL AND MECHANICAL CONFIGURATIONS AVAILABLE
- EASILY CUSTOMIZED
- LOW POWER CONSUMPTION
- BUBBLE-TIGHT SHUT-OFF

**Electrical Specifications**
- Coil and connection resistance: 75–85 ohms
- Coil inductance: 25 mH
- Opening Voltage: 2.5–7 Vdc
- Control Range Span: 1–2 Vdc
- Power dissipation: 0.8 watts typical

**Mechanical Specifications**
- Maximum operating pressure: 200 PSIG
- Maximum operating temperature: 85°C (185°F)
- Custom configurations available to 200°C (392°F)
- Available $C_v$’s range from 1.6 x 10⁻⁵ to 4.0 x 10⁻⁸
- Flow capacity: Maximum ranges from 40 sccm up to 10,000 sccm (nitrogen at 70°F & 5 PSID)
- Rangeability (typical): 50:1
- Fitting sizes and type: 1/16”, 1/8” or 1/4” compression fittings

**Materials of Construction**
- Valve base (body): Aluminum (black anodized) or stainless steel
- Orifice: Brass or stainless steel
- Valve Trim: Stainless steel
- O-rings and valve seat: Buna N, ethylene propylene, Kalrez®, Neoprene® or Viton®
- Fittings: Brass or stainless steel

*Kalrez, Neoprene and Viton are registered trademarks
E.I. DuPont de Nemours & CO, Inc.*
Dimensional Data

Model EPC
(With Valve Base and Compression Fittings)

Manifold-Mount Model EPC
(Less Valve Base and Compression Fittings)

Ordering Information
To order, please specify:
1. Model number
2. Valve base (body) material
3. O-ring material
4. Valve seat material
5. Fitting size and type
6. Gas type
7. System flows (minimum, nominal & maximum)
8. Operating temperature
9. Upstream (inlet) pressure
10. Downstream (outlet) pressure

Example:
Model: EPC A 00 A B V B AA
Assembly/Test Procedures:
AA: Factory Standard
BB: 1/8" Compression Fitting
CC: 1/4" Compression Fitting
DD: 1/16" Compression Fitting

O-ring and Valve Seat Material
BB: Buna N
EE: Ethylene Propylene
KK: Kalrez
LL: Neoprene
VV: Viton

Compression Material
BB: Buna
SS: Stainless Steel

Porter Instrument Company, Inc.

2. Pressure sensor data sheet:

ASDXL Series
Microstructure Pressure Sensors
0 in to ±5 in H₂O, 0 in to 10 in H₂O, 0 in to ±10 in H₂O

DESCRIPTION
The ASDXL Series pressure sensors are fully calibrated and temperature compensated with on-board Application Specific Integrated Circuitry (ASIC). This ASDXL sensor is in a DIP format (Dual In-line Package) and provides digital correction of sensor offset, sensitivity, temperature coefficients and non-linearity. The ASDXL Series has an analog output that is ratiometric with supply voltage over the compensated supply range with 11-bit resolution.

FEATURES
- Available in differential and gauge packages
- Calibrated and temperature compensated output
- Analog output with 11-bit resolution
- Pressure ranges from 0 in to ±5 in H₂O, 0 in to 10 in H₂O, ±10 in H₂O
- Response time of 8 ms
- DIP package
- ASIC-enhanced output

POTENTIAL APPLICATIONS
- Medical equipment
- HVAC controls
- Pneumatic controls

All ASDXL sensors are accurate to within ±2.5% Full Scale Span (FSS) and are intended for use with non-corrosive, non-ionic working fluids such as air and dry gases. (Contact factory for media compatibility on G2/D4 packages).

This series is designed and manufactured in accordance with ISO 9001 standards and is compliant with the WEEE and RoHS directives.
ASDXL Series
0 in to ±5 in H₂O, 0 in to 10 in H₂O, 0 in to ±10 in H₂O

GENERAL SPECIFICATIONS

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Parameter</th>
<th>Characteristic</th>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply voltage (Vs)</td>
<td>4.75 Vdc to 5.25 Vdc</td>
<td>Lead soldering temperature</td>
<td>4 s at 250 °C [482 °F]</td>
</tr>
<tr>
<td>Maximum supply voltage</td>
<td>6.50 Vdc max.</td>
<td>Vibration</td>
<td>10 g at 20 Hz to 2000 Hz</td>
</tr>
<tr>
<td>Current consumption</td>
<td>6 mA typ.</td>
<td>Shock</td>
<td>100 g for 11 ms</td>
</tr>
<tr>
<td>Output current - sink</td>
<td>2 mA max.</td>
<td>Life</td>
<td>1 million cycles min.</td>
</tr>
<tr>
<td>Output current - source</td>
<td>2 mA max.</td>
<td>Position sensitivity</td>
<td>50 μV/V/g typical</td>
</tr>
</tbody>
</table>

ENVIRONMENTAL SPECIFICATIONS

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Range</th>
<th>Listing</th>
<th>Pressure Range</th>
<th>Burst Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compensated</td>
<td>0 °C to 85 °C [32 °F to 185 °F]</td>
<td>ASDXL05</td>
<td>0 in to ±5 in H₂O</td>
<td>3 PSI</td>
</tr>
<tr>
<td>Operating</td>
<td>-20 °C to 105 °C [-4 °F to 221 °F]</td>
<td>ASDXL10</td>
<td>0 in to 10 in H₂O</td>
<td>3 PSI</td>
</tr>
<tr>
<td>Storage</td>
<td>-40 °C to 125 °C [40 °F to 257 °F]</td>
<td></td>
<td>0 in to ±10 in H₂O</td>
<td></td>
</tr>
</tbody>
</table>

PERFORMANCE CHARACTERISTICS 4D R

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Min.</th>
<th>Typ. (5)</th>
<th>Max.</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full scale span (FSS)</td>
<td></td>
<td>4,000</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>Zero pressure offset</td>
<td>2,400</td>
<td>2,500</td>
<td>2,600</td>
<td>V</td>
</tr>
<tr>
<td>Output at full scale pressure (P2)</td>
<td>4,400</td>
<td>4,500</td>
<td>4,600</td>
<td>V</td>
</tr>
<tr>
<td>Output at full scale pressure (P1)</td>
<td>0.400</td>
<td>0.500</td>
<td>0.600</td>
<td>V</td>
</tr>
<tr>
<td>Accuracy</td>
<td></td>
<td>±2.5 % FSS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quantization error</td>
<td>2.44</td>
<td></td>
<td></td>
<td>mV</td>
</tr>
<tr>
<td>Response time</td>
<td></td>
<td>8</td>
<td>11</td>
<td>ms</td>
</tr>
</tbody>
</table>

PERFORMANCE CHARACTERISTICS 4R R

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full scale span (FSS)</td>
<td></td>
<td>4,000</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>Zero pressure offset</td>
<td>0.400</td>
<td>0.500</td>
<td>0.600</td>
<td>V</td>
</tr>
<tr>
<td>Output at full scale pressure</td>
<td>4,400</td>
<td>4,500</td>
<td>4,600</td>
<td>V</td>
</tr>
<tr>
<td>Accuracy</td>
<td></td>
<td>±2.5 % FSS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quantization error</td>
<td>2.44</td>
<td></td>
<td></td>
<td>mV</td>
</tr>
<tr>
<td>Response time</td>
<td></td>
<td>8</td>
<td>11</td>
<td>ms</td>
</tr>
</tbody>
</table>

Notes:
1. If burst pressure is exceeded, even momentarily, the package may leak or the pressure sensing die may fracture.
2. Reference conditions (unless otherwise noted): supply voltage, Vₖ=5.0 ±0.01 Vdc, Ta=25 °C [77 °F].
3. Span is the algebraic difference between the output voltage at the specified pressure and the output at zero pressure.
4. Output is ratiometric within the supply voltage range (Vs).
5. Output of the device when maximum positive pressure is applied on the backside (P2) or the front side (P1) of the sensing element.
6. Accuracy is the combined errors from offset and span calibration. Linearity, pressure hysteresis, and temperature effects. Calibration errors include the deviation of offset and full scale from nominal values. Linearity is the measured deviation based on a straight line. Hysteresis is the maximum output difference at any point within the operating pressure range for increasing and decreasing pressure and temperature.
7. Minimum step size in the output due to a change in the input pressure.
8. Response time for 5 PSI to full scale pressure step change, 10% to 90% rise time.
9. 220 nF capacitor required between +Vs and GND.
Microstructure Pressure Sensors

ELECTRICAL CONNECTIONS

ASDXLYYD4ZZ

Notes:
1. N/C means no connection. Connecting to ground or other potential may damage sensor.
2. Capacitor 330 nF required between +Vs and GND.
3. The sensor is not reverse polarity protected. Incorrect application of excitation voltage or ground to the wrong pin can cause electrical failure.
   Application of supply voltage above the maximum can cause electrical failure.

DIMENSIONS (For reference only, mm/in.)

D4 Package

G2 Package

BLOCK DIAGRAM

Honeywell Sensing and Control
3. Power FET

**Data Sheet**

**IRFR220, IRFU220**

**January 2002**

---

**4.6A, 200V, 0.800 Ohm, N-Channel Power MOSFETs**

These are N-Channel enhancement mode silicon gate power field effect transistors. They are advanced power MOSFETs designed, tested, and guaranteed to withstand a specified level of energy in the breakdown avalanche mode of operation. All of these power MOSFETs are designed for applications such as switching regulators, switching converters, motor drives, relay drivers, and drivers for high power bipolar switching transistors requiring high speed and low gate drive power. These types can be operated directly from integrated circuits.

Formerly developmental type TA9600.

---

**Features**

- 4.6A, 200V
- \( V(DS)(ON) = 0.800 \text{Ohm} \)
- Single Pulse Avalanche Energy Rated
- SOA is Power Dissipation Limited
- Nanosecond Switching Speeds
- Linear Transfer Characteristics
- High Input Impedance
- Related Literature
  - T8234 "Guidelines for Soldering Surface Mount Components to PC Boards"

---

**Ordering Information**

<table>
<thead>
<tr>
<th>PART NUMBER</th>
<th>PACKAGE</th>
<th>BRAND</th>
</tr>
</thead>
<tbody>
<tr>
<td>IRFR220</td>
<td>TO-252AA</td>
<td>IRFR20</td>
</tr>
<tr>
<td>IRFU220</td>
<td>TO-251AA</td>
<td>IRFU20</td>
</tr>
</tbody>
</table>

**Symbol**

![Symbol Diagram](image)

---

**Packaging**

JEDEC TO-251AA

JEDEC TO-252AA

---

©2002 Fairchild Semiconductor Corporation
### Absolute Maximum Ratings

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Test Conditions</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drain to Source Voltage</td>
<td>$V_{DS}$</td>
<td>$I_D = 250\mu A$, $V_{GS} = 0\text{V}$ (Figure 10)</td>
<td>200</td>
<td>-</td>
<td>-</td>
<td>V</td>
</tr>
<tr>
<td>Drain to Gate Voltage</td>
<td>$V_{DS}$</td>
<td>$I_D = 250\mu A$</td>
<td>4.6</td>
<td>-</td>
<td>-</td>
<td>A</td>
</tr>
<tr>
<td>Continuous Drain Current</td>
<td>$I_D$</td>
<td>$V_{GS} = 0\text{V}$</td>
<td>2.9</td>
<td>-</td>
<td>-</td>
<td>A</td>
</tr>
<tr>
<td>Pulsed Drain Current</td>
<td>$I_{PM}$</td>
<td>$V_{GS} = 0\text{V}$</td>
<td>15</td>
<td>-</td>
<td>-</td>
<td>A</td>
</tr>
<tr>
<td>Gate to Source Voltage</td>
<td>$V_{GS}$</td>
<td>$I_D = 250\mu A$</td>
<td>1.8</td>
<td>-</td>
<td>-</td>
<td>V</td>
</tr>
<tr>
<td>Maximum Power Dissipation</td>
<td>$P_D$</td>
<td>$V_{GS} = 0\text{V}$</td>
<td>50</td>
<td>-</td>
<td>-</td>
<td>W</td>
</tr>
<tr>
<td>Linear Drating Factor</td>
<td>$F_A$</td>
<td>$V_{GS} = 0\text{V}$</td>
<td>0.4</td>
<td>-</td>
<td>-</td>
<td>W/°C</td>
</tr>
<tr>
<td>Single Pulse Avalanche Energy Rating (Note 4)</td>
<td>$E_{AS}$</td>
<td>$V_{GS} = 0\text{V}$</td>
<td>85</td>
<td>-</td>
<td>-</td>
<td>mJ</td>
</tr>
<tr>
<td>Operating and Storage Temperature</td>
<td>$T_{J}$, $T_{STG}$</td>
<td>$V_{GS} = 0\text{V}$</td>
<td>-55 to 150</td>
<td>-</td>
<td>-</td>
<td>°C</td>
</tr>
<tr>
<td>Maximum Temperature for Soldering</td>
<td></td>
<td></td>
<td>300</td>
<td>-</td>
<td>-</td>
<td>°C</td>
</tr>
<tr>
<td>Leads at 0.063in (1.6mm) from Case for 10s</td>
<td>$T_{PKG}$</td>
<td></td>
<td>260</td>
<td>-</td>
<td>-</td>
<td>°C</td>
</tr>
</tbody>
</table>

**CAUTION:** Stresses above those listed in "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress only rating and operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied.

**NOTE:**
1. $T_{J} = -25\text{°C}$ to $125\text{°C}$.

### Electrical Specifications

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Test Conditions</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drain to Source Breakdown Voltage</td>
<td>$V_{DSS}$</td>
<td>$I_D = 250\mu A$, $V_{GS} = 0\text{V}$ (Figure 10)</td>
<td>200</td>
<td>-</td>
<td>-</td>
<td>V</td>
</tr>
<tr>
<td>Gate Threshold Voltage</td>
<td>$V_{GS(th)}$</td>
<td>$V_{GS} = V_{DS}$, $I_D = 250\mu A$</td>
<td>2.0</td>
<td>-</td>
<td>-</td>
<td>V</td>
</tr>
<tr>
<td>Zero Gate Voltage Drain Current</td>
<td>$I_{DS}$</td>
<td>$V_{GS} = \text{Rated}$ $V_{DSS}$, $V_{GS} = 0\text{V}$</td>
<td>-</td>
<td>25</td>
<td>-</td>
<td>µA</td>
</tr>
<tr>
<td>On-State Drain Current (Note 2)</td>
<td>$I_{D(on)}$</td>
<td>$V_{GS} &gt; 10\text{V}$(ON) $X$ $V_{GS}$ MAX, $V_{GS} = 10\text{V}$, (Figure 7)</td>
<td>4.6</td>
<td>-</td>
<td>-</td>
<td>A</td>
</tr>
<tr>
<td>Gate to Source Leakage Current</td>
<td>$I_{GS}$</td>
<td>$V_{GS} = 10\text{V}$</td>
<td>-</td>
<td>-</td>
<td>100</td>
<td>nA</td>
</tr>
<tr>
<td>Drain to Source On Resistance (Note 2)</td>
<td>$R_{DS(on)}$</td>
<td>$I_D = 2.4\text{A}$, $V_{GS} = 10\text{V}$ (Figures 9, 9)</td>
<td>0.47</td>
<td>-</td>
<td>0.80</td>
<td>Ω</td>
</tr>
<tr>
<td>Forward Transconductance (Note 2)</td>
<td>$g_{m}$</td>
<td>$V_{GS} = 10\text{V}$, $I_D = 2.4\text{A}$, $R_{DS} = 16\Omega$, $R_{L} = 16\Omega$, $V_{GS} = 10\text{V}$</td>
<td>2.6</td>
<td>-</td>
<td>-</td>
<td>S</td>
</tr>
<tr>
<td>Rise Time</td>
<td>$t_{r}$</td>
<td>$V_{DD} = 10\text{V}$</td>
<td>15</td>
<td>-</td>
<td>-</td>
<td>ns</td>
</tr>
<tr>
<td>Turn-On Delay Time</td>
<td>$t_{D(on)}$</td>
<td>$V_{DD} = 10\text{V}$, $I_{D} = 4.6\text{A}$, $V_{GS} = 0\text{V}$ (Figure 12)</td>
<td>2.6</td>
<td>-</td>
<td>-</td>
<td>ns</td>
</tr>
<tr>
<td>Rise Time</td>
<td>$t_{r}$</td>
<td>$V_{DD} = 10\text{V}$</td>
<td>13</td>
<td>-</td>
<td>-</td>
<td>ns</td>
</tr>
<tr>
<td>Turn-Off Delay Time</td>
<td>$t_{D(off)}$</td>
<td>$V_{DD} = 10\text{V}$</td>
<td>27</td>
<td>41</td>
<td>41</td>
<td>ns</td>
</tr>
<tr>
<td>Fall Time</td>
<td>$t_{f}$</td>
<td>$V_{DD} = 10\text{V}$</td>
<td>21</td>
<td>32</td>
<td>32</td>
<td>ns</td>
</tr>
<tr>
<td>Total Gate Charge (Gate to Source + Gate to Drain)</td>
<td>$Q_{g(TOT)}$</td>
<td>$V_{GS} = 10\text{V}$, $I_{D} = 4.6\text{A}$, $V_{GS} = 0\text{V}$ (Figure 14)</td>
<td>12</td>
<td>18</td>
<td>18</td>
<td>nC</td>
</tr>
<tr>
<td>Gate Charge</td>
<td>$Q_{g}$</td>
<td>Effective Gate Charge is Essentially Independent of Operating Temperature</td>
<td>12</td>
<td>18</td>
<td>18</td>
<td>nC</td>
</tr>
<tr>
<td>Gate to Drain &quot;Miller&quot; Charge</td>
<td>$Q_{gd}$</td>
<td>$V_{GS} = 0\text{V}$, $f = 1\text{MHz}$ (Figure 11)</td>
<td>4.5</td>
<td>6.8</td>
<td>6.8</td>
<td>nC</td>
</tr>
<tr>
<td>Input Capacitance</td>
<td>$C_{iss}$</td>
<td>$V_{GS} = 25\text{V}$</td>
<td>390</td>
<td>-</td>
<td>-</td>
<td>pF</td>
</tr>
<tr>
<td>Output Capacitance</td>
<td>$C_{oss}$</td>
<td>$V_{GS} = 0\text{V}$</td>
<td>120</td>
<td>-</td>
<td>-</td>
<td>pF</td>
</tr>
<tr>
<td>Reverse Transfer Capacitance</td>
<td>$C_{oss}$</td>
<td>$V_{GS} = 0\text{V}$</td>
<td>41</td>
<td>-</td>
<td>-</td>
<td>pF</td>
</tr>
<tr>
<td>Internal Drain Inductance</td>
<td>$L_{D}$</td>
<td>Measured From the Drain Lead, 6.0mm (0.25in) From Package to Center of Die</td>
<td>4.5</td>
<td>-</td>
<td>-</td>
<td>nH</td>
</tr>
<tr>
<td>Internal Source Inductance</td>
<td>$L_{S}$</td>
<td>Measured From the Source Lead, 6.0mm (0.25in) From Package to Source Bonding Pad</td>
<td>7.5</td>
<td>-</td>
<td>-</td>
<td>nH</td>
</tr>
<tr>
<td>Thermal Resistance, Junction to Case</td>
<td>$R_{JUC}$</td>
<td>Measured MOSFET Symbol Showing the Internal Device Inductances</td>
<td>2.5</td>
<td>-</td>
<td>-</td>
<td>°C/W</td>
</tr>
<tr>
<td>Thermal Resistance, Junction to Ambient</td>
<td>$R_{JUA}$</td>
<td>Typical Solder Mount</td>
<td>110</td>
<td>-</td>
<td>-</td>
<td>°C/W</td>
</tr>
</tbody>
</table>
Source to Drain Diode Specifications

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>SYMBOL</th>
<th>TEST CONDITIONS</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous Source to Drain Current</td>
<td>ISD</td>
<td>Modified MOSFET Symbol showing the Integral Reverse P-N Junction Rectifier</td>
<td>-</td>
<td>-</td>
<td>4.6</td>
<td>A</td>
</tr>
<tr>
<td>Pulse Source to Drain Current (Note 3)</td>
<td>ISDM</td>
<td></td>
<td>-</td>
<td>-</td>
<td>1.8</td>
<td>A</td>
</tr>
<tr>
<td>Source to Drain Diode Voltage (Note 2)</td>
<td>VSD</td>
<td>T_J = 25°C, I_SD = 4.6A, VGS = 0V, (Figure 13)</td>
<td>-</td>
<td>-</td>
<td>1.8</td>
<td>V</td>
</tr>
<tr>
<td>Reverse Recovery Time</td>
<td>ts</td>
<td>T_J = 25°C, I_SD = 4.6A, dI/dt = 100A/µs</td>
<td>69</td>
<td>170</td>
<td>400</td>
<td>ns</td>
</tr>
<tr>
<td>Reverse Recovery Charge</td>
<td>QRR</td>
<td>T_J = 25°C, I_SD = 4.6A, dI/dt = 100A/µs</td>
<td>0.30</td>
<td>0.72</td>
<td>1.8</td>
<td>µC</td>
</tr>
</tbody>
</table>

NOTES:
2. Pulse test: pulse width < 300µs, duty cycle < 2%.
3. Repetitive rating: pulse width limited by maximum junction temperature. See Transient Thermal Impedance curve (Figure 3).
4. V_SD = 10V, starting J_T = 25°C, L = 6.18mH, R_D = 50Ω, peak I_SD = 4.6A.

Typical Performance Curves

![Performance Curves](image)

**Figure 1.** Normalized Power Dissipation vs Case Temperature

**Figure 2.** Maximum Continuous Drain Current vs Case Temperature

**Figure 3.** Maximum Transient Thermal Impedance

©1982 Fairchild Semiconductor Corporation
4. DAQ

NI USB-6366
X Series Data Acquisition

- 8 simultaneous analog inputs at 2 MS/s/ch with 16-bit resolution; 16 MS/s total AI throughput
- Deep onboard memory (32 or 64 MS) to ensure finite acquisitions, even with competing USB traffic
- Two analog outputs, 3.33 MS/s, 16-bit resolution, ±10 V
- 24 digital I/O lines (8 hardware-timed up to 10 MHz)
- Four 32-bit counter/timers for PWM, encoder, frequency, event counting, and more
- Advanced timing and triggering with NI-STC3 timing and synchronization technology

Overview
NI X Series multifunction data acquisition (DAQ) devices for USB provide a new level of performance with NI-STC3 timing and synchronization technology, NI Signal Streaming for high performance over USB, a completely redesigned mechanical enclosure, and multicores-optimized driver and application software.

NI-STC3 Technology
NI-STC3 timing and synchronization technology delivers advanced timing features, including independent analog and digital timing engines, retargetable measurement tasks, and four counter/timers with more functionality than ever before.

NI Signal Streaming
USB X Series devices include patented NI Signal Streaming, a technology that uses message-based instructions and device-side intelligence to ensure high-speed, bidirectional data transfer over USB. With USB X Series, you can concurrently transfer analog, digital, and counter data in both directions. The total device throughput over USB is PC-dependent; on some systems, up to 32 MS/s sustained transfers are possible.

Data Acquisition Software
X Series devices include multithreaded NI-DAQmx driver software, which is compatible with the following versions (or later) of NI application software - LabVIEW 8.5, LabWindows™/CVI 8.1, or Measurement Studio 8.0.1; LabVIEW SignalExpress 2.x; or LabVIEW with the LabVIEW Real-Time Module 8.5. X Series devices are also compatible with ANSI C/C++ and Microsoft Visual Studio .NET. NI-DAQmx includes free LabVIEW SignalExpress LE data-logging software and hundreds of shipping examples to help you get started quickly with your application.

The mark LabWindows is used under a license from Microsoft Corporation. Windows is a registered trademark of Microsoft Corporation in the United States and other countries.

Specifications