**PSS laser shutter chassis design package**

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**This document describes the design goals and final system construction of a dual safety shutter controller for use in accredited safety control systems.**

Design goals:

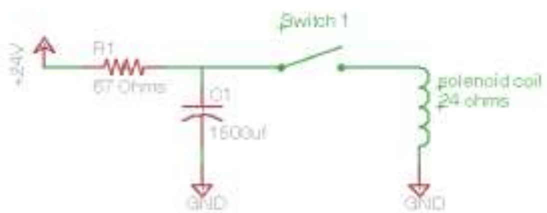
1. Make a failsafe circuit that uses "off the shelf" components that can drive several brands of commercial or homemade solenoid type laser shutters.
2. There shall be no microcontrollers or programmable logic in the device, so any technician can reproduce the item anytime in the future.
3. Make the circuit board relatively compact.
4. Provide feedback information of the shutter status
5. System should operate on 24VDC

Background:

As demonstrated below, a spring loaded solenoid is a failsafe device when the non-powered state is blocking a laser beam.


If the solenoid is rated to open at 24V, then let’s look at various drive methods:


In the simple schematic shown above we see a 24V source on the 24ohm coil. When switch 1 is closed, the solenoid will open and the current draw from the power supply will be 1 ampere. This seems fine, but the solenoid coil will be dissipating 24 Watts of heat, which will burn up many types of coils. Let’s see if we can do better.

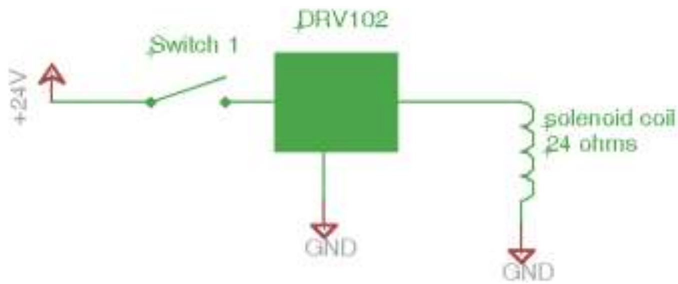



Driving a solenoid requires a momentary high current to draw the solenoid open, and then a much smaller holding current to maintain the solenoid in the open position. Let’s analyze the circuit above.

While switch 1 is open, capacitor C1 charges to 24 volts through R1. When switch 1 is first closed, C1 can provide the full 24V inrush voltage to open the solenoid. This is the instantaneous 1 ampere of current required to open. After the capacitor has discharged slightly, the solenoid wants power from 24V supply via R1. If we calculate the resistance of the circuit, we see that total resistance is 91 ohms, so total current is now 208 mA, which produces a sufficient magnetic field to hold our solenoid open. R1 is dropping 19 volts and the solenoid sees 5 volts in this state. This is much better than our first circuit, but we still have operational issues.

1. We must make sure switch 1 is open long enough to allow C1 to charge to full voltage or the solenoid will fail to open on the next try.
2. 67 ohms at 208mA is still a significant amount of heat on the resistor (2.9 watts), but now the solenoid is only dissipating 1 watt.

We can still do better




The DRV102 is a single IC chip designed for solenoid driving. It has timing protocols that are programmed by selecting the values of a resistor and a capacitor. It will apply the full power supply current to the solenoid for a programmed time period, and then it will chop the incoming voltage with a PWM duty factor circuit to reduce the current draw for holding the solenoid. Since it is a PWM chopper drive at a high frequency, there is negligible resistive heat loss in the drive circuit.

As you can see by the schematic above, this circuit is still failsafe in the fact that if switch 1 is opened, there is no power to the solenoid and the shutter will close. This circuit is highly reliable and will always provide a pulse of sufficient time and power to open the shutter.

It is also worth noting that this driver chip is very forgiving of the solenoid coil winding resistance. Our chosen shutter has a winding resistance of 15 ohms, so for a very brief opening time, it receives a surge current of 1.6 amps, then it quickly reduces current to a reasonable 250mA to hold the shutter open.

The driver circuit has been employed on a small circuit board as seen below and it slips inside a 2"W by 4"H by 5"D metal enclosure. This single board has two isolated circuits designated as system A and system B. There are no electrical connections between circuits.

The laser shutter we are presently using is the LST400. This shutter has TTL logic feedback of shutter position, which is less than ideal for our safety systems feedback, so we have placed relays on our board that are opened and closed based on the state of the TTL signal. This provides dry contact information more suitable for feedback. There is one relay for the open state indication, and another for the closed state.

Datasheet of the LST400 from nmlaser.com


# Model LST400 Series Specifications

This model is designed for use as a safety interlock and for some processing applications. For high activity processing, consider the LS055W8 model. The LST400 provides TTL output position sensors for the open and closed states as standard equipment. The thin body style and 8 mm aperture accommodate many popular laser sources. The –IR suffix replaces the over-coated aluminum mirror with gold, for use in the IR, including CO2. This option must be used for CO2 lasers.

Compatible system controllers include user built capacitor discharge, PWM current drivers, and our controller models CX3000B, CX1100, and CX2450B.

Options are available using a suffix code system. Many options cannot be installed after manufacture, so choose carefully. Choose the –IR suffix for CO2 and IR use, starting at about 700 nm. The standard over-coated aluminum mirror is good from deep UV to about 4 microns. Special mirrors are not currently available, except for OEM applications. Cable options are available, call for details.

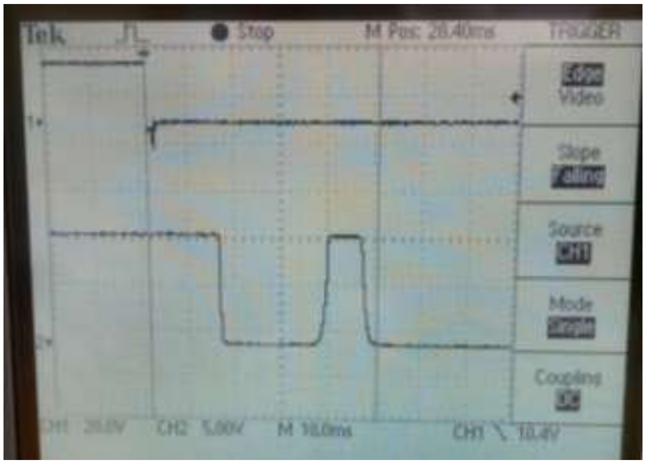
See the "Mechanical Drawing" tab for dimensions. Also see the "Application Notes" tab on the home page menu for important operational issues including: thermal mounting, user-built circuits, polarization, lifetime, jitter, vacuum operation, and contamination. See the "Accessories" tab for useful system components.

Special Considerations for this model include damage threshold assessment. The shutter is not designed for high energy, low repetition rate Q-switched lasers. See LS055W8 and LSTXY-W8 for these applications. Thermal mounting must be given strong attention if optical power dissipation is near the upper limit of the rating.

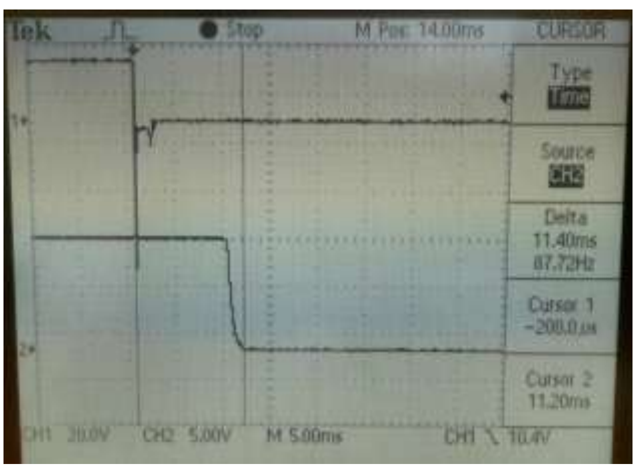
Restricted use for this model is only limited to damage threshold and wavelength considerations. It can be used in any orientation w/r to gravity.

| RECOMMENDED CONTROLLER = | USER CIRCUIT — OUR CONTROLLER |
|---|---|
| Aperture Diameter = | 8.0 mm |
| Typical Beam Diameter used for Specs = | 6.0 mm |
| Maximum Shutter Repetition Rate = | 3 Hz |
| CW and Quasi-CW Optical Power Handling = | 25 W (OEM to 50 W |
| Typical Damage Threshold, Aligned Polarization = | 300 mJ/cm |
| Delay to Begin Opening after Command Open = | 10 ms |
| Opening Time Switching Speed = | 20 ms |
| Delay to Begin Closing after Command Close = | 10 ms |
| Closing Time Switching Speed = | 20 ms using CX3000B |
| Minimum FWHM Exposure Capability = | 30 ms using CX3000B |
| Thermal Power Dissipation Holding Open = | 4 W |
| Thermal Power Dissipation, Repetitive Cycling = | 8 W @ 3 Hz |
| Nominal Magnetic Winding Impedance = | 15 Ohms |
| Cable/Wire Type and Length = | 18 inch, 6 leads 22 g. |
| Mounting Surface for Thermal Sinking = | Base Plate |
| Position Sensors = | Logic TTL, Require 5 VDC @ 20 mA |
| Weight = | 4 Oz. |
| Size (see mechanical drawing) = | 3.80 x 2.06 x .64 Inches |

The shutter closing time from this drive circuit has been evaluated and the results are shown below.




The top trace is the removal of the 24V command line to hold the shutter open. The bottom trace shows the shutter closing approximately 15ms later as measured by a laser passing through the shutter into a fast photodiode. You will also notice that the shutter opens again for about 10ms. This is a mechanical bounce of the shutter blade and it is only witnessed if the beam is sent through the shutter near the top of the shutter window. The shutter does not bounce completely open again over its entire aperture.




In the image above, the laser was aligned closer to the bottom of the aperture and we do not see the bounce. In this case we have a complete closure in 11.4ms after loss of the hold open command.

**Since we cannot guarantee that the alignment will always be away from the bouncing blade, we will assume a <u>worse case shutter closure time of 50ms</u>.**

**Chassis connections**

The chassis has the male Burndy chassis mount connector part #G0B12-88PNE

The mating cable connector is part # G6F12-88SNE

| Pin | Purpose | Internal connection to terminal # (X1 for system A, X2 for B) |
|---|---|---|
| A | Bulk 24VDC power input | 1 |
| B | Common return for bulk 24VDC | 2 |
| C | 24VDC to open shutter | 3 |
| D | Common return for open shutter command | 4 |
| E | Shutter is OPEN dry contact (shorts when open) | 5 |
| F | Shutter is OPEN dry contact | 6 |
| G | Shutter is CLOSED dry contact (shorts when closed) | 7 |
| H | Shutter is CLOSED dry contact | 8 |

**Parts list: (refer to system schematic)**

| Part | description | Source and part number |
|---|---|---|
| X1,X2 | 8 pin terminal strip 3.5mm spacing | Phoenix contact 1751303 |
| IC1,IC3 | Solenoid driver chip | Texas Instruments DRV102F |
| K1,K4 | 24V coil relay | SGR282ZK or Schrack SR2M V23047-A1024-A501 |
| K2,3,5,6 | 5V coil relay | Kemet EC2-5NU |
| Diodes D1,2,3,4,5,6 | SMC package Schottky diode | ON semiconductor MBRS3100T3G (or equiv) |
| C3,C6 | .1uf capacitor | Any 805 size rated >24V |
| R2,R4 | 40K resistor (+/- 5%) | Any 805 size |
| R1,R3 | 10 ohm resistor (5%) | Any 1206 size |

| | | |
|---|---|---|
| IC2,IC4 | 5V regulator type 7805TV | On Semi MC7805CTG or equiv |
| C2,5,7,8,9,10 | 10uf 25V capacitor | Panasonic ECA-1EM100B or equiv |
| C1,C4 | 1000uf 35V capacitor | Nichicon UHE1V102MHD6 or equiv |
| J1,J2 | 8P8C RJ-45 connector | Amp 54602-908LF or equiv |
| J3 | 6P4C RJ-11 connector | Assman A-2004-0-2-N or equiv |
| Enclosure | Hammond Manufacturing 1455 series | 1455N1201 (digikey) |
| DIN rail clip | Optional mounting method for box | Hammond HM1361-ND (digikey) |

Custom front panel from Front Panel Express

**The full design package for this device is located on the M: drive at:**

**M:\inj_group\Official Electronic Design Packages**

The folder contains the following files:

GERBER files zipped and ready for manufacture

Eagle board and schematic files

Board schematic in DXF format.

Front Panel Express – front panel layout (.fpd file) and bitmap images of panel and purchase.

Front Panel Express file exported as DXF

Schematic of printed circuit board in PDF format.