uTile Application Note
I/O Interfacing Methods

This application note describes several methods of adding input and output buffers to the Arduino UNO controller board to improve the galvanic isolation between the sensitive micro-controller I/O pins communicating with real-world devices, sensors, and loads. The ideas presented are general and apply equally well to other types of controller boards.

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1 Introduction

This application note covers a number of methods for adding input and output buffers to the Arduino UNO I/O pins.

The ATmega328P chip I/O pins are rated to operate between 0 V and a Vcc between 2.7 V to 5.5 V, at an output pin current of around 20 mA source or sink. For a clock frequency of 16 MHz the required Vcc range is to 4.5 to 5.5 V. For the purposes of this application note a nominal Vcc of 5.0 V is assumed.

Input pins operate over a 0 to 5 V range, with V_{IL} = -0.5 V min. to 0.3 V max. and V_{IH} = 0.6 V min. to 5.5 V max.

output pins switch over a 0 to 5 V range, with V_{OL} = 0.8 V @ 20 mA max. to V_{OH} = 4.1 V @ 20 mA min.

The first part of the document covers several methods for buffering input field voltages from devices or sensors that typically at levels greater than 5 V, usually from 12 to 24 V.

The second part of the document covers several methods for increasing the output drive power to external loads operating at higher voltage and current levels that are outside of the output pin specifications.

The third and final part of the document covers special interface considerations for switching high power loads.

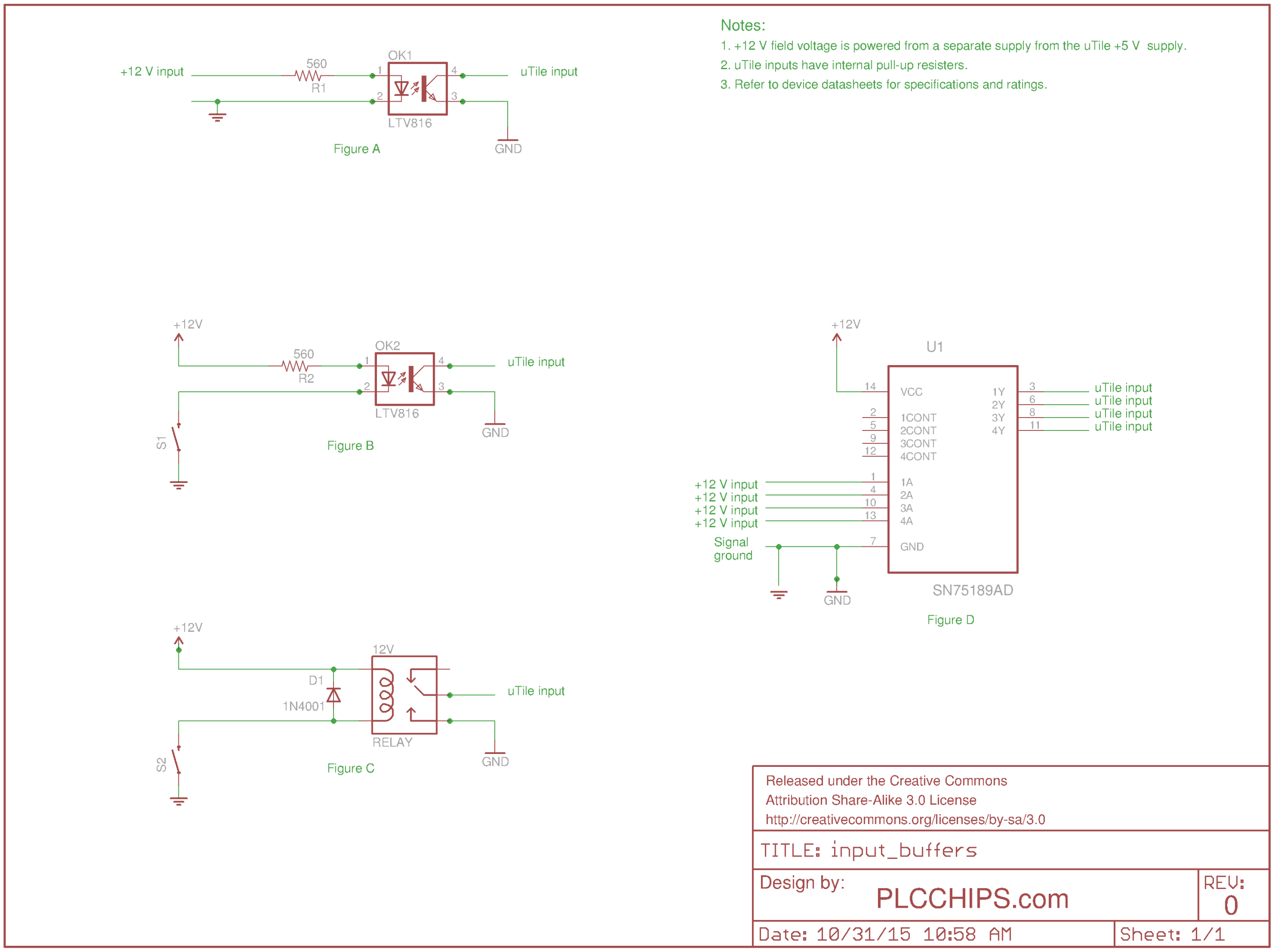
2 Input buffering methods

Input signals come from a variety of field devices which may be active as well as passive. Passive devices such as mechanical switches are common in control circuits and do not require electrical power to operate. These devices need some form of field voltage supply for interrogation to determine the state of the switch.

The field voltage is normally supplied from the automation control circuit and is typically 12 to 24 V (dc). A 12 V field voltage supply is a good choice for small automation projects and suitable 12 V (dc) power supplies are widely available.

You could use the 5 V logic supply voltage to interrogate a field device if it is mounted close by the controller board, say on the same panel which houses the controller. We do not recommend using the controller's logic supply if the field device is located remotely from the controller by several metres or more. Doing so may expose the logic supply to noise pickup and possible short circuits caused by physical damage to the wiring. Any corruption of the 5 V logic supply for the controller board due to induced noise will lead to erratic and unreliable control system operation.

Please refer to the schematic diagram below which shows a number of input buffer schemes, Figures A through D. The left hand side of each figure represents the input connection to the field device. This input device side is supplied with +12 V (dc) sensing voltage for interrogating the input device. This signal enters the buffer device, and from there the output signal goes to a uTile input pin. Let's now dicuss the merits and drawbacks of each buffer scheme.



<u>Figure A — Opto-coupled signal isolator</u>

A Liteon LTV816 opto-isolator provides galvanic isolation between the field device and the uTile input. A current limiting resistor R1 in series with +12 V input signal and the opto-isolator input diode limits the current to a recommended safe 20 mA.

With no drive signal to the OK1 opto-isolator, the output transistor collector connected to the uTile input pin is pulled high since the transistor is turned off. A +12 V drive signal turns on the transistor and pulls the uTile input pin to ground.

The advantage of this scheme is the very high voltage isolation afforded by the opto-isolator. The disadvantage is the added cost and complexity of the buffer hardware.

Figure B – Opto-coupled signal isolator with input switch

This scheme is a variation of the Figure A input buffer with a mechanical switch acting as the input sense device. The advantages of this method is the bullet-proof high voltage isolation, elimination of possible ground loops. The downside is the higher cost and complexity of the buffer hardware.

Figure C – Relay isolated input switch

An electromechanical relay is used in this scheme in place of the opto-isolator in Figure B. A very rugged input buffering solution, but bulkier and higher cost hardware. If you have a lot of relays on hand you can use this scheme.

Figure D – Quadruple RS-232 line receiver buffer scheme

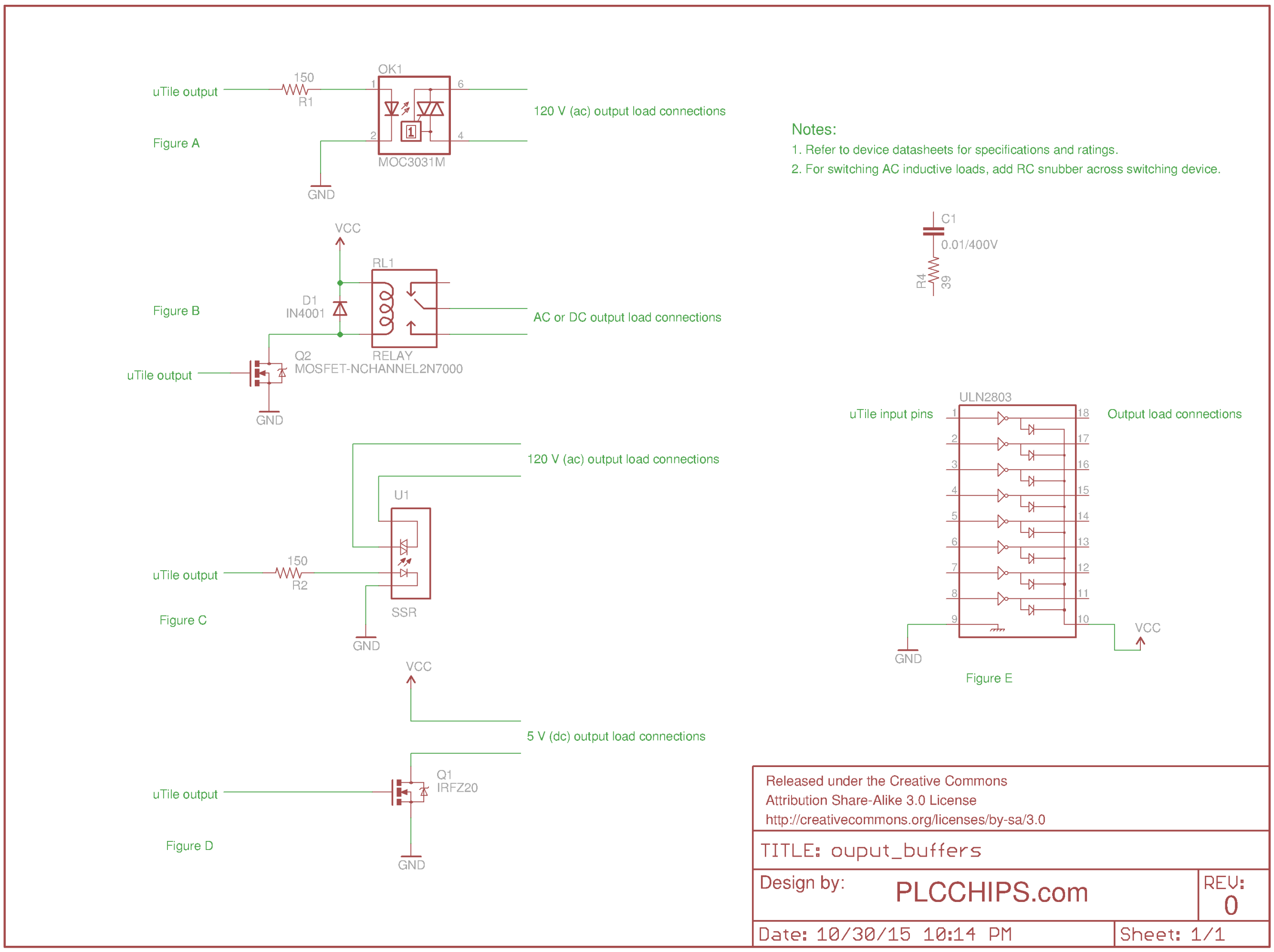
The SN75198A quadruple RS-232 line receiver has input characteristics that are suitable for handling 12 V input signals from the field devices of interest to automation users. The input signal range for the line receiver is +/- 30 V, it has built-in input hysteresis (double thresholds), and it is a fairly rugged device. We have used the SN75189A device for input buffering of field inputs to automation controllers and they have performed well in practice.

The inputs are voltage driven and you can connect a field device such as a switch between the input and signal ground to pull the input low when the switch is activated. Note that the line receivers are inverters, so a low input voltage causes the output to go high.

3 Output buffering methods

The low power digital output pins of the Arduino UNO controller are generally not capable of driving typical load devices such as high power relays, incandescent lamps, heaters, motors and other real world control devices. Some type of output buffering is usually required to switch high power loads.

Please refer to the schematic diagram below which shows a number of output buffer schemes, Figures A through D.



<u>Figure A — Opto-isolated zero-crossing triac driver</u>

This output buffer is designed to drive another high power triac or back-to-back SCRs to switch loads powered from the AC mains (120 V or 240 V (ac) voltage. Please refer to the data sheet of the MOC3031 device and other application notes for this device for further information.

Figure B – Electromechanical relay and MOSFET driver

A 5 V coil electromechanical relay is used in this scheme in place of the opto-isolated triac driver in the Figure A scheme. A 2N7000 MOSFET is used to drive the relay since the UNO output pin may not be able to handle the relay coil current. The coil is an inductive load and it is not a good idea to drive such loads directly with an output pin even if the pin can handle the current.

The relay contacts can be used for general purpose switching duties, and it provides a rugged and versatile output buffering solution, but is bulkier and higher in cost than all solid-state buffers.

The downside of this scheme is the larger footprint and number of extra parts needed.

Figure C – Solid State Relay for driving AC loads

The classic SSR is comes in many sizes and ratings and is a good choice for switching AC type loads. The diagram shows a typical way to drive the SSR from a UNO output pin, with only an R2 current limiting resistor in series with the SSR input needed. The 150 ohm R2 resistor limits the GaAs diode current to 20 mA typically. This resistor may not be required if the SSR has a voltage input circuit, you should refer to the specific SSR data sheet specifications for drive requirements.

The advantages of the SSR is the very wide range of devices available at reasonable cost. The downside of course is SSR are not applicable for switching DC loads

Figure D – Power MOSFET

Power MOSFETS are widely available and are well suited as output buffer devices. The IRFZ20 device is used as an example to show how simple it is to drive a power MOSFET. You won't get the full rated drain current of 15 A from this device in this application since the gate drive voltage from the UNO is close to the gate threshold voltage and you need about 10 V gate voltage to fully turn on the

MOSFET. You should get up to 1.5 A drain current with the UNO driving the IRFZ20, which is quite sufficient for a lot of applications. If you require more drain current, choose a device with a lower turn-on voltage.

Figure E - Darlington high current drivers

The ULN2803A is an 8 channel darlington transistor array rated for loads up to 500 mA and 50 V, with internal output clamp diodes. This IC device is ideal for applications where a lot of output buffers are required. The device is designed to be TTL or 5 V CMOS compatible, so it interfaces directly with UNO output pins.

When driving inductive loads such as small relay coils, solenoid valves and such, you connect the common clamp diode cathode connection to the positive load supply to quench the inductive reverse voltage developed when the loads are switched off. If you fail to do this, don't wonder why your controller goes haywire when it tries to switch inductive loads.

The ULN2803 is just one on many output buffer IC devices designed for use with microcontrollers. We use it as an example because of its availability, ruggedness and ease of use.

4 Special considerations

Your controller board should preferably be mounted in a metal enclosure that can provide shielding from external electromagnetic fields and mechanical protection as well. The enclosure should be grounded to an electrical safety ground connection.

All 120 V (ac) mains powered electrical circuits must be designed, installed and inspected in accordance with the local electrical codes and standards before putting the circuit into operation. Only knowledgeable qualified people should work on circuits operating at this voltage level.

When switching inductive electrical loads such as a standard flourescent lighting fixture with two 4 ft long 40 W lamps and an inductive ballast unit, you need to add a snubber circuit (series connected resistor and capacitor) across the lighting fixture to snub the transient voltage developed when the lighting fixture is switched off.

Note 2 in the output_buffers schematic diagram shows a typical snubber network. We have used a 0.12 uF 400V paper capacitor in series with a 180 ohm 1 W resistor as an effective snubber across an 80 W flourescent lighting fixture with rapid start ballast.

5 Device data sheets

A collection of device data sheets referenced in this application note are included as part of the documentation for your convenience.