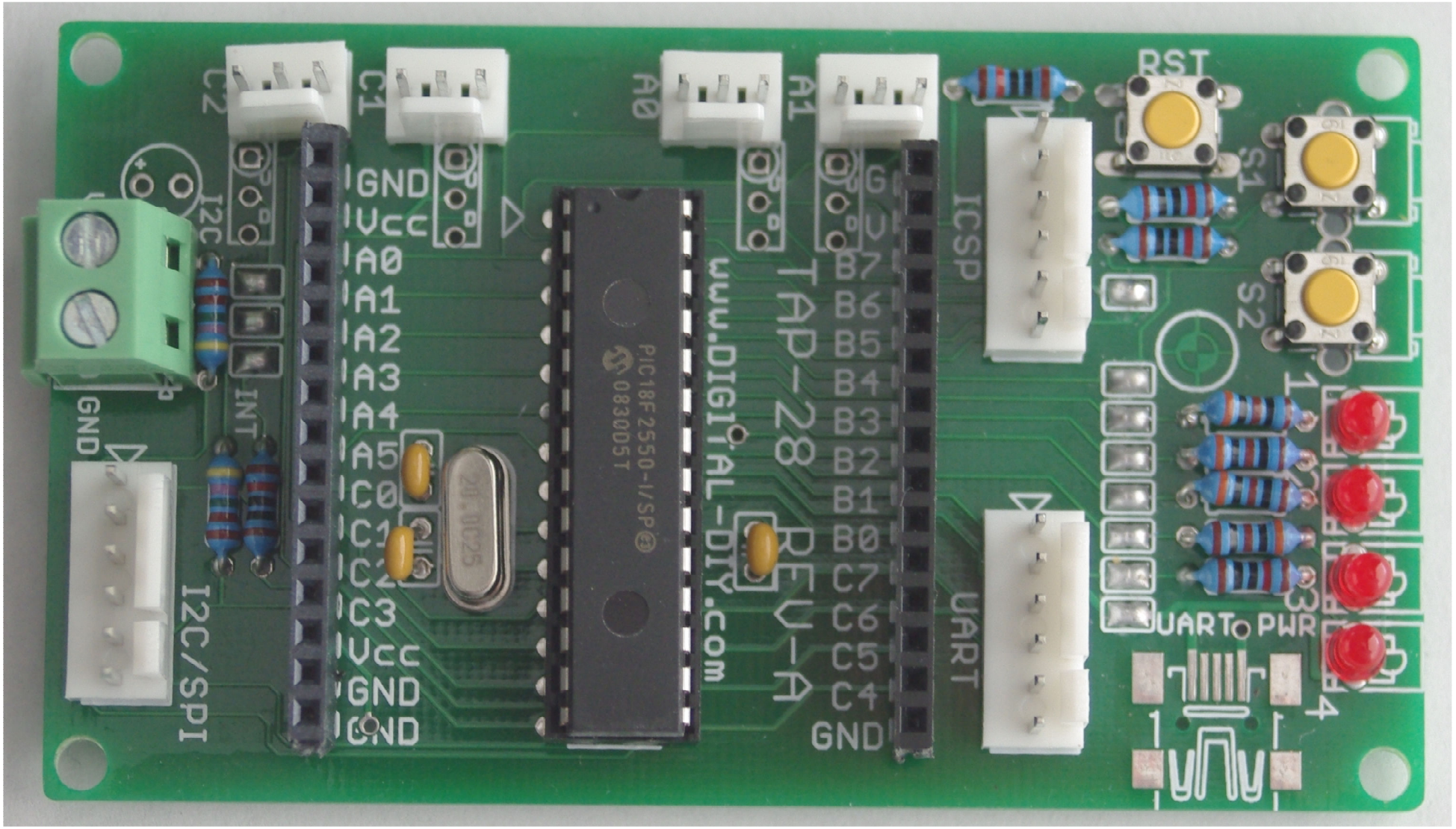
TAP-28, Rev. A

October 31, 2010, JKC



An Assembled TAP-28 Rev A Board

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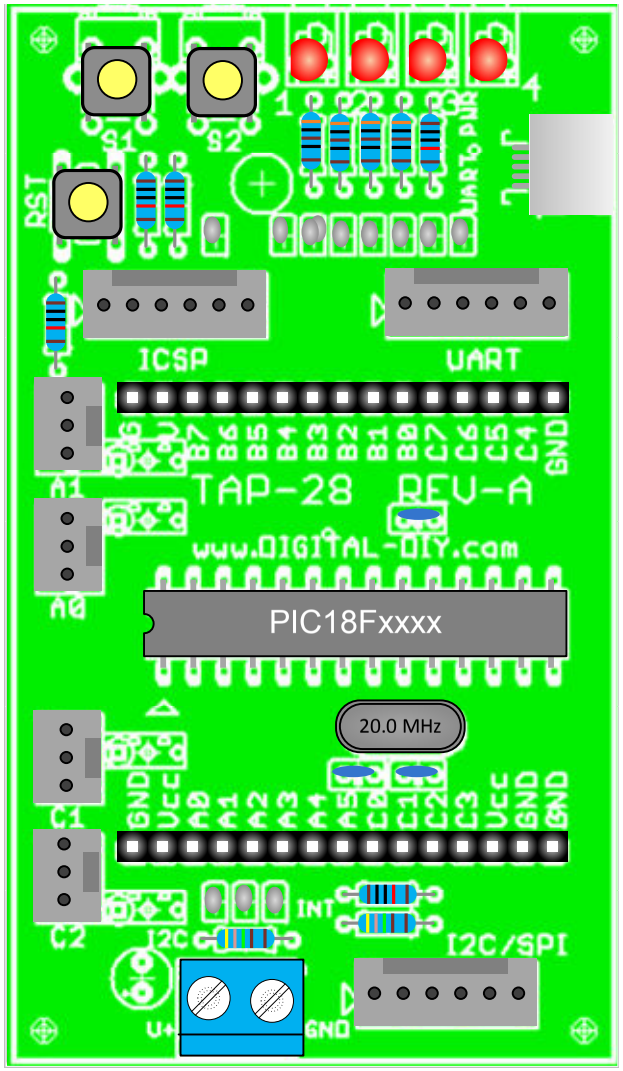

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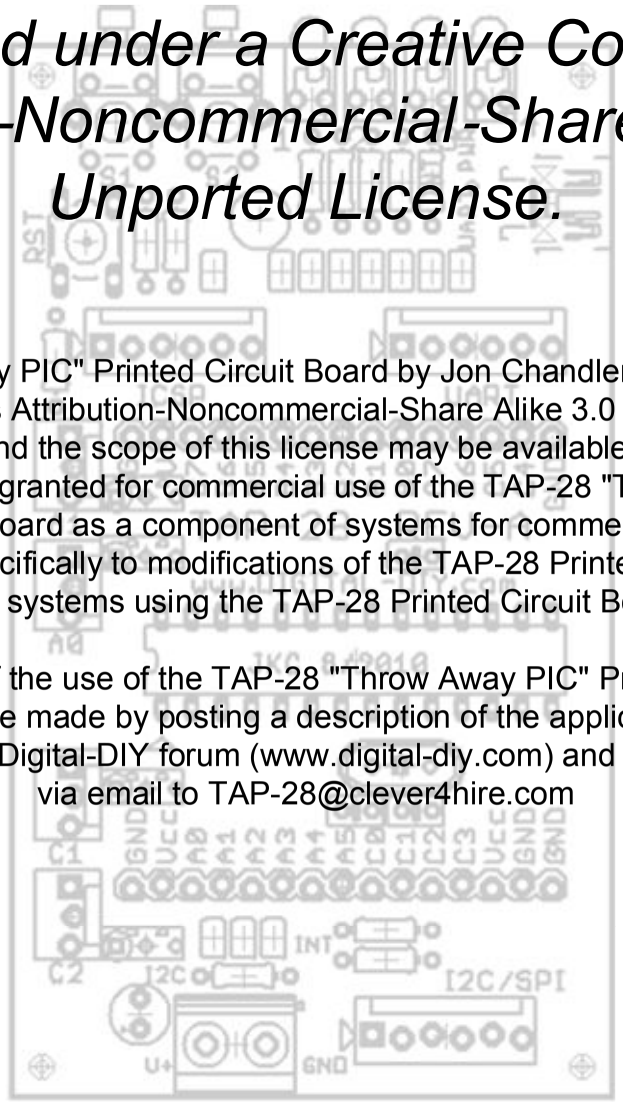


Introduction

Microprocessor applications often require only a simple microprocessor circuit to control an external board, read a few sensors, control a motor or LED using PWM or even run a servo. Implementation of such a circuit is a hassle: dedicating a complex dev board to the task, maybe using a solderless breadboard or hand-assembling the circuit on perf board. None of these is an ideal solution, costing more than needed, having a less-than-robust solution or taking more time than should be needed.

An extremely low-cost circuit that can accomplish simple tasks without any extra hardware or features, yet can serve as a building block to more complex projects would be an ideal solution. The "Throw-Away PIC" (TAP-28) circuit board is so cheap that it can be dedicated to a project without worrying about getting it back.

The TAP-28 supports many of the popular PIC 18F-series 28 pin parts. It includes 2 general-purpose pushbutton switches and 4 LEDs, connectors for ICSP, UART and I2C/SPI and includes 2 analog input/ general purpose and 2 PWM/general purpose I/O connectors on a 2" x 3.5" 2-sided printed circuit board. The board uses through-hole parts for easy assembly. A daughter board may be connected to use additional components with this board.

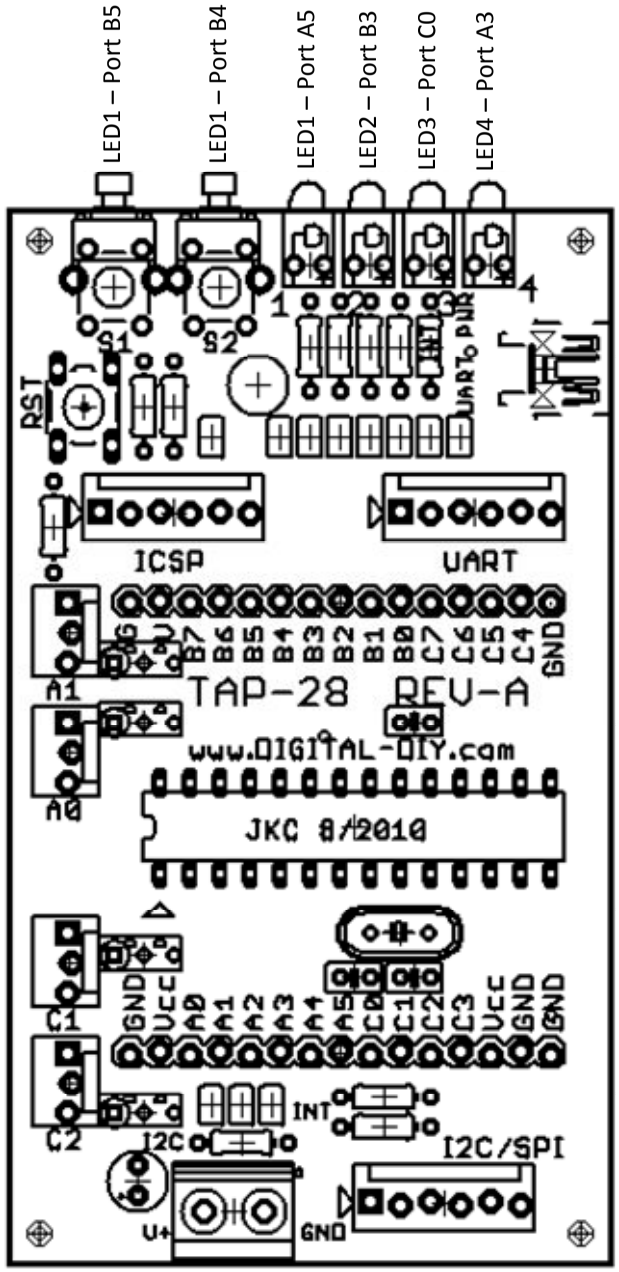
The TAP-28 is designed to support growth in the PIC development community, and as such, the design is licensed to the community under a Creative Commons License detailed elsewhere in this document. No claims are made as to the performance or reliability of this board, nor to its suitability for any particular application. *No safeguards to protect an inexperienced user from causing damage to the microcontroller have been included on this board – this board is intended as an alternative to a hand-assembled perf board, so some level of knowledge is assumed.*

To determine if a particular PIC microprocessor is suitable for use on this board, compare its pinouts to the examples shown. For technical support, please consult your favorite PIC forum.

Port Mapping

TAP-28, Rev. A

Keep this page handy when programming the TAP-28. It maps out all the port connections so that you know which port pins are connected to what.



RESET

ICSP
1. /MCLR
2. V+
3. GND
4. RB7
5. RB6
6 RA2

PORT A1

Port A0

Port C1

Port C2

V+ GND
POWER

USB – Power Only

UART
1. RB1/INT1 - pullup
2. V+
3. GND
4. RC6/TxD
5. RC7/RxD
6. RB2/INT2

I2C/SPI
1. RB0/INT0/CS - pullup
2. V+
3. GND
4. RC4/SDA/SDI - pullup
5. RC5/SCL/SCK - pullup
6. RC5/SDO

Minimum Configuration

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The TAP-2 is extremely flexible and can be used in a variety of configurations with components selected to suit the application. Not using unneeded parts can keep the cost low for embedded applications.

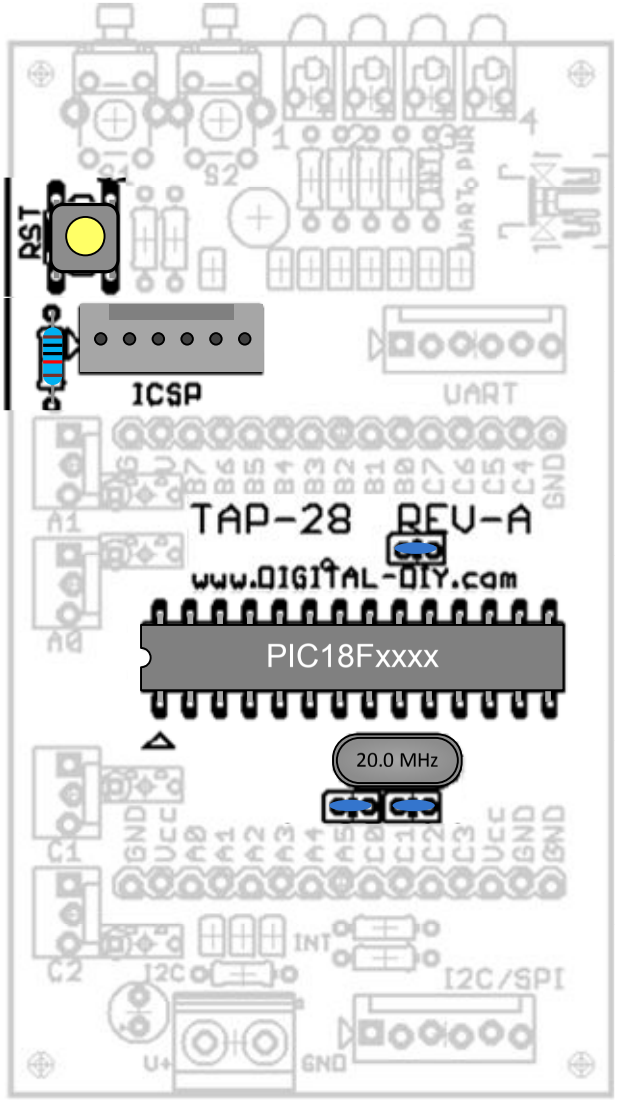
Options

The typical minimal configuration is shown at right. This is based on using ICSP for programming and an external crystal for the oscillator.

The bypass capacitor (0.1 µF) above the microcontroller is essential to operation and should not be left off.

Some 18F-series microcontrollers have internal oscillators; if the internal oscillator is used, the crystal and associated capacitors may be eliminated.

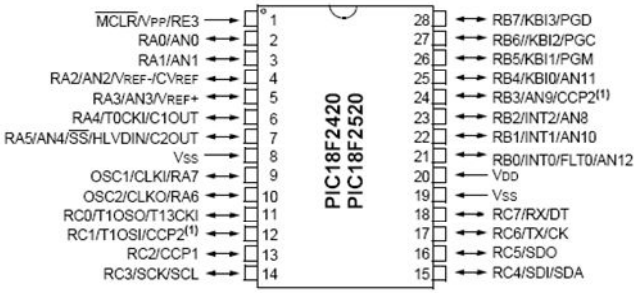
A socket for the microcontroller is usually recommended in case you want to try different types or the PIC dies a tragic death.



Microcontrollers

Many PIC18F-series parts may be used with the TAP-28. If the port/function mapping matches the pin diagram below, the part may be used with the TAP-28.

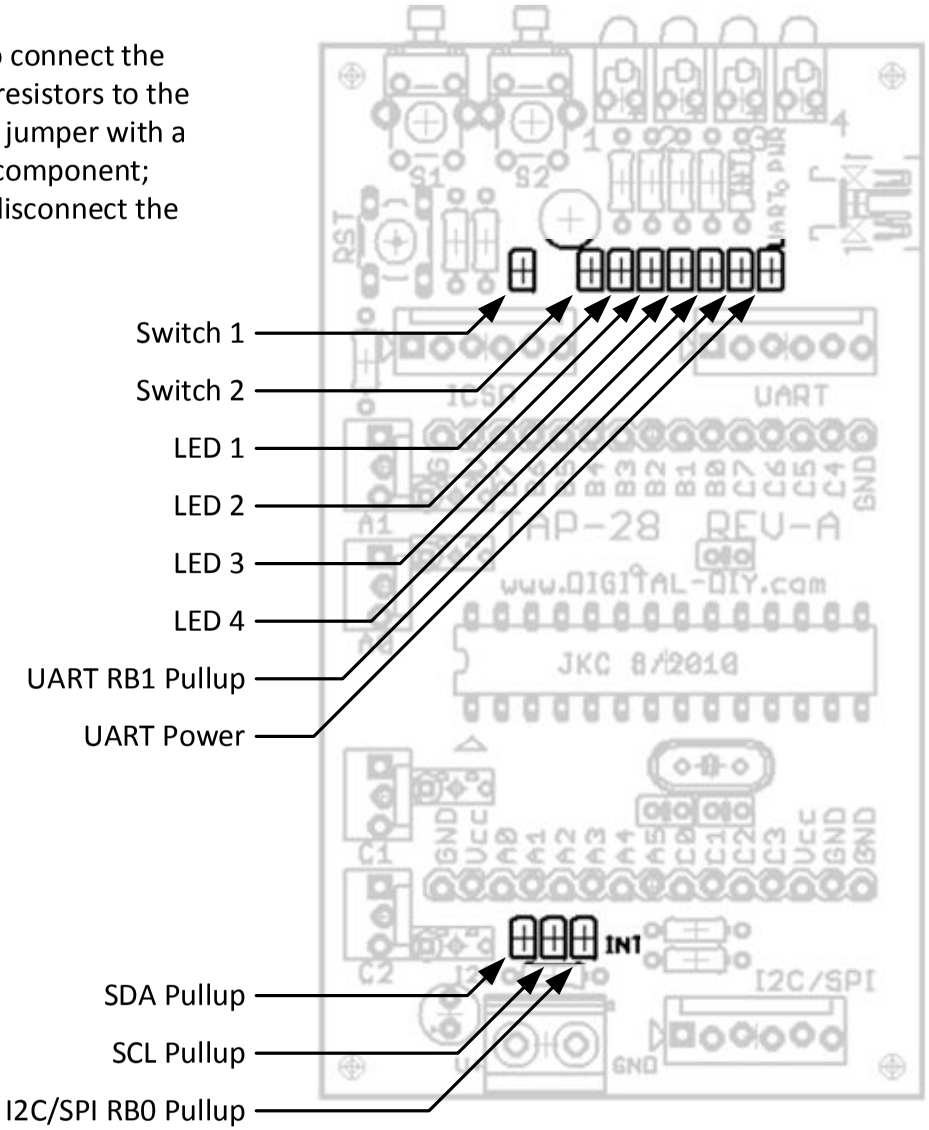
Other parts may be used if power and ground match the pin diagram but some of port pins will not map correctly to the 3-pin and 6-pin connectors.

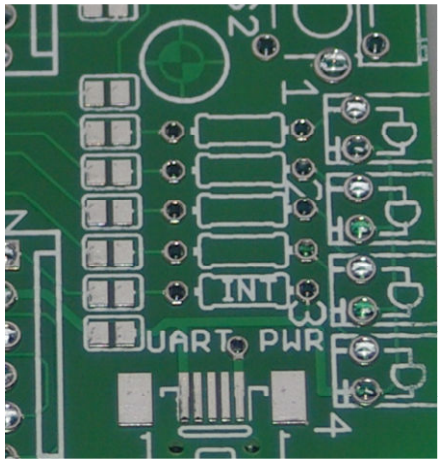


Jumper Locations

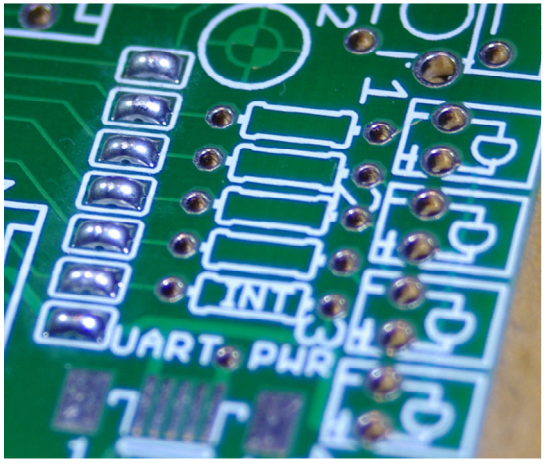
TAP-28, Rev. A

Solder jumpers are used to connect the switches, LEDs and pullup resistors to the microcontroller. Short the jumper with a solder ball to connect the component; remove the solder ball to disconnect the component.





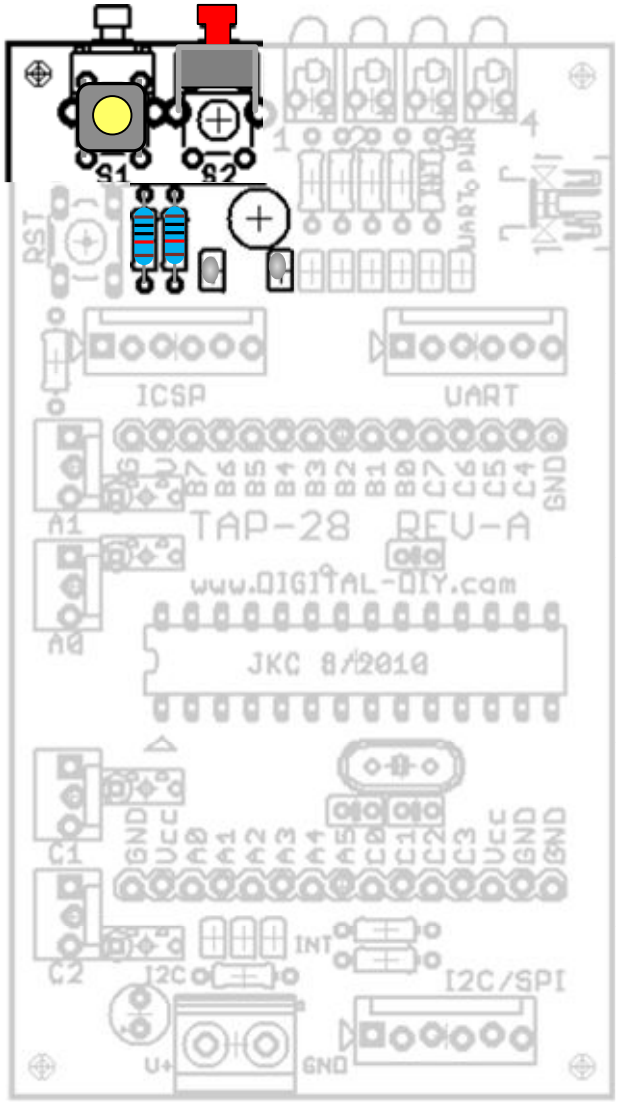
Open Solder Jumpers



Shorted Solder Jumpers

Switches

The switches may be used for general program input. Uses include starting a process or selecting an option.



Options

Vertical switches may be used with the button in the plane of the board (the switch with the yellow button in the illustration. Horizontal switches may be used to extend through an end panel if the TAP-28 will be mounted in an enclosure (the red switch in the illustration).

Programming Guidance

S1 is connected to port B.5
S2 is connected to port B.4
When a switch is not pressed, the port pin will be pulled high by the pullup resistor.
When a switch is pressed, the port pin will be pulled low.

Configuration

Select either vertical or horizontal switches depending on the application.

10kΩ is suggested for the pullup resistors.

The solder jumpers must be bridged to connect the switches into the circuit.

LEDs

LEDs can be used to indicate program information, status and are very useful for troubleshooting.

Options

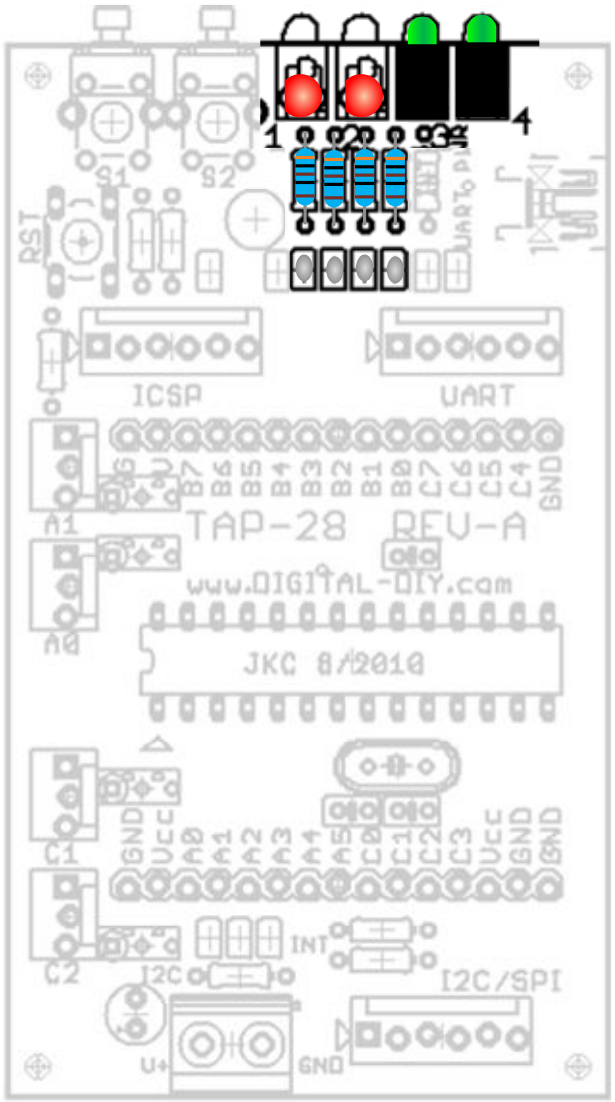
Standard T1 LEDs may be used as indicators (the red LEDs in the illustration) or right-angle LEDs may be used so that the LEDs can extend through a panel (the green LEDs in the picture.

LEDs may be the same or different colors. The Vf of some colors may be too high to operate with 3.3V PICs.

Programming Guidance

LED1 is connected to port A.5
LED2 is connected to port B.3
LED3 is connected to port C.0
LED4 is connected to port A.3

An LED is illuminated when the associated port pin is low. The LED is extinguished when the port pin is high or configured as input.



Configuration

The port pins on most PIC microcontrollers can source or sink 25 mA. Usually 10 mA is satisfactory for indicator LEDs.

$R_{LED} = (VDD – Vf_{LED})/I$

Where

R_{LED} = Resistor for the LED
VDD = supply voltage
Vf_{LED} = forward voltage of the LED
I = current in AMPS

301Ω is suggested for general purpose red LEDs.

Diffused LEDs are recommended.

Six-Pin Connectors

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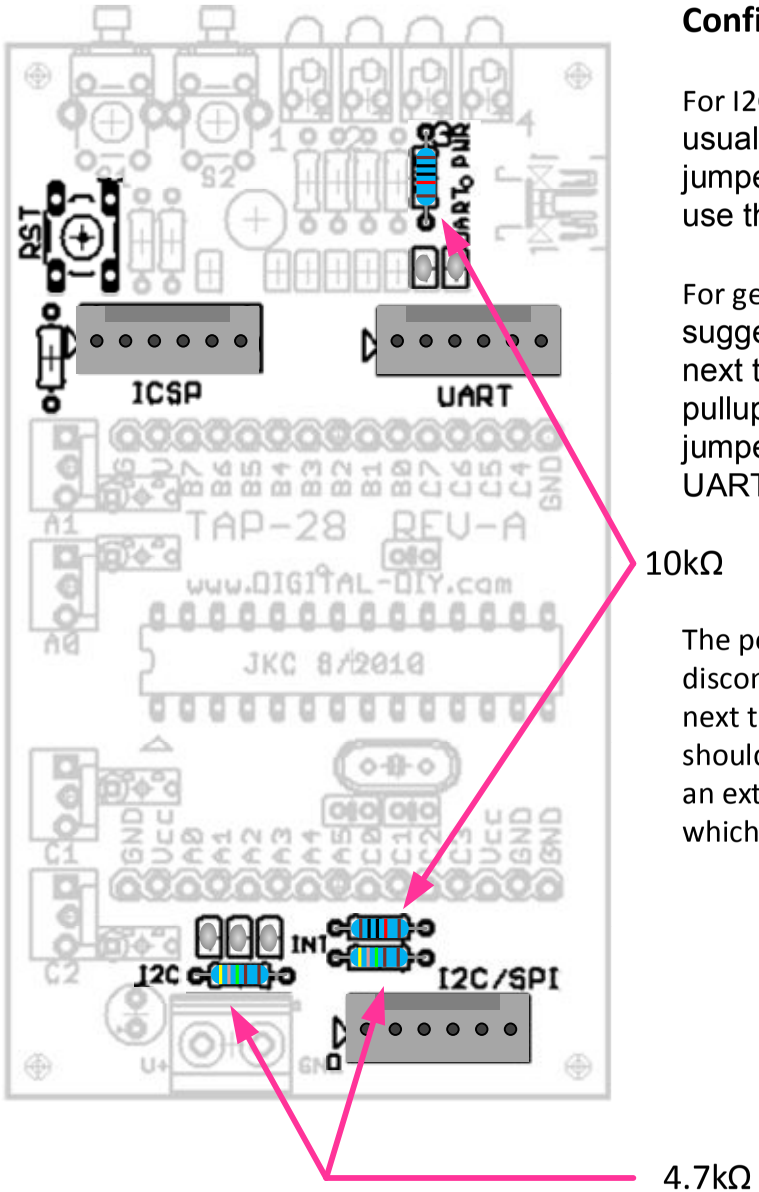
The 6-pin connectors are arranged by PIC hardware function: ICSP, UART and I2C/SPI. Each connector includes power and ground and may be used for the listed function or as 3 or 4 general-purpose port pins.

The port pin connections are shown on the "cheat sheet" page. The ICSP connector is unique – it has only 3 port pins (the other being /MCLR), but one of the 3 may be used as an analog input.

Options

The SCL and DTA lines on the I2C/SPI have pullup resistors, with a suggested value of 4.7k Ω. One pin on the I2C/SPI connector and one pin on the UART connector are connected to PIC interrupt lines and may have pullup resistors (10k Ω suggested) for use with open-drain interrupt lines on external devices. Solder jumpers must be bridged to connect the pullup resistors.

The V_{DD} pin of the UART connector features a solder jumper. If a USB-UART adapter is used and the TAP-28 is powered by another source, this jumper should be open.



Configuration

For I2C, 4.7kΩ pullup resistors are the usual choice. Short the left-hand pair of jumpers next to the I2C/SPI connector to use there resistors.

For general pullup resistors, 10kΩ is suggested. Short the right-hand jumper next to the I2C/SPI connector to use the pullup on its interrupt pin. Short the jumper adjacent to the resistor by the UART connector to use its pullup.

The power on the UART connector may be disconnected from the TAP-28 if the jumper next to the UART connector is open. This should be done if the TAP-28 is powered by an external supply and a USB-UART adapter which supplies power is used.

Three-Pin Connectors

The 3-pin connectors each feature one port pin, power and ground. Two of these connectors are analog inputs or general purpose I/O. The other two feature CCP/ PWM port pins which are used for PWM (pulse width modulation) output, counter inputs or general purpose I/O.

These connectors are ideal for analog or digital sensors, servos or for driving LEDs at variable brightness or motors at variable speeds.

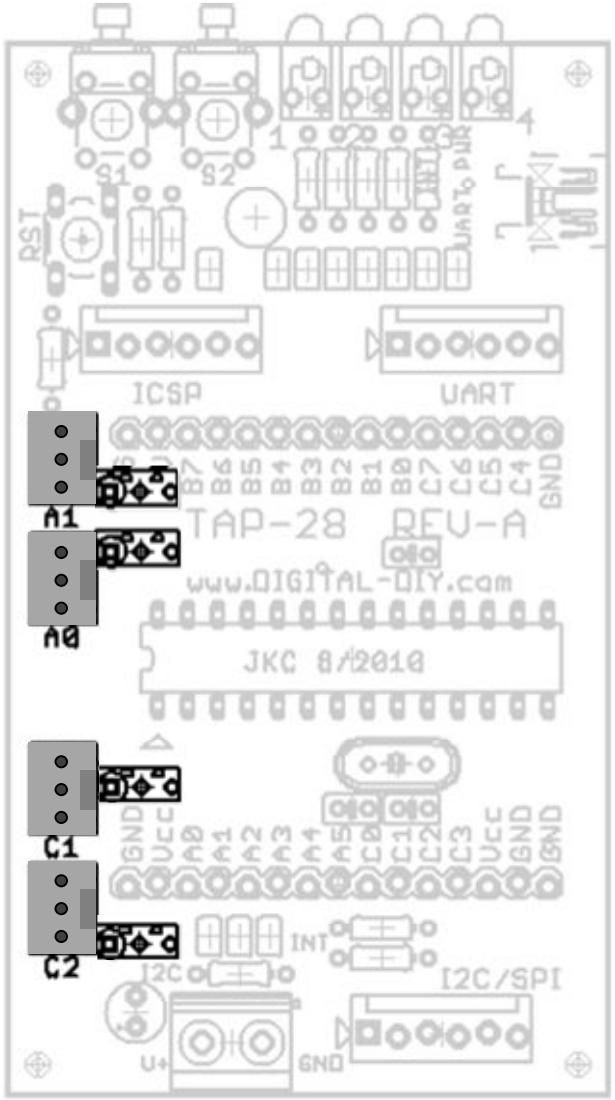
Options

None of these connectors feature built-in pullup resistors, but there is a mounting location adjacent to each connector where a pullup or pulldown resistor may be placed or a capacitor to either V+ or ground.

Pullup Resistor

Pulldown Resistor

To add a pullup or pulldown resistor, one end of the resistor will be inserted in the pad closest to the connector. The other end will be inserted in the second pad for connection to V+ or the third pad for connection to ground.



Programming Guidance

Connector	Function
A1	Analog Input or General I/O
A0	Analog Input or General I/O
C1	PWM or General I/O
C2	PWM or General I/O

Note that CCP1 is connected to port pin C2, while CCP2 is connected to port pin C1.

Using either the ADC input or PWM output requires specific setup beyond the scope of this document. Consult your language reference or user's group for details.

Power Connections

Power can be supplied to the TAP-28 in several ways.

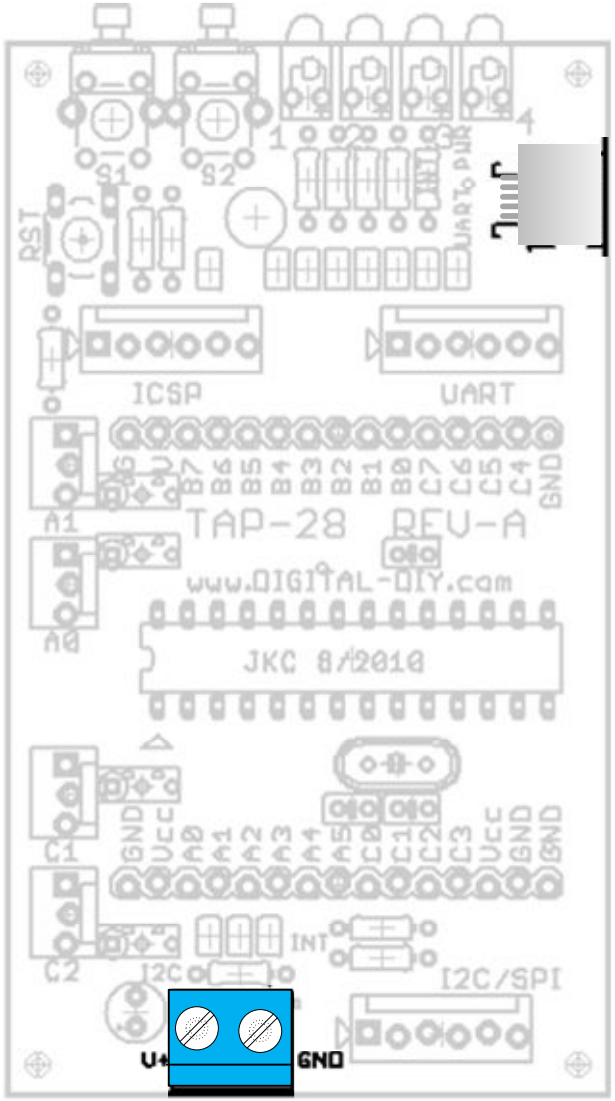
Caution: The TAP-28 board does not include a voltage regulator or reverse-polarity protection. Use a regulated external supply of the appropriate voltage.

Power may be provided via a mini-USB-B connector (power only), a two position terminal strip or through any of the 6-pin or 3-pin connectors.

Options

During development, power may be supplied from a PICkit 2 or PICkit 3 programmer.

If a USB-UART adapter is used, it may be used to supply power to the board. These adapters often have an option of either 5 volts or 3.3 volts, making them ideal for use with low-voltage microcontrollers. If an adapter will be used for power, the right-hand jumper above the UART connector must be shorted.



Configuration

A regulated supply must be used with the TAP-28. A regulated 5 volt supply from a cell phone is often a convenient choice.

If a low-voltage microcontroller is used (PIC18F25K20, used with the Amicus system, for example), a 3.3 volt supply must be used.

For low-voltage applications, a pair of AA batteries may be a good choice for power.

Daughterboard

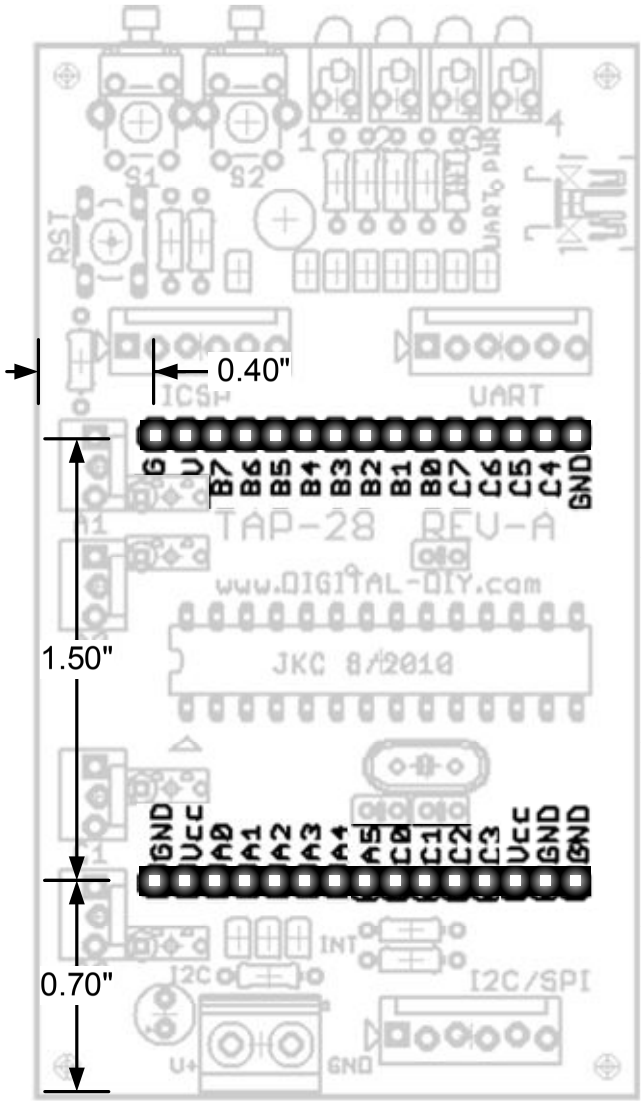
The daughterboard connectors bring out all port pins for access. Components may be added to the TAP-28 using the daughterboard connectors or external components or circuits may be connected to the TAP-28 board using jumpers.

Options

Female headers are the usual choice for the daughterboard connectors. A small circuit board with header pins may be plugged into the female headers. Jumpers may also be inserted into the female headers to make port pins accessible to a bread board or other circuit.

The size of a daughterboard installed on top (the component side) of the TAP-28 is limited by the connectors and connector access.

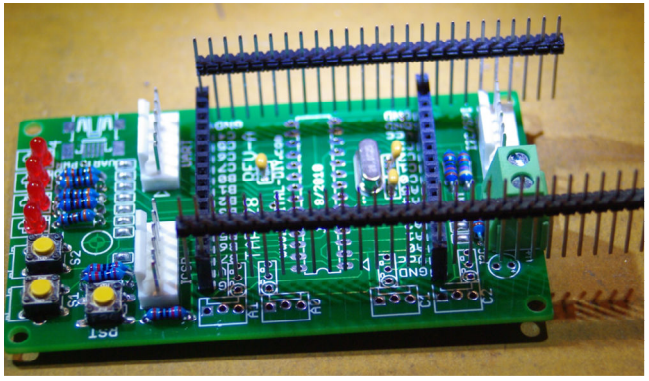
Alternatively, the header connectors may be installed on the bottom (non-component side) of the TAP-28; in this case, the daughterboard can be as large as desired. This is useful for added an LCD display to the TAP-28 as an example.



Construction Tips

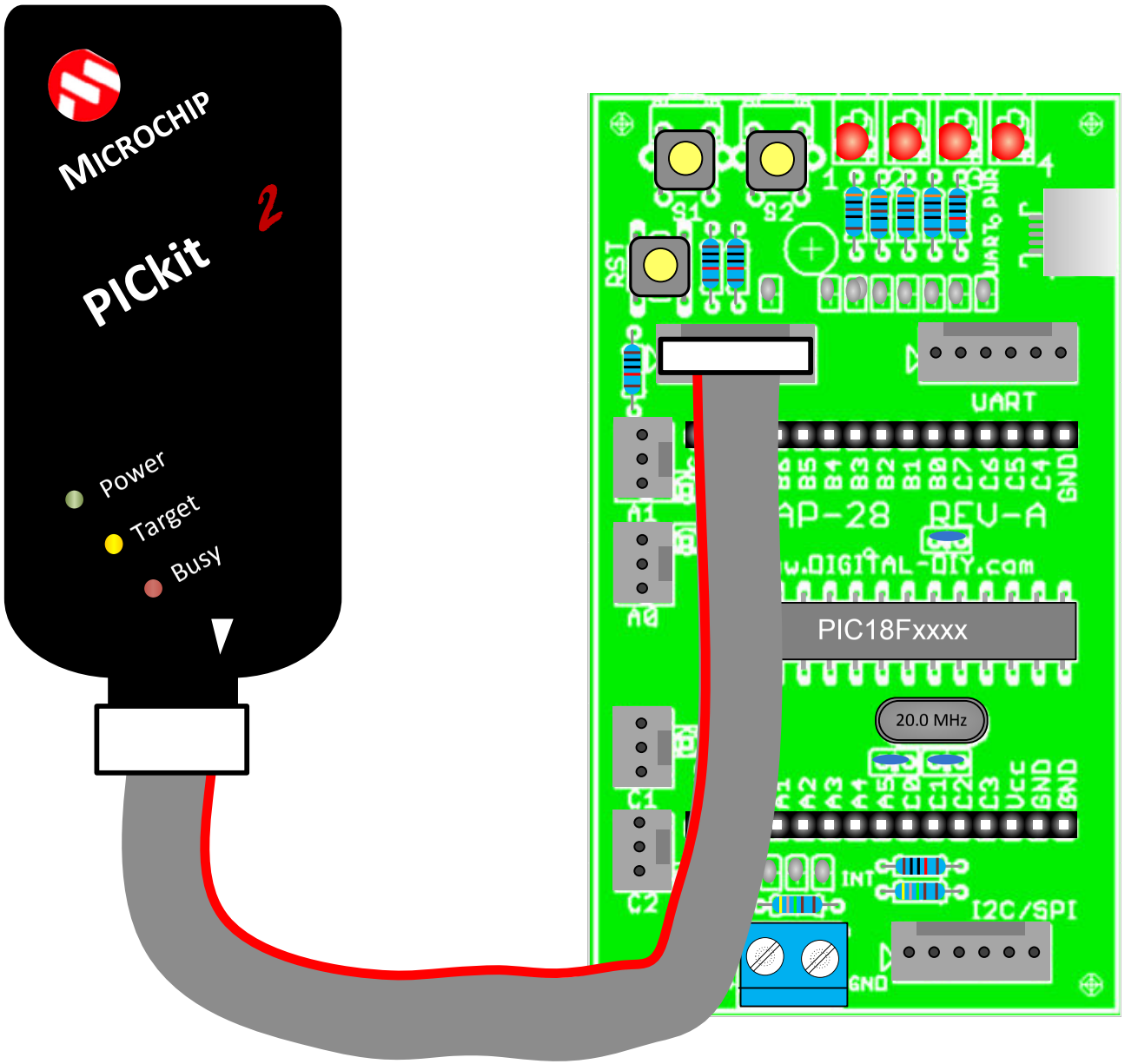
Longer sections of either female header strips or pin strips may be trimmed to length.

In order to get the header strips perpendicular to the board, the strips may be bridged with one or two sections of header pins to hold them in alignment while they are soldered into position.



ICSP (In-Circuit Serial Programming)

TAP-28, Rev. A



The microcontroller on the TAP-28 may be programmed in place using ICSP (In-Circuit Serial Programming).

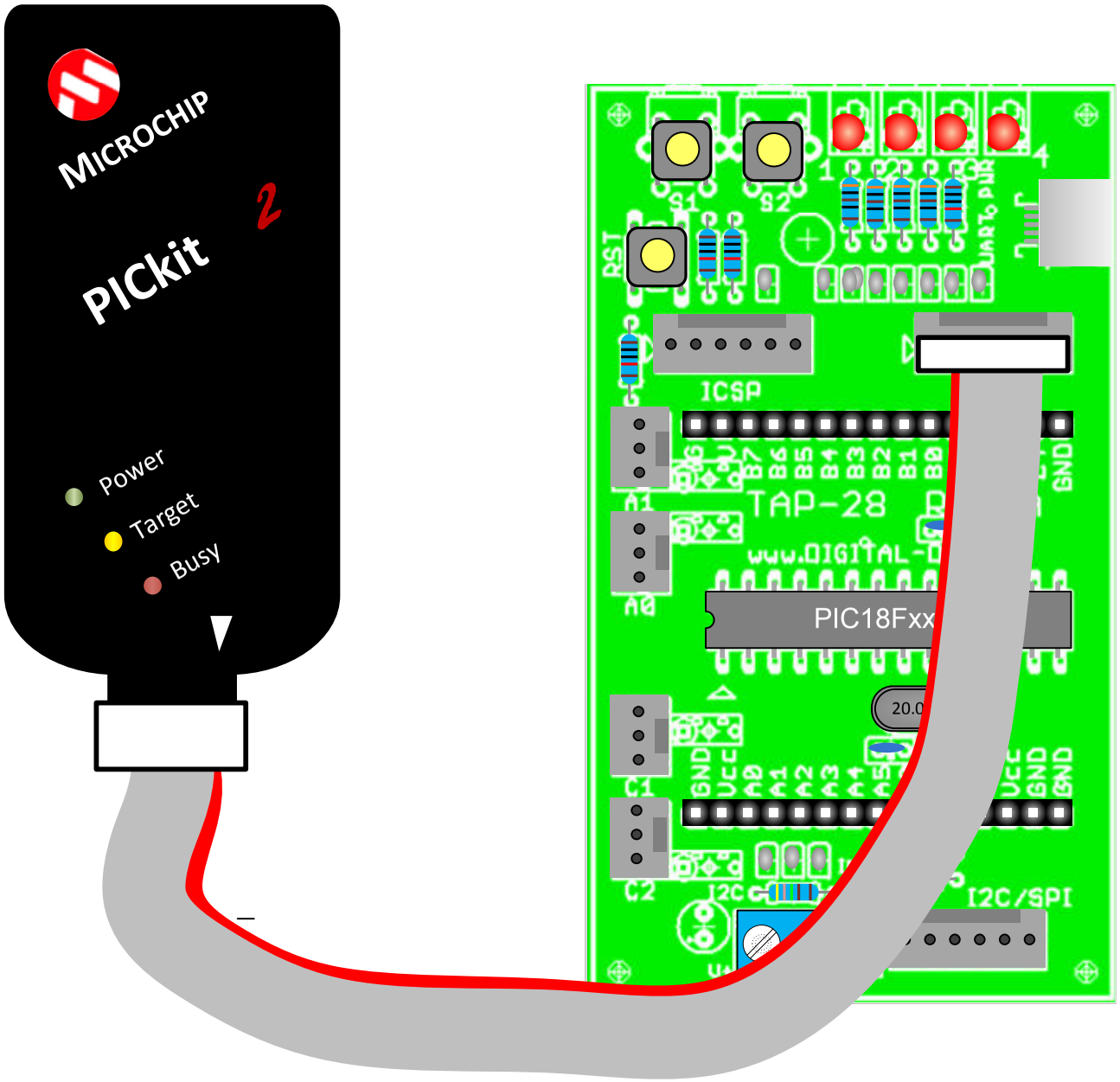
The PICkit 2 or PICkit 3 programmers from Microchip are recommended for programming. The ISCP connector on the TAP-28 matches the PICkit programmers. The programmer can be plugged in directly, but using a 6-pin jumper is recommended.

Be sure to match the pin 1 indicators no matter how the PICkit is connected.

See the TAP-28 web page for connection alternatives.

PICkit 2 UART Tool

TAP-28, Rev. A



The PICkit 2 contains a UART tool (this feature is not available on the PICkit 3 at this time) that allows serial communications with a host PC. This is extremely handy for monitoring program operation and troubleshooting.

The UART connector on the TAP-28 matches the PICkit 2 pinout. The PICkit may be connected directly, but a short jumper cable is recommended.

Be certain to match the pin 1 indications no matter how the connections are made.

Programming Guidance

The baud rate and other serial parameters must be configured in the code running on the TAP-28 and in the UART Tool GUI to match. For example, a setting of

9600N1

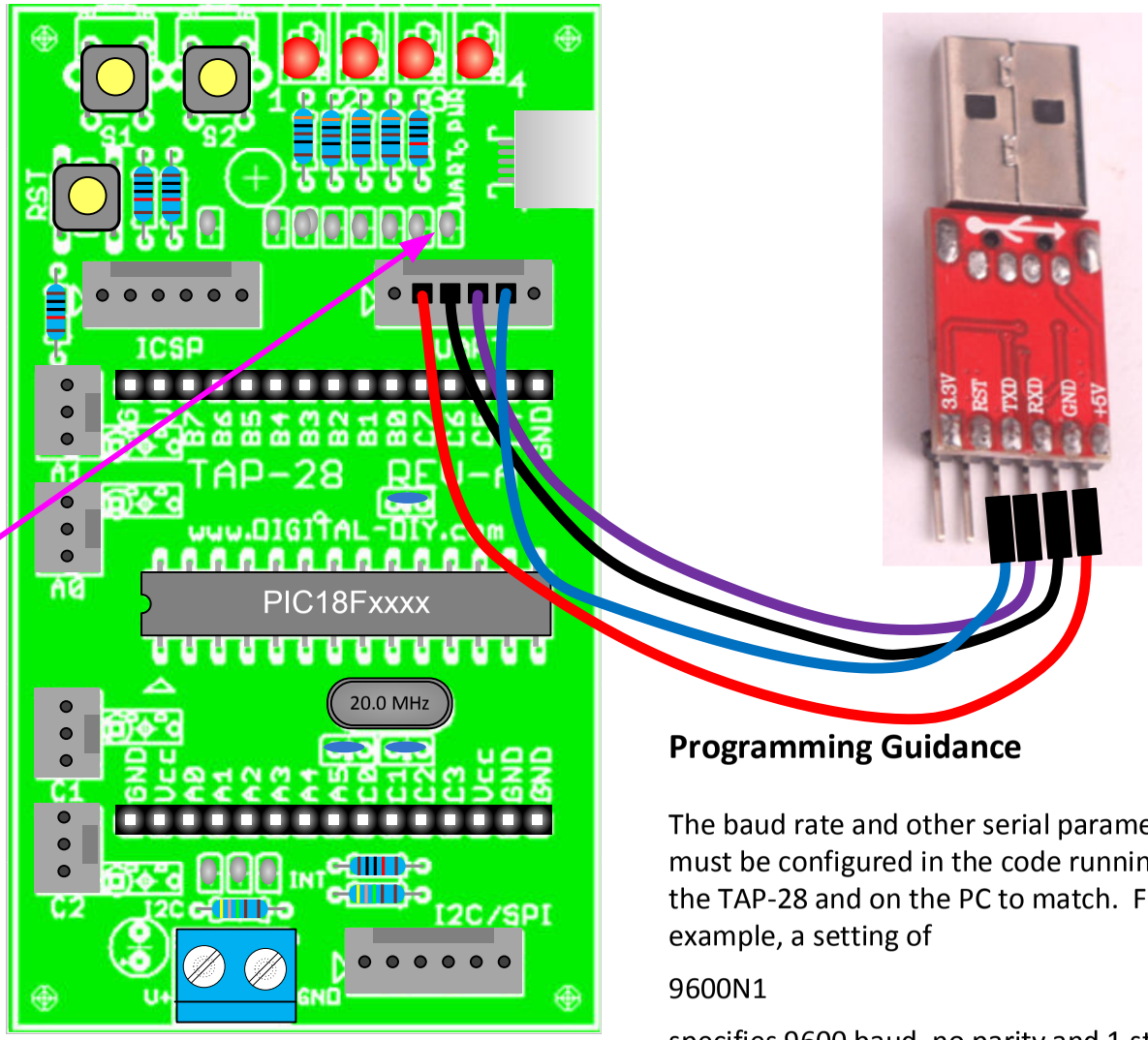
specifies 9600 baud, no parity and 1 stop bit. If parameters don't match, the transmission will be garbled..

USB-UART Adapter

TAP-28, Rev. A

UART (serial) I/O allows communication between the TAP-28 board and a PC. This may be useful during program development or may profile a user-interface on a computer. It may also be used as part of a data-logger to off-load data to a PC.

The USB adapter shown and similar types are available cheaply on ebay. In addition to providing communications to a PC, they may also provide power to the TAP-28 board. In the case shown, either 5v or 3.3v power may be selected, making this adapter very handy for use with the PIC18F25K20 required by Amicus or other low voltage parts.



Configuration

TAP-28 power should be isolated from adapter power if the TAP-28 is powered by another source. To isolate power, the UART PWR solder jumper should be open.

The GND connections of the TAP-28 and adapter must be connected. The TxD line from the adapter goes to the RxD line of the TAP-28 and vice versa.

Note: Some adapters are labeled from the micro's point of view, in which case the connections would be reversed.

Programming Guidance

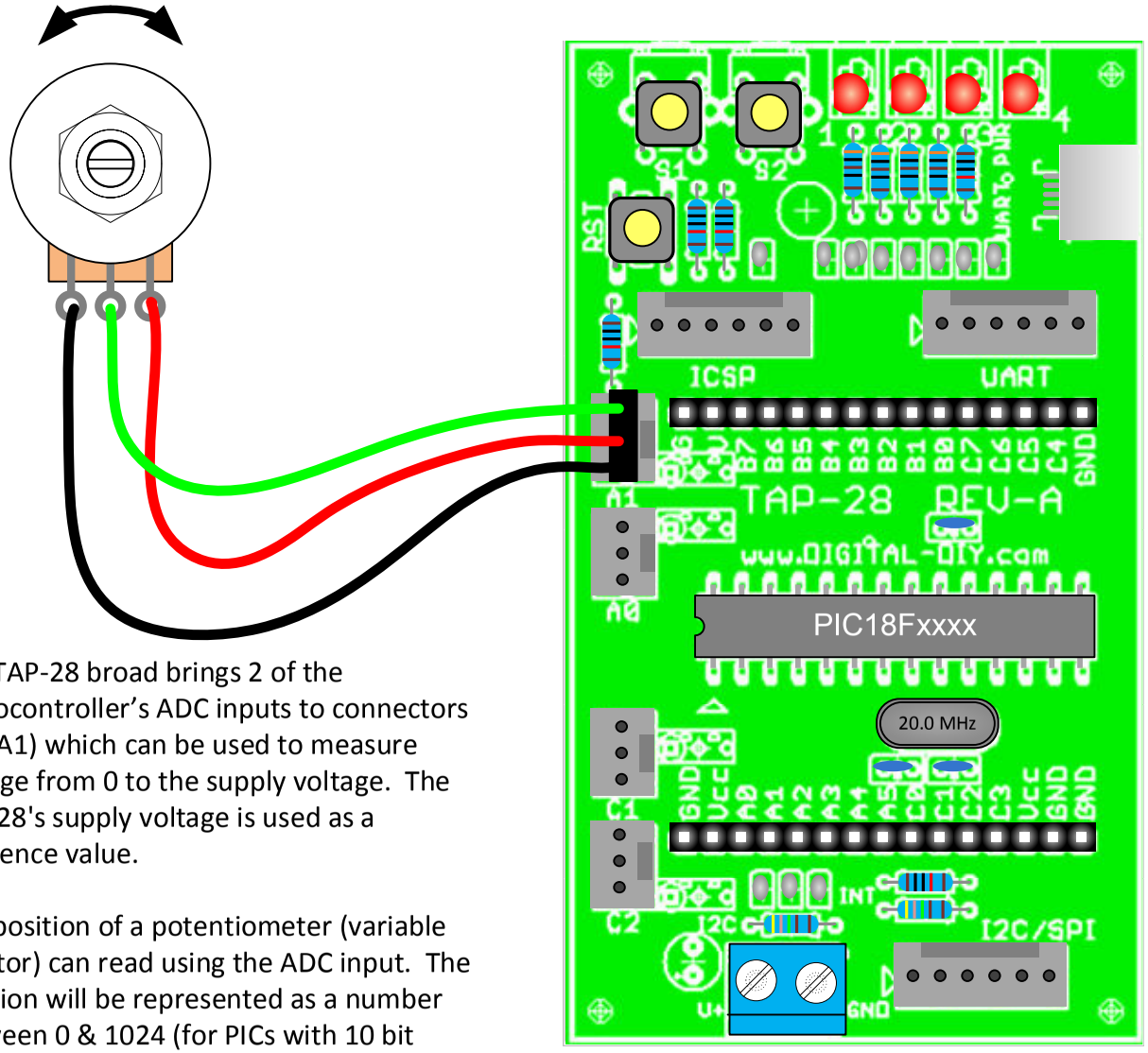
The baud rate and other serial parameters must be configured in the code running on the TAP-28 and on the PC to match. For example, a setting of

9600N1

specifies 9600 baud, no parity and 1 stop bit. If parameters don't match, the transmission will be garbled..

Potentiometer / ADC Input

TAP-28, Rev. A



The TAP-28 broad brings 2 of the microcontroller's ADC inputs to connectors (A0, A1) which can be used to measure voltage from 0 to the supply voltage. The TAP-28's supply voltage is used as a reference value.

The position of a potentiometer (variable resistor) can read using the ADC input. The position will be represented as a number between 0 & 1024 (for PICs with 10 bit ADCs.)

As the pot is rotated, the voltage at the wiper terminal varies from 0 to V_{supply}. This can be used to test ADC readings, to simulate an analog sensor or to provide a control input to code running on the microcontroller.

Programming Guidance

Several parameters must be configured properly to use the ADCs. The exact syntax required depends on the programming language used and is beyond the scope of this document.

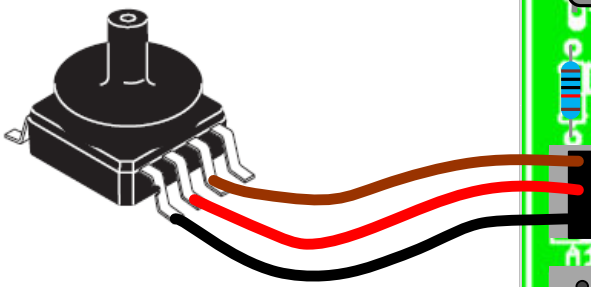
One important point is that the Port A pins have analog and digital functions. The pins must be configured as analog inputs to read an analog signal.

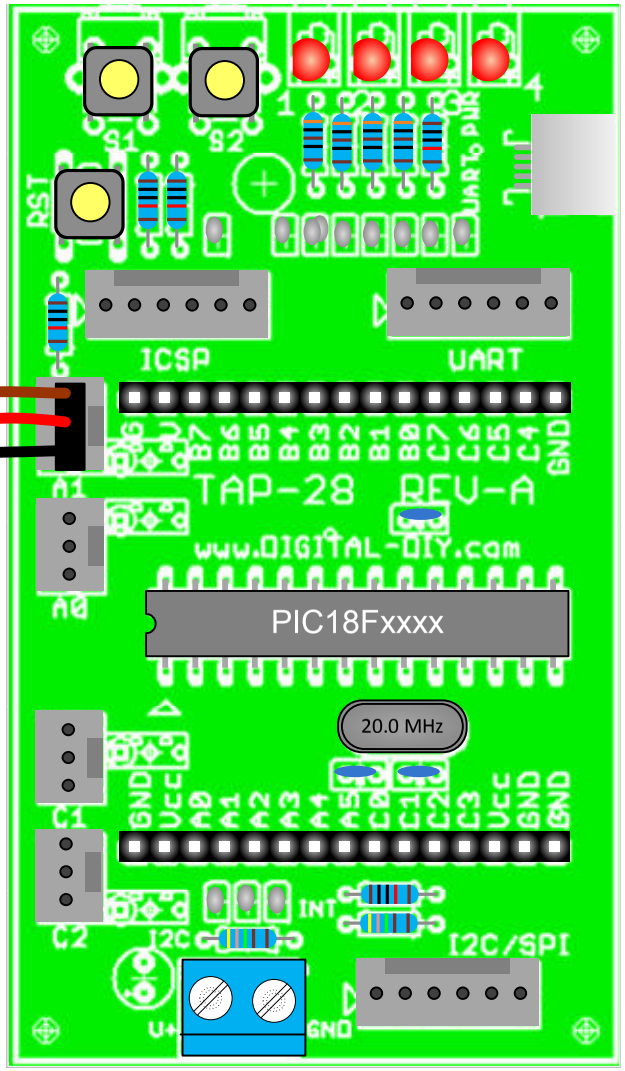
The output from the ADC will vary between 0 & 1024. Scaling will be needed to convert to relevant units. Some microcontrollers have 12-bit ADCs – these may be used where more resolution is needed.

Analog Sensor / ADC Input

TAP-28, Rev. A

One common function of an embedded microcontroller is reading analog sensors. The TAP-28 board brings two analog inputs to connectors (A0, A1) which may be used to read voltage levels over a 0 – V_{supply} range.





Sensors are available in different configurations. The easiest-to-use analog sensors have integral signal conditioning and provide an output tailored for use with microcontrollers.

Sensors without built-in signal conditioning may put out a maximum level of less than 1 volt. This type of sensor will require additional circuitry to increase the output level to the desired range.

Programming Guidance

Several parameters must be configured properly to use the ADCs. The exact syntax required depends on the programming language used and is beyond the scope of this document.

One important point is that the Port A pins have analog and digital functions. The pins must be configured as analog inputs to read an analog signal.

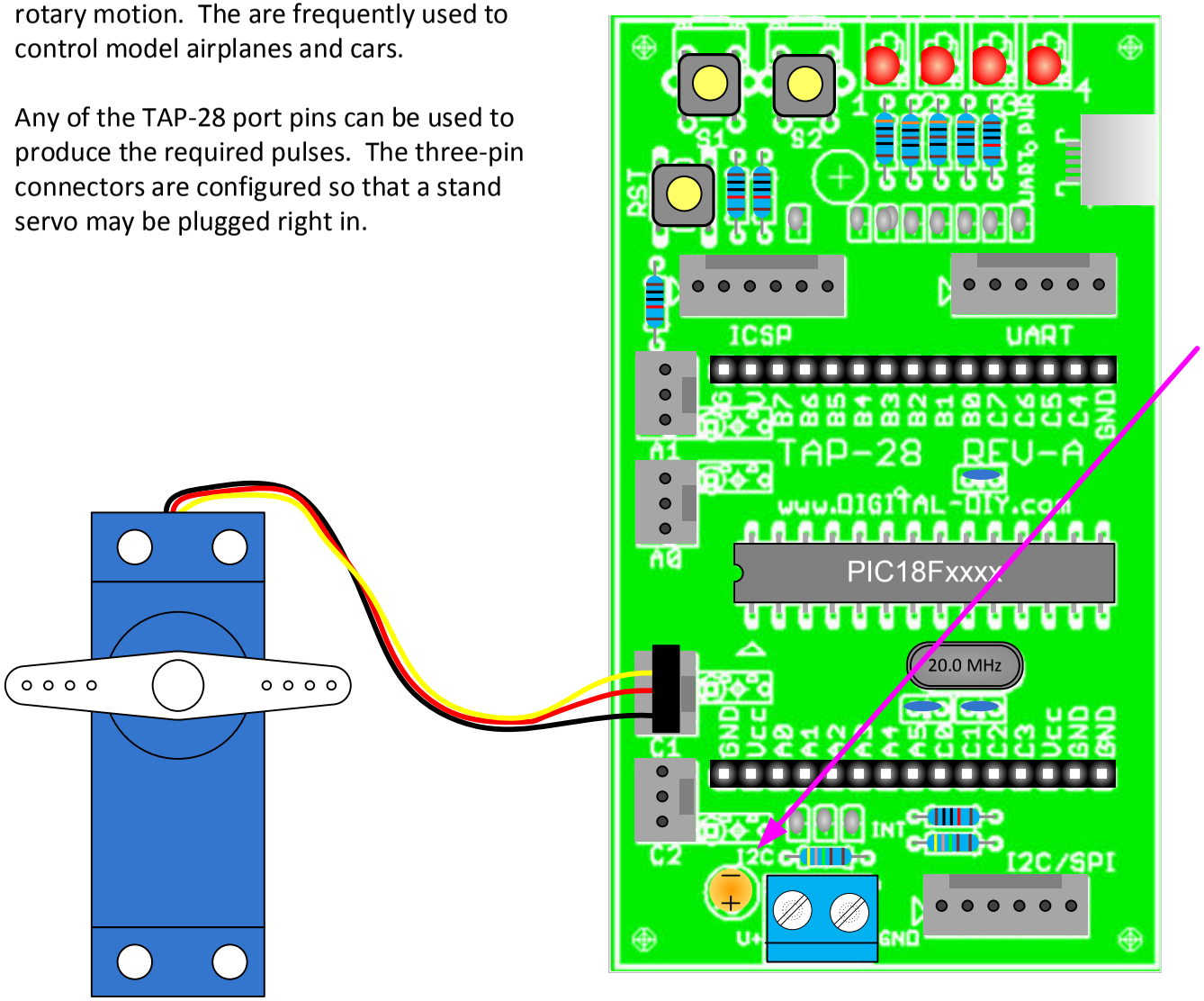
The output from the ADC will vary between 0 & 1024. Scaling will be needed to convert to relevant units. Some microcontrollers have 12-bit ADCs – these may be used where more resolution is needed.

If a transducer produces a low output level, say 0.5 volts, only a small part of the ADC range will be used – in this case, the output would only vary by 100 counts from minimum to maximum.

Servo

Hobby servos convert a pulse train into a rotary motion. The are frequently used to control model airplanes and cars.

Any of the TAP-28 port pins can be used to produce the required pulses. The three-pin connectors are configured so that a stand servo may be plugged right in.



Configuration

Two color codes are used for servo connections. Servos should be connected as follows:

Signal	Power	Ground
white	red	black
yellow	orange	brown

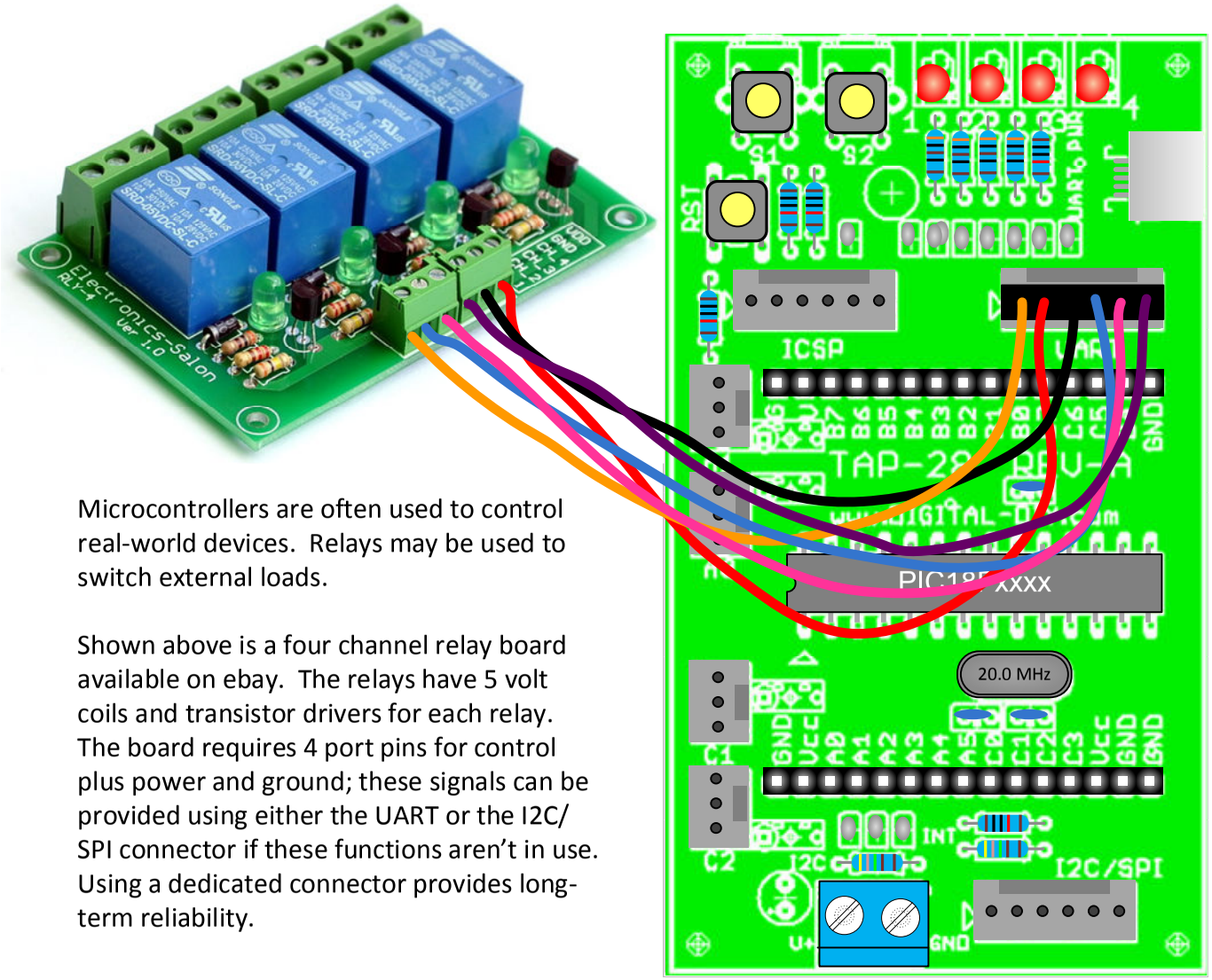
An electrolytic or tantalum capacitor of 1 µF to 10 µF may be desirable to suppress spikes generated when driving a servo.

Programming Guidance

Numerous examples of controlling servos with a microcontroller exist on the web, including some excellent examples at Digital-DIY.com.

Relay Board – 4 Channels

TAP-28, Rev. A



Microcontrollers are often used to control real-world devices. Relays may be used to switch external loads.

Shown above is a four channel relay board available on ebay. The relays have 5 volt coils and transistor drivers for each relay. The board requires 4 port pins for control plus power and ground; these signals can be provided using either the UART or the I2C/SPI connector if these functions aren't in use. Using a dedicated connector provides long-term reliability.

Programming Guidance

Relay	UART	I2C/SPI
1	Port B.1	Port B.0
2	Port C.6	Port C.4
3	Port C.7	Port C.3
4	Port B.2	Port C.5

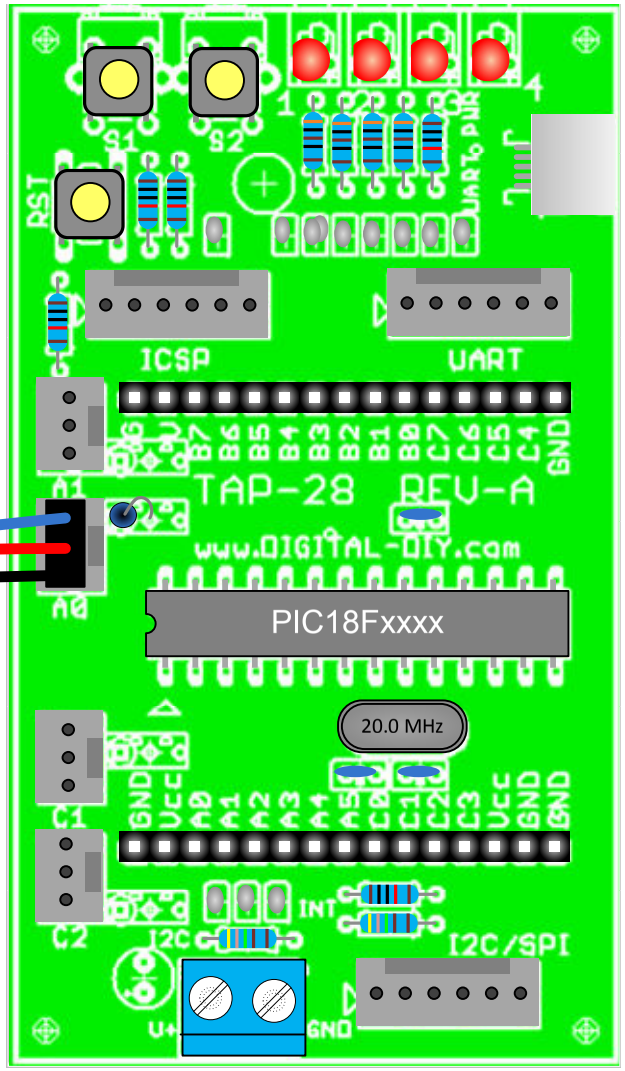
The six-pin connectors follow the same pinout pattern, so either the UART or I2C/SPI connector may be used by changing which port pins are used.

This relay board features SPDT contacts. The coil is energized when the port pin is high.

Note: This relay board is available with either 5v or 12v coils. If 5v coils are used, the board may be powered for the same source as the TAP-28. If 12v coils are used, the relay board will need a separate 12v power supply.

Dallas One-Wire

TAP-28, Rev. A

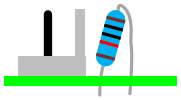


Maxim-Dallas makes a variety of chips and sensors that can communicate over a "One-Wire" bus (actually data, ground and sometimes power). One of the most popular sensors is the DS18B20 temperature sensor. Shown above is a temperature sensor assembly produced by Sure Electronics using the DS18B20. One or many sensors may be used on a single One-Wire bus.

The DS18B20 is accurate to 0.5°C without calibration and does not require use of an ADC input.

Configuration

One-Wire devices require a pullup to V_{DD}. Adjacent to each three-pin connector are mounting pads where a pullup or pulldown resistor may be installed. 4.7KΩ is typically used. Install the pullup resistor as shown below.

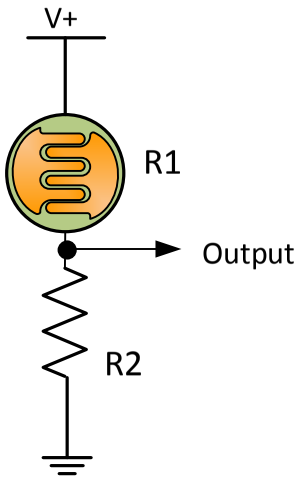


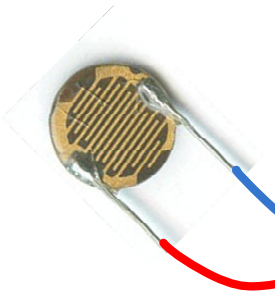
Programming Guidance

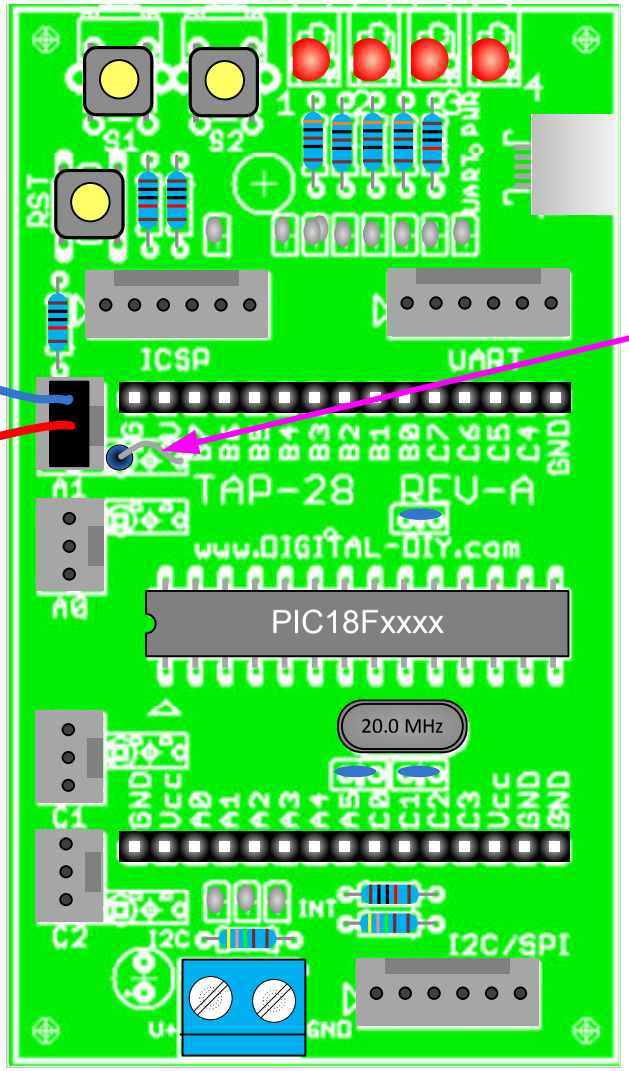
Any (digital) port pin may be used for a One-Wire interface. The three-pin connectors are ideal for this application because the needed pullup resistor may be easily added.

Note: The pinout of the Sure Electronics temperature probe does not correspond to the pinout on the TAP-28 board. An adapter cable may be made to match the pinouts. If a single sensor is to be used, the contacts may be removed from the connector housing and re-arranged to match the TAP-28.

Using a Photocell







A photocell changes resistance with light level. A photocell can be used to tell when a light beam is interrupted, to determine when it's dark enough to turn on the lights or to provide an indication of light level.

An ADC input can't measure resistance directly. To convert the photocell's resistance into something easy to measure, a voltage divider may be used. The output voltage from a voltage divider is proportional to the ratio of the resistors as shown above and by this equation:

$$V_{out} = V_{in} \frac{R2}{R1 + R2}$$

Since the resistance of the photocell drops with increasing light, the output voltage from the voltage divider increases.

Configuration

Connector A1 or A0 may be used for analog input. R2 in the schematic may be installed directly on the TAP-28 board in the mounting location adjacent to the connector. A value of 10kΩ is a good starting point, although this may vary depending on the photpcell characteristics.

One side of the photocell connects to pin 1 of the connector, which is the ADC input. The other side of the photocell connects to pin 2, which is V+.

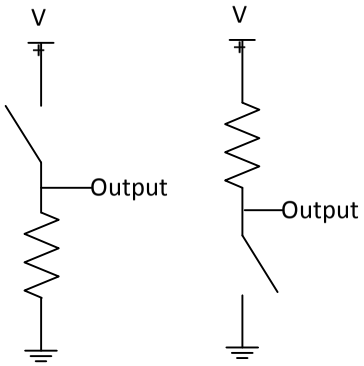
Configuration of the ADC input depends on the programming language used and is beyond the scope of this document. Consult the language reference or your favorite PIC forum.

Connecting an External Switch

TAP-28, Rev. A

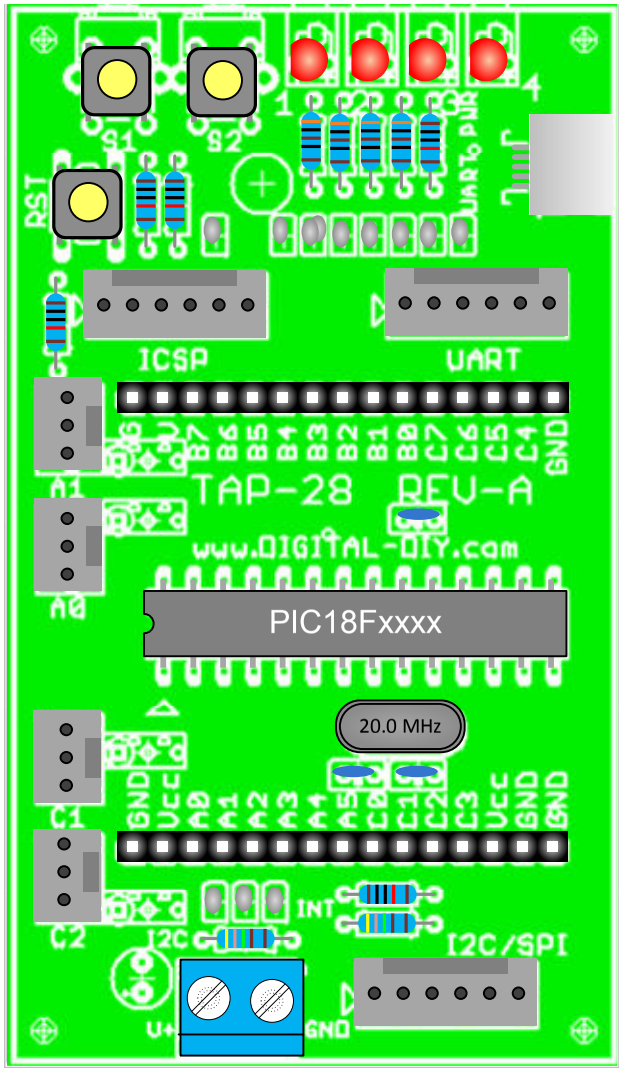
An external switch may be useful for remote control or sensing some external parameter. A magnetic reed switch could be used to detect a door opening, or a pressure mat (which closes a contact when stepped on) might be used to detect a visitor.

A switch must be connected to a pullup or pulldown resistor for the microcontroller to detect an open or closed contact.



The switch on the left is pulled low by the resistor when low. When the switch is closed, the output is high.

The switch on the right is pulled high by the resistor when open. When the switch is closed, the output is low.



Configuration

Any of the 3-pin connectors is great for use with an external switch. The necessary pullup or pulldown resistor may be added on the TAP-28 board in the mounting pads adjacent to the connector used.

A value of 10kΩ is suitable for the resistor.

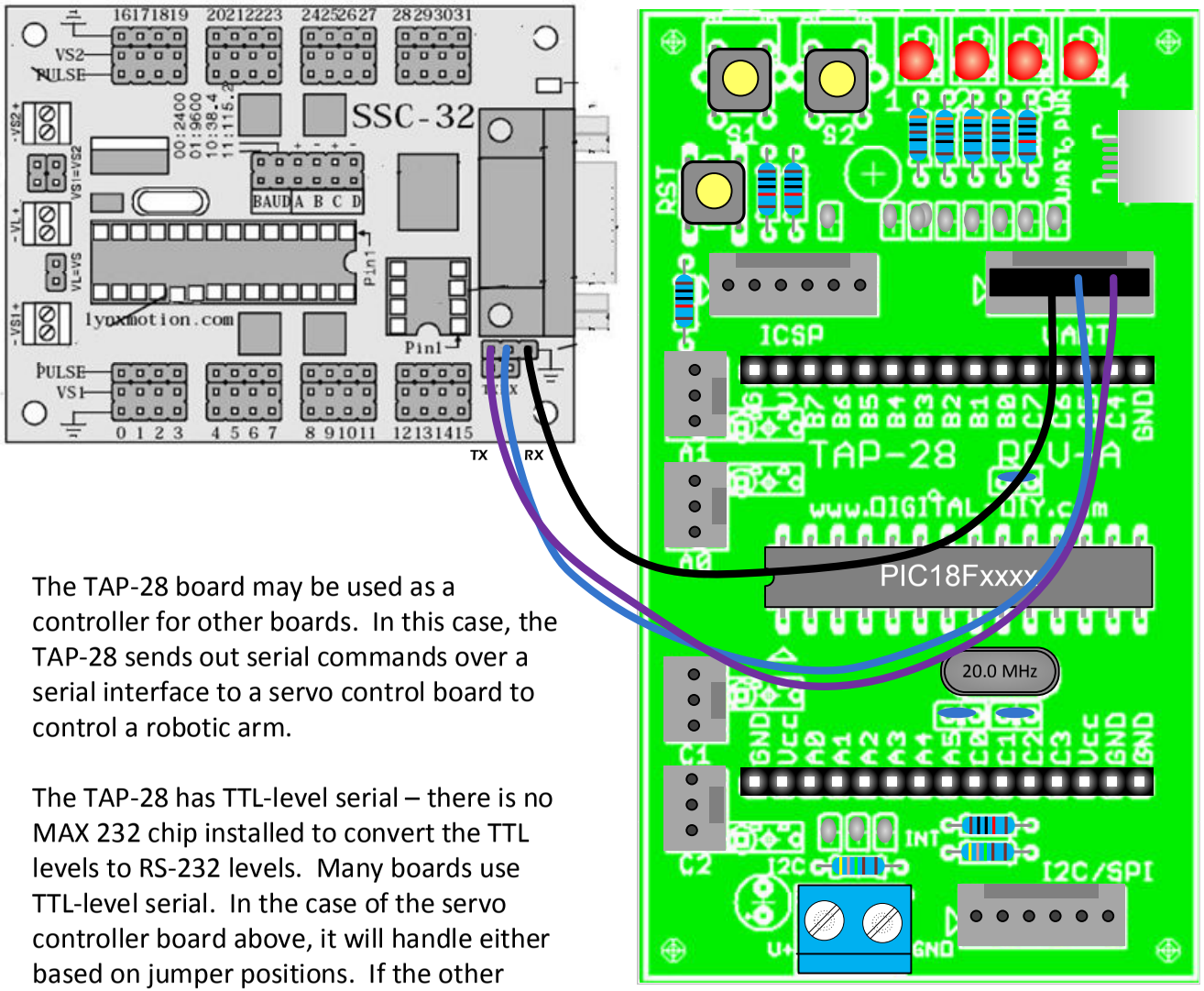

Pullup Resistor


Pulldown Resistor


Magnetic Reed Switch

Serial Communication

TAP-28, Rev. A



The TAP-28 board may be used as a controller for other boards. In this case, the TAP-28 sends out serial commands over a serial interface to a servo control board to control a robotic arm.

The TAP-28 has TTL-level serial – there is no MAX 232 chip installed to convert the TTL levels to RS-232 levels. Many boards use TTL-level serial. In the case of the servo controller board above, it will handle either based on jumper positions. If the other board has only RS-232 levels, a level converter must be used between the boards.

Configuration

One board's TxD line must be connected to the other board's RxD line and vice versa. This is sometimes confused by the labeling on some boards where the labels are from the perspective of what's being connected rather than its own signals. Check the documentation to be sure. A ground connection must always be made between the two boards.

Programming Guidance

The baud rate and other serial parameters must be configured in the code running on the TAP-28 and on the the other board to match. For example, a setting of

9600N1

specifies 9600 baud, no parity and 1 stop bit. If parameters don't match, the transmission will be garbled..

Bootloader

TAP-28, Rev. A

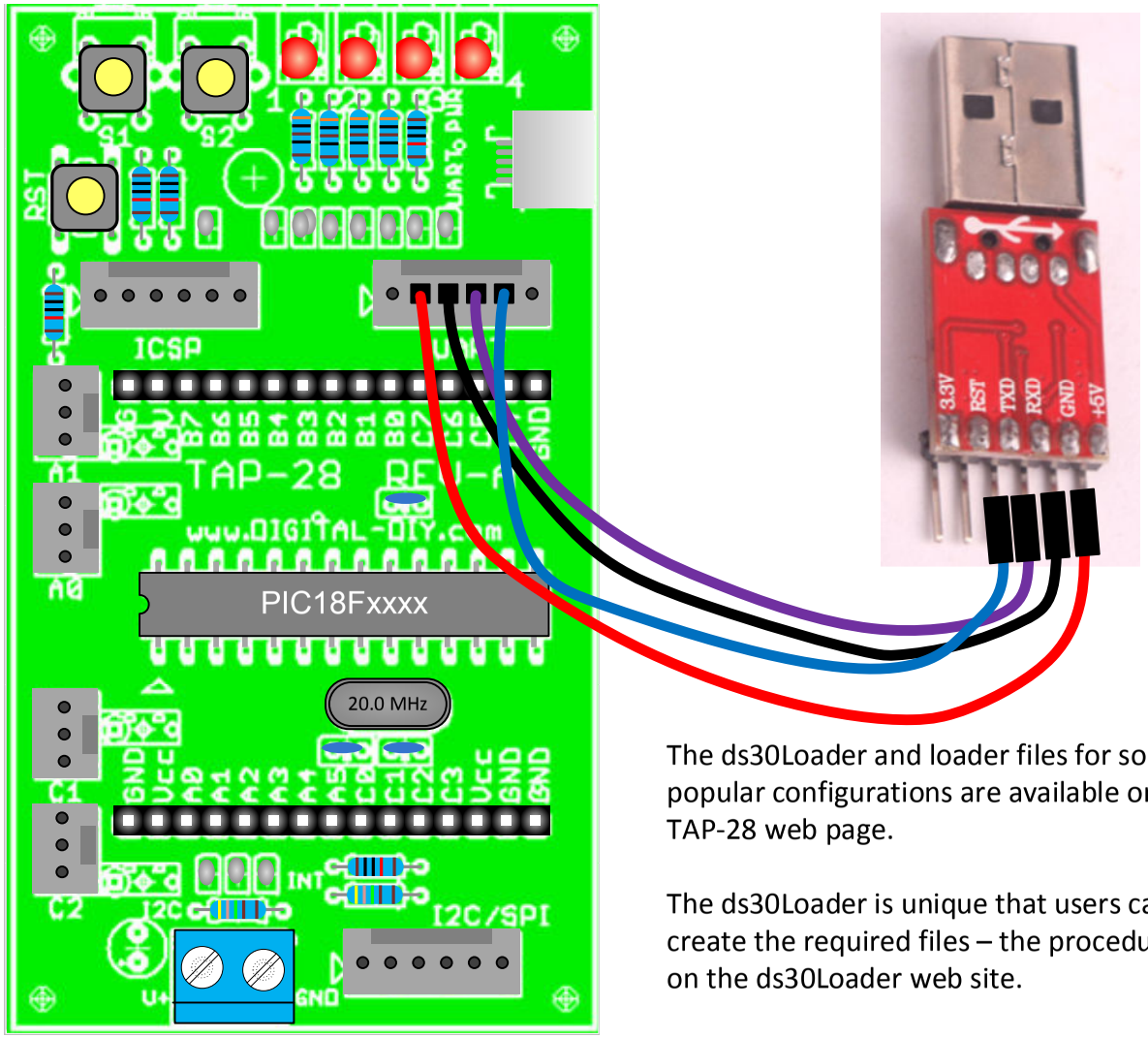
A bootloader can be used to load code into the microcontroller without the need for a programmer; *note however that to use a bootloader, a tiny program must be installed on the microcontroller, which does require a programmer.* After this code is loaded, it remains on the microcontroller until needed for use.

A bootloader is handy for making changes in the field at a later time, and might save you the need to have a programmer if someone with a programmer loads the required file for you.

Configuration

A UART-USB adapter or UART-RS-232 converter is needed to connect the TAP-28 to a PC to load program code. Loading code is simply a matter of connecting the TAP-28 to the PC, running the bootloader application on the PC and pressing the reset button on the TAP-28

The file loaded into the microcontroller must be matched to the clock speed, the type of micro and other optional parameters.



The ds30Loader and loader files for some popular configurations are available on the TAP-28 web page.

The ds30Loader is unique that users can create the required files – the procedure is on the ds30Loader web site.

Assembling The TAP-28

TAP-28, Rev. A

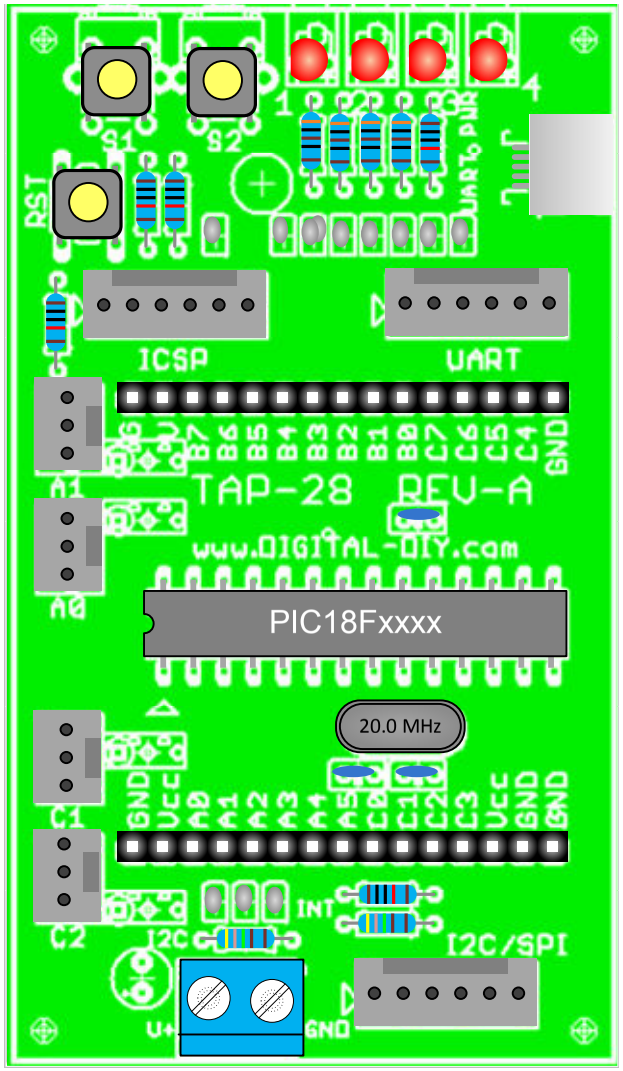
Browse the preceding pages and decide on any options you want to include. If the TAP-28 is being used as a general purpose development board, using the recommended parts is a good starting point.

A parts list with typical parts along with part numbers for Digikey and Mouser follows this page. The parts listed will work but they may not be the best choice for your particular application or the lowest cost parts available. Use the parts list for guidance. In general, buying small parts like resistors and capacitors one at a time is an expensive way to purchase them. The parts used on the TAP-28 are common values, so you might want to evaluate the price break points.

Assembly Order

The TAP-28 is fairly easy to assemble with no special techniques required. Starting with the solder jumpers is a good idea - it's easier to short them with some room to work.

Install the smaller parts first - it's easier to fit them in that way. The connectors should be the last items installed as their size limits access to the smaller parts.

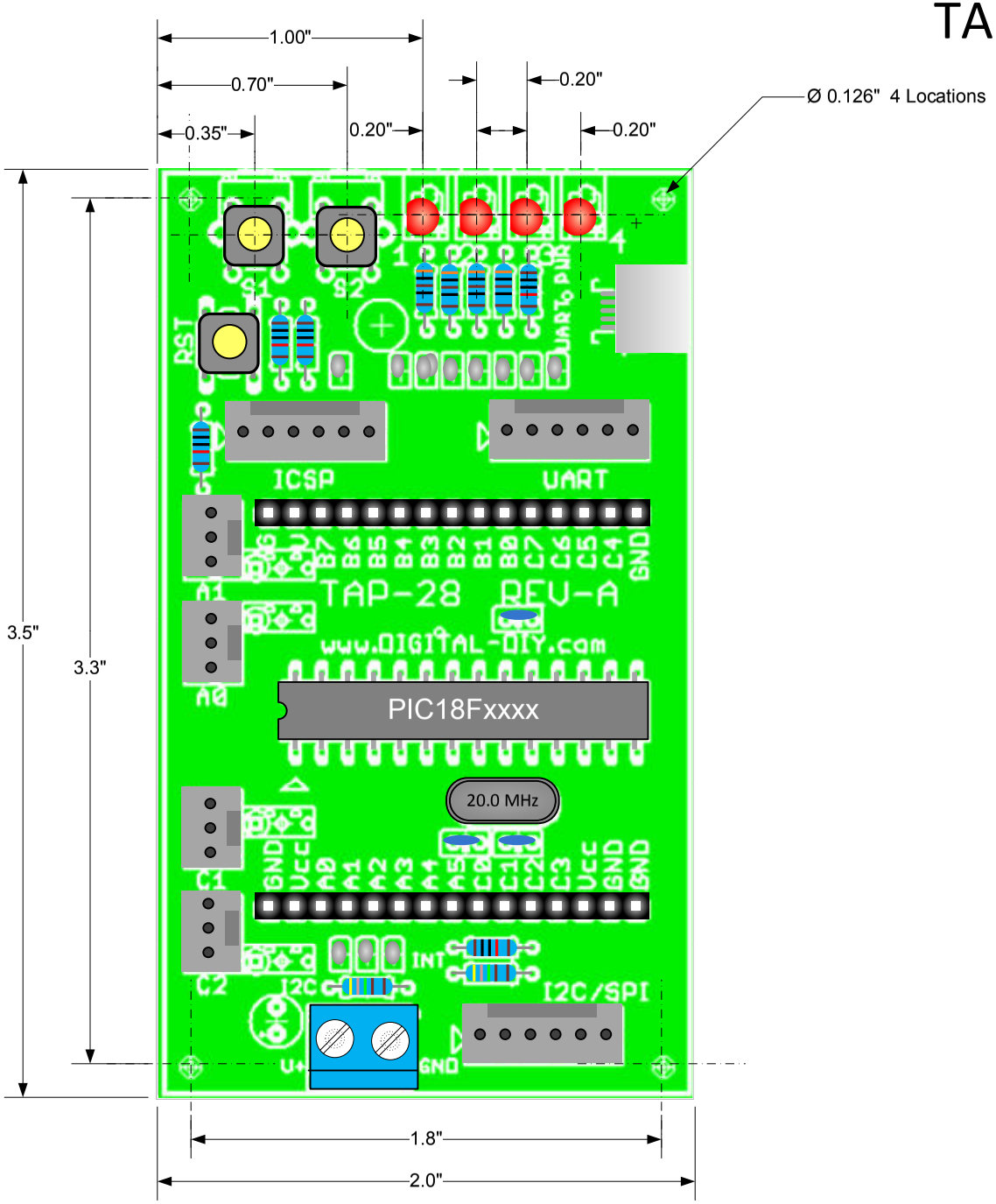


Notes

- The polarity of the LEDs is important. The flat side should be oriented towards the switches.
- The direction of keyed connectors is important. Locate them with the alignment tabs as shown.
- A socket is recommended for the microcontroller.
- Install the microcontroller with pin 1 in the marked location.

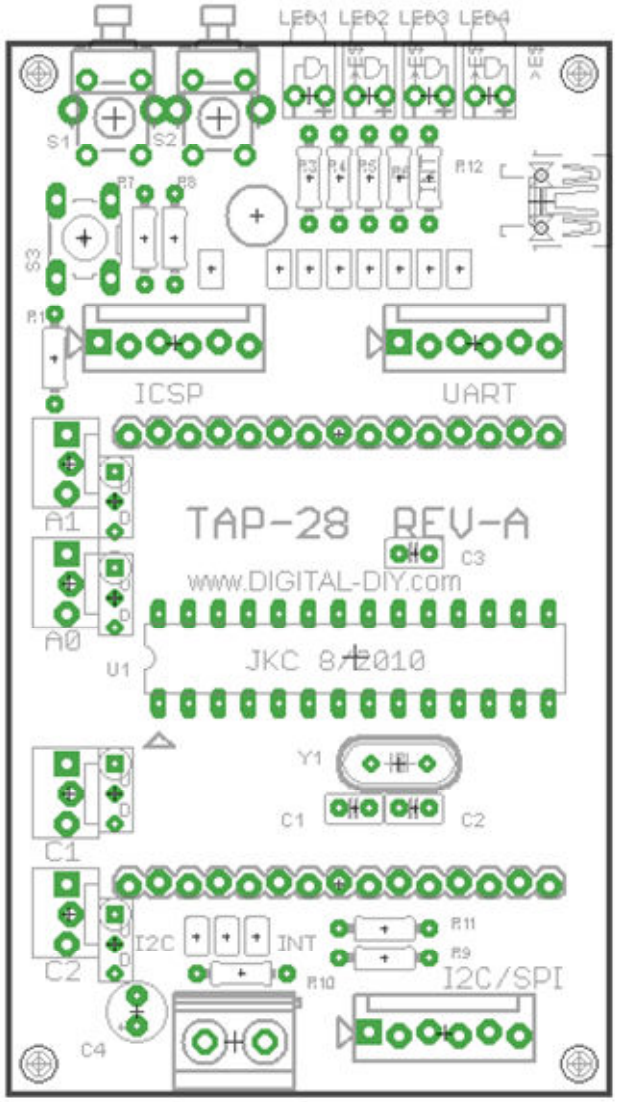
Dimensions

TAP-28, Rev. A



Part Locations

TAP-28, Rev. A



Part Locations

TAP-28, Rev. A

QTY	Designator/Part	Value	Manufacturer and P/N	Digikey P/N	Mouser P/N
2	C1, C2	22 pF, 0.1" lead spacing	Murata RPE5C1H220J2P1Z03B	490-3708-ND	81-RPE5C1H220J2P1Z03
1	C3	0.1 µF, 0.1" lead spacing	Kemet C315C104M5U5TA399-4151-ND	399-4151-ND	810-FK18Y5V1H104Z
1	C4	1 µF - 100 µF, 0.1" lead spacing - optional for servos	depends on application		
4	3-Pin Connectors	Molex 22-27-2031 (header pin section may be used)	Molex 22-27-2031	WM4112-ND	538-22-27-2031
1	USB Connector	Cypress 32005-201 or equal	Tyco 1734035-2	A31727CT-ND	571-1734035-2
2	Daugtherboard Hdr	Female 0.1" Center, 15 position	Sullins PPTC151LFBN-RC	S7013-ND	517-929850-01-20-RA (cut to length)
3	6-Pin Connector	Molex 22-23-2061 (header pin section may be used)	Molex 22-23-2061	WM4204-ND	538-22-23-2061
1	Terminal Block	2 position, 0.2" spacing	On Shore Technology EDZ250/2	ED1973-ND	571-282834-2
4	LED1, LED2, LED3, LED4	LED-3MM-T1, diffused, any color	Kingbright WP7104ID	754-1243-ND	604-WP7104ID
5	R1, R7, R8, R11, R12	10000Ω, ¼ W, 1% metal film	Yageo MFR-25FBF-10K0	10.0KXBK-ND	271-10K-RC
4	R3, R4, R5, R6	301Ω, ¼ W , 1% metal film	Yageo MFR-25FBF-301R	301XBK-ND	271-301-RC
2	R9, R10	4750Ω, ¼ W, 1% metal film	Yageo MFR-25FBF-4K75	4.75KXBK-ND	271-4.75K-RC
2	S1, S2	OMRON-COMBO-TACT	Onron B3F-1002	SW401-ND	653-B3F-3155
1	S3	B3F-10XX	Onron B3F-1002	SW401-ND	653-B3F-3155
1	U1	PIC 28-pin, 0.3" wide DIP	See supported Device List		
1	Y1	20 MHz. HC49 package	ECS-200-20-4X	X1076-ND	520-HCU2000-20X
1	IC Socket	28-pin, 0.3" wide	3M 4828-3004-CP	3M5480-ND	517-4828-3004-CP
4	LED1, LED2, LED3, LED4	LED-3MM-RT-ANGLE, diffused, any color	Kingbright WP934CB/ID	754-1298-ND	604-WP934CB/ID
2	S1, S2	OMRON B3F series right angle	Omron B3F-3152	SW410-ND	653-B3F-3152
2		Cap for tactile switch	Omron B32-1630	SW848-ND	653-B32-1630

The parts used on the TAP-28 board are extremely common and non-critical. The mounting patterns on the circuit board are nearly generic and parts from most manufacturers will fit.

The well-stocked junk box will often have appropriate parts buried in its depths. The above parts will work on the TAP-28 board. They may not be the best choice for all applications, nor may they be the cheapest alternative, but the parts list serves as a starting point.

The items shown in blue are alternates. Either vertical or right-angle switches and LEDs may be used depending on the application.

When buying components, look at quantity discounts. Buying resistors and capacitors one at a time doesn't make much sense if more will be needed a short time later.