

MSP430 microcontroller basics: Home-made demonstration boards

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Home-made demonstration boards

I made two small demonstration boards on stripboard to test aspects of the F20xx devices, which are the only types of MSP430 that come in plastic dual-in-line packages (PDIPs). This is called an ‘N’ package in the TI catalogue. I should say up front that I do not recommend stripboard. It is easy to lay out printed circuit boards nowadays and they are not expensive to manufacture, even one-off. The process is more reliable and the performance of a PCB is better, particularly for sensitive analog inputs. You might therefore prefer to design your own circuit, perhaps based on the ideas here. However, stripboard remains one of the easiest ways of building a circuit without special equipment so I thought I would try it out. Construction is almost entirely straightforward except for a pair of pins on the JTAG header, as I’ll explain later.

The first board has only LEDs and pushbuttons and was really to test the idea. This sounds too simple to be useful but I found it helpful for exploring the Timer_A. The second board was more ambitious and was intended for exercising the range of analog inputs offered by the F20xx. Figure B.1 on the following page shows a photograph of the two boards. Some features are common to both.

- The copper tracks run horizontally on the bottom of the boards and I generally ran wires vertically on top. (You might be able to spot an exception on the analog board where I made an error in the layout. Mistakes are easily made on stripboard, which is a reason to prefer a PCB.)
- A row of pins on each side of the MSP430 allows you to connect an oscilloscope probe easily. I left a gap to avoid the IC getting in the way.
- There is at least one ground pin for an oscilloscope probe or voltmeter.

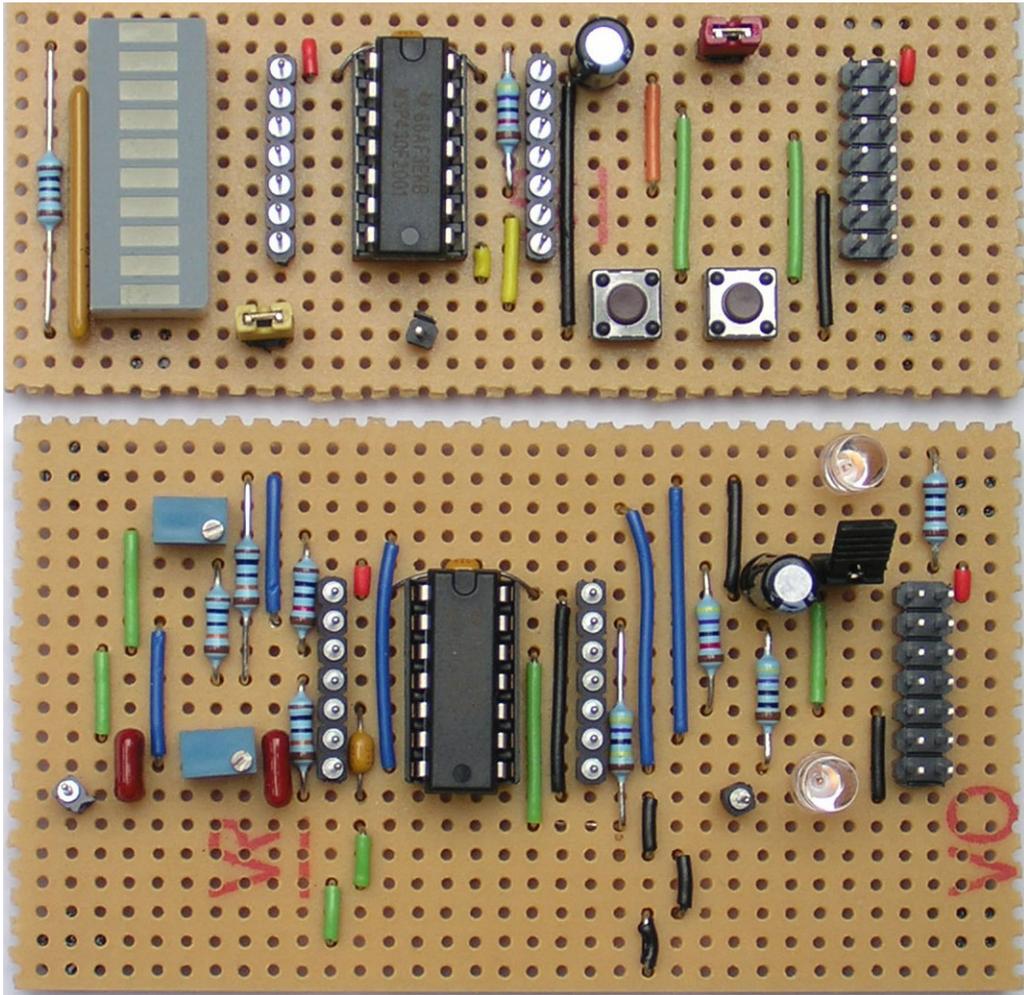


Figure B.1: Photograph of home-made demonstration boards on stripboard. The upper board has LEDs on port P1 and pushbuttons on port P2; the bottom board has a range of circuits to exercise the various analog inputs of the different F20xx devices. Both have 14-pin headers on the right for the JTAG interface with pin 1 at top left. The area below the MSP430 on the analog board is connected as the capacitor for a touch sensor. This board's jumper looks strange because it has a tab, which has been bent upward. I made a couple of mistakes during construction of this board.

Table B.1: Functions available on port pins of F20xx devices. ‘General functions’ are available on all devices except that the F20x1 lacks the USI and therefore does not provide SCLK, SDO, SDI, SCL and SDA. I have distinguished between inputs CCI_nA and outputs TAn for the Timer_A and have ignored the connections for 4-wire JTAG. The pins are configured for digital input/output by default except for P2.6 and P2.7.

Port pin	General functions	F20x1	F20x2	F20x3
P1.0	TACLK, ACLK	CA0	A0	A0+
P1.1	CCI0A, TA0	CA1	A1	A0-, A4+
P1.2	CCI1A, TA1	CA2	A2	A1+, A4-
P1.3	—	CA3, CAOUT	A3, ADC10CLK, VREF-, VeREF-	VREF, A1-
P1.4	SMCLK	CA4	A4, VREF+, VeREF+	A2+
P1.5	TA0, SCLK	CA5	A5	A2-
P1.6	TA1, SDO, SCL	CA6	A6	A3+
P1.7	SDI, SDA	CA7, CAOUT	A7	A3-
P2.6	XIN (default), TA1	—	—	—
P2.7	XOUT (default)	—	—	—

- The MSP430 is in a socket, not soldered directly to the board. This is good practice in general and essential for the analog board, which is intended for any F20xx device.
- An LED shows when power is applied. Power is taken from the FET through the 14-pin JTAG header but you could of course use a battery or other supply instead.
- The JTAG headers are bare, with no shell around them to enforce the correct orientation. Pin 1 is at the top left and I should have marked this on the boards. It corresponds to the red wire in the ribbon cable if you use a TI FET.

My starting point for designing these boards was the range of functions available on the port pins of the F20xx. I’ve listed these in table B.1. Four pins remain, of which two are for power and ground. The final pair are for the Spy-Bi-Wire (SBW) interface. One of these pins is shared with the $\overline{\text{RST}}$ /NMI function but I have reserved this pin for debugging only.

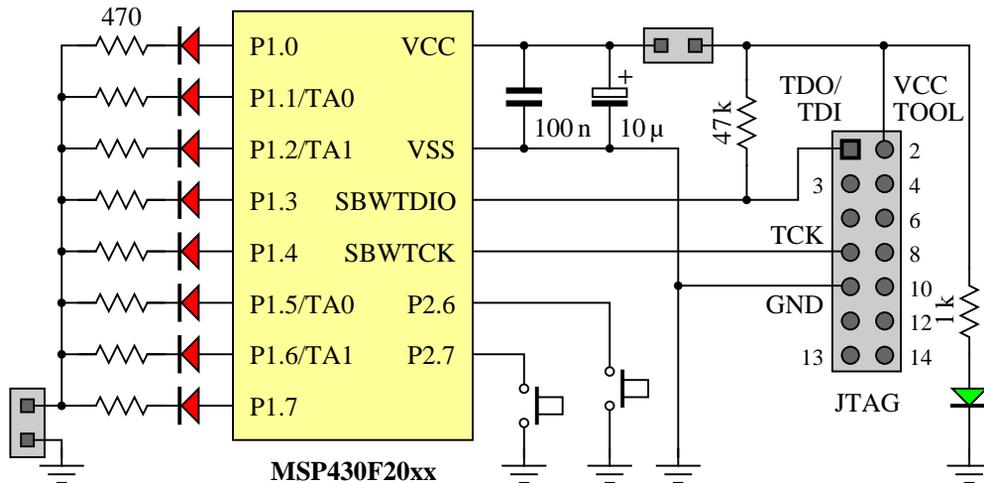


Figure B.2: Complete circuit of simple demonstration board. The pins of the JTAG header are shown as viewed from the top of the board with pin 1 at top left, indicated by the square. I have numbered the pins where space permits. The pins of the MSP430 are not in their geometric positions and I have marked only their relevant functions.

B.1 Simple demonstration board

This board has LEDs connected to all eight pins of port P1, active high, and pushbuttons connected to both pins of port P2, active low. That's almost all, apart from power and debugging. I also included two jumpers, one to disable the LEDs and a second to measure the supply current. The circuit is drawn in figure B.2. There are no pullup resistors on the pushbuttons so the internal pullups must be activated. Some of the LEDs can be driven directly from the Timer_A to demonstrate PWM. Unfortunately the capture inputs are available only on port P1 and are therefore not useful in this circuit because I put the pushbuttons on port P2; I preferred to have a full port of LEDs.

Look first at the connections to the JTAG header. This has 14 pins but only four are used with SBW. I have shown the layout of the pins viewed from the *top* of the board in the figure; note that the *MSP-FET430 Flash Emulation Tool (FET) User's Guide* (slau138) shows the view from the *bottom* of the board.

- Pin 9 is ground, connected to V_{SS} .

- Pin 1 carries the data and is called TDO/TDI. The corresponding pin on the MSP430 is called SBWTDIO and this function is shared with the $\overline{\text{RST}}$ /NMI function. It needs a 47 k Ω pullup resistor to V_{CC} but a capacitor to ground is *not* recommended for the SBW interface. This differs from the 4-wire JTAG interface, where a 10 nF capacitor is typically installed between this pin and ground to suppress noise on $\overline{\text{RST}}$ /NMI.
- Pin 7 is called TCK and provides the clock. The corresponding pin on the MSP430 is SBWTCK. The circuit diagram in the *FET User's Guide* is a little confusing for this pin because they also show the connection required to blow the security fuse. I didn't bother with this.

The final pin is used for the power connection and can be treated in two ways.

- The FET can supply power to the board. In this case V_{CC} is taken from pin 2 of the JTAG interface, called VCC TOOL. I have done this in figure B.2.
- Alternatively, the board may provide its own power. In this case pin 4 of the JTAG interface, called VCC TARGET, should be connected to V_{CC} on the board. This voltage sets the levels used for the SBW signals.

Only *one* of these pins, either 2 or 4, must be connected – never both.

The only problem with constructing this circuit on stripboard is that both pins 1 and 2 of the JTAG header are needed if the FET powers the board. Unfortunately they lie next to each other on the same strip of copper. You normally break a strip with a drill centred on one of the holes. This requires an unused hole between the components and therefore won't work here. Instead you must scrape away the copper between the holes used for pins 1 and 2. This is awkward and you should check carefully that the conducting strip is completely broken. I cut plenty of breaks under and around the JTAG header to ensure that none of the unused pins was inadvertently connected to anything.

I followed normal practice by installing two decoupling capacitors, a 100 nF multilayer ceramic and a 10 μF electrolytic type. The 100 nF component is connected as close to the MSP430 as possible, as seen in figure B.1 on page 2. I was more relaxed about the position of the 10 μF capacitor. Remember to observe its polarity.

I used a packaged 'bar graph' instead of individual LEDs to give a neater display. This provided 10 LEDs so I used one of the spare ones for the power indicator and left one unused. The series resistors for the eight LEDs on port P1 are in a single-in-line (SIL) pack

for convenience. This pack has the common connection to all the resistors connected to a pin at one end, so ensure that you install it the correct way around. I used a higher value of resistance for the power LED to save current but this is hardly necessary because the FET can supply 100 mA. I'm just economical.

Follow the usual construction practice for stripboard. Check that all breaks are indeed broken and are not bridged by solder after you have installed the components. Ensure particularly that pins 1 and 2 of the JTAG header are not shorted. *Before you put the MSP430 into its socket*, connect the board to the FET and confirm that the receptacles for each pin show the correct voltages, notably V_{SS} and V_{CC} . Don't forget to place the jumpers if you included them. Finally, install the MSP430, write something like `ledson.c`, download it and watch the LEDs light up!

B.2 Analog demonstration board

The design of this board was tricky because I wanted to use it for all three types of analog peripherals offered by the F20xx. I therefore tried to make each part of the circuit useful for as many inputs as possible. I have not drawn the whole circuit together in figure B.3 on the facing page but have broken it into the separate functions for clarity. The power and debugging connections are omitted completely because they are identical to the simple board. This is the function of each sub-circuit.

- (a) Two resistors are connected to a grounded capacitor and to an input. These can be used in two ways.
 - The capacitor can be charged or discharged through one or other of the resistors. The duration of this *RC* transient process is measured with the Comparator_A and Timer_A to make a *slope conversion* of the resistance. The circuit including the comparator is shown in figure 9.3 and the method is described in section 9.1.3. A common technique is to compare the unknown resistor (on P1.6 here) with a known resistor (on P1.5). The resistor that is not used in a particular measurement should be isolated by setting the appropriate bit in the CAPD register. Both resistors can be driven directly from outputs of the Timer_A so that the charge or discharge process can be started at a precise time by using a Compare event.

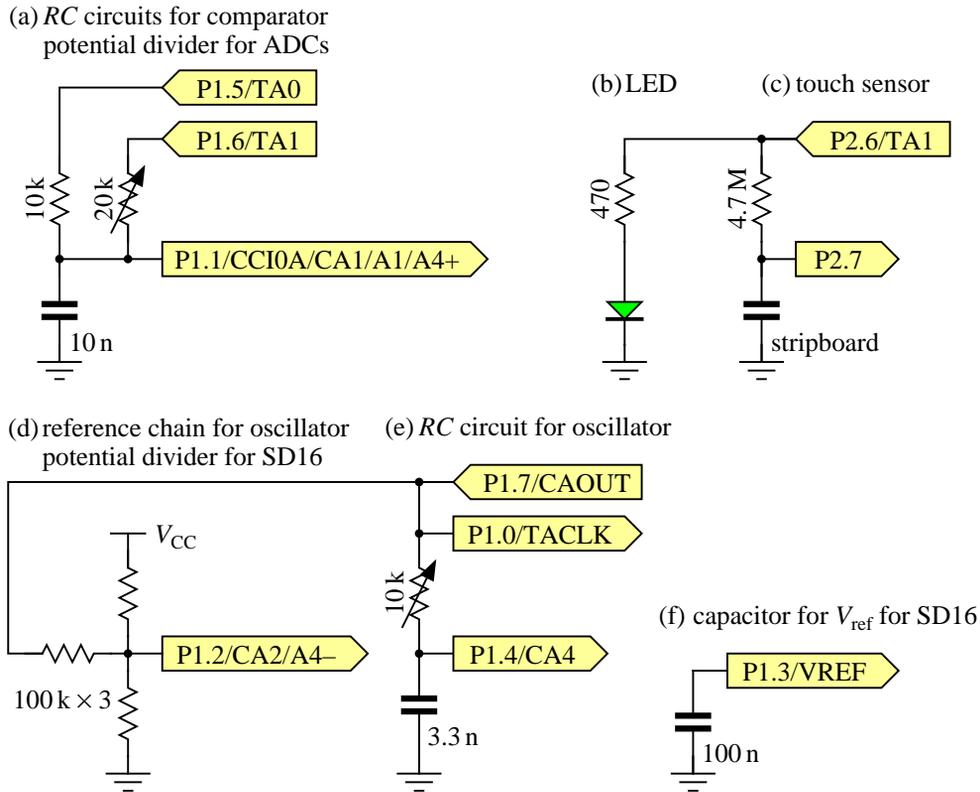


Figure B.3: Circuit of analog demonstration board. I have marked only the relevant functions for each pin and have omitted the connections for power and JTAG.

The time-constant is around $\tau = RC \approx 10\text{k}\Omega \times 10\text{nF} = 100\mu\text{s}$, which can be measured with reasonable precision if the timer has a clock of a few MHz.

- The two resistors can be used as a potential divider to provide an input to either of the ADCs. This is shown in figure 9.17, where P1.6 is driven to ground (V_{SS}) and P1.5 to V_{CC} . The capacitor suppresses noise on the analog input and acts as a reservoir to charge the input capacitance of the ADC more quickly. This is explained in sections 9.5.1 and 9.5.2 for the ADC10, where the potential divider provides input A1. The same circuit provides the single-ended input A4+ for the SD16_A in section 9.10.1.

(b) Pin 2.6 drives an LED for output in the usual, active high, configuration. This is

used for many of the examples as a trivial action in response to the analog input. I chose this pin because it can be driven directly from channel 1 of the Timer_A and is therefore available for hardware PWM. This is used for several of the examples in section 9.6.

- (c) Pin 2.6 also drives an *RC* timing circuit that I intended to use as a capacitive touch sensor. The theory is described in section 9.1.5 and the area of stripboard below the MSP430 in figure B.1 acts as the capacitor. It was formed by isolating part of five strips on the board; the outer two and the middle one were connected to ground, while the two interleaved strips were connected to the resistor and P2.7. The resulting capacitance is clearly small, hence the high value of resistance. I ran out of inputs to the Comparator_A and Timer_A so the timing had to be performed with the port interrupt, relying on the Schmitt trigger on the input rather than a comparator.

The sensor didn't work well and I ran out of time to develop the software to give a reliable indication of when a finger was placed on the active region.

- (d) Three equal resistors are connected to give voltage at central node of $\frac{1}{3}V_{CC}$ or $\frac{2}{3}V_{CC}$, depending on the voltage driven from P1.7 (CAOUT). The operation of the potential divider is illustrated in figure 9.6. This has two uses.
- The main purpose is to form a relaxation oscillator with the Comparator_A, as described in section 9.1.4. In this mode, the central node of the potential divider provides the reference voltage for the comparator to CA2. It is switched every half-cycle when CAOUT toggles and limits the excursion of the oscillation.
 - With a steady supply from P1.7 (or P1.0), the central node provides the second voltage A4- for a differential input to channel 4 of the SD16_A. This is used in section 9.10.2.
- (e) An *RC* network forms the heart of a relaxation oscillator with the Comparator_A, described in section 9.1.4. The time-constant is around $5\text{k}\Omega \times 3.3\text{nF} \approx 17\mu\text{s}$ so the frequency of oscillation is in the tens of kHz. This is a compromise because the frequency can be measured in two ways.
- The **frequency** can be measured directly by connecting CAOUT to TACLK and using the oscillations as the clock for the Timer_A. You then capture ACLK or another signal with a slow, known frequency and counter the number of cycles of TACLK. The circuit has an external link from CAOUT (P1.7) to TACLK (P1.0) with this in mind; there is no internal connection.

This method is best suited to fast oscillation. Typically $f_{\text{ACLK}} = 32 \text{ KHz}$, although ACLK must be taken from the slower VLO here. This is not much slower than the relaxation oscillator with the values of components that I used, which is unhelpful for this approach. Solutions are to divide ACLK or count the number of cycles over several successive captures.

- The **period** can be measured directly by using the Comparator_A in the usual way. This method is best suited to slow oscillation.
- (f) An external storage capacitor is required for the reference voltage generator in the SD16_A. A larger value of capacitance should be used if you wish to use the reference voltage externally. (Do not connect external capacitance to the reference voltage of the ADC10.) This capacitor could also be used to provide a sample-and-hold function for the Comparator_A on CA3 but I do not cover this in the book. There is a code example `msp430x20x1_ca_03.c` and the principles are described in the MSP430x2xx Family User's Guide.

I'm not sure that this board is laid out in the best way because I had originally planned to connect the touch sensor to the Comparator_A. I changed my mind during construction (a bad idea!) because I thought that it would be more useful to drive both resistors for the RC timing in figure B.3(a) from the outputs of the Timer_A.

There are no extra difficulties in constructing this board compared with the simple one; the most awkward part is again to break the track between pins 1 and 2 of the JTAG header. Stripboard is generally a poor choice for high-quality analog electronics but it performs well enough here because I kept the resistances fairly low and the capacitances high, so that the frequencies are well below 1 MHz. The exception is the touch sensor, which didn't work well, but I suspect that this was simply lack of effort on the software.