– Manual v1.0 –

I/O Expander … "IOX"

OVERVIEW

The I/O Expander is a 28-pin SX microcontroller that is programmed to operate as a slave I/O processor to a host controller in your projects. IOX interfaces peripheral components (LCD, A/D Converter, digital pot, and matrix keypad) to the host processor over a conventional asynchronous serial line. Additionally, the IOX chip has a "frequency counting" capability, providing the host processor with both raw count information and processed frequency values over selectable time gate periods. The IOX chip interfaces to the host processor using a standard asynchronous serial line operating at 2400 baud.

DESCRIPTION

Input and output pins are very precious resources in small digital projects these days. Popular small microcontrollers like the PIC, 8051, SX, BASIC Stamp, etc., may only have 8-to-16 lines of I/O available for use, while we typically have a need to drive LCD displays, LEDs and frequency synthesizers; and read A/D converters, keyboards, shaft encoders and more. Hardware interfacing is the name of the game, and you can never have too much I/O capability on a processor to handle all these tasks.

Well, here's a relatively simple project called the I/O Expander, or IOX for short, that will greatly ease that I/O pin crunch on your current microcontroller project. At first it looks like a clone of the common "serial LCD" controller – but when you look under the hood, you'll see an I/O processor that's chock full of goodies that we use everyday in our ham applications: serial display driver, frequency counting, A/D conversion, keypad processing and digital potentiometer control. Drop this single chip IOX into your next design and you'll be able to handle a lot more I/O than you originally thought possible.

A Ubicom SX-28 is programmed to be controlled by the host microcontroller of your project using a standard asynchronous serial port running at 2400 baud, thus acting as the host's "henchman" in performing various I/O functions. The host (e.g., a PIC) issues a simple 1- or 2-byte command over this serial link and the SX processor goes off and does its thing. Sometimes the SX outputs the specified data (to the display or digital pot), while at other times it gathers input data (from the frequency counter, A/D converter, or keypad) and sends it back to the host over that serial port.

The block diagram on the following page illustrates this master-slave concept for expanding the I/O capabilities of a host microcontroller.

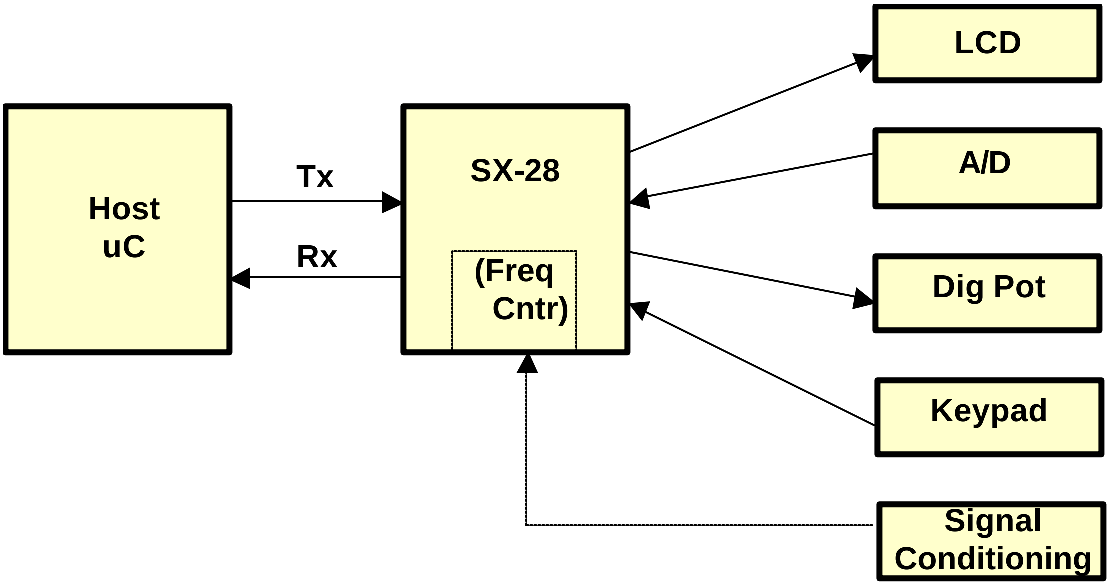

Figure 1: Block Diagram of the I/O Expander in a System

Operation as a Serial LCD Driver

What a joy not having to put all those pesky LCD driver routines in your host processor! Just have the host send the string to be displayed to the SX chip and let IOX take care of the timing! The SX chip accepts bytes in the range of 0-to-253 from the host and displays them on the LCD display connected to its own I/O pins. When a special "command" byte of 254 is sent by the host, the SX chip waits for another character which is called the function byte. As can be seen in Table 1: I/O Expander Command-Response Structure, display functions include clearing the display, setting the cursor to home or to a prescribed position, blank display, scroll the display, and more. Thus when the host processor sends a 2-byte sequence of 254 and 1, the display will be cleared of all data.

Operation as a Frequency Counter

The IOX software is designed to count the frequency of a signal applied to its RTCC input pin. The user/programmer can select one of two counter prescale values (1:1 or 1:4) to use with the single 1-second counting window. (Other gating periods may be added in the future.) Then, when commanded by the host to "read frequency", the SX chip starts counting. When the host later commands IOX to deliver counting results to the host, IOX sends back the most recent three-byte accumulation of the applied signal's frequency. Alternatively, the host may commanded IOX to send an 8-byte series of BCD numbers representing the counter values. The counting algorithm is very similar to the measurement routines used in other projects, whereby the software counts transitions on the RTCC pin of the SX chip and accumulates the counts in three internal storage locations. Based on the counter prescale value selected, the host uses the values directly (for the 1:1 setting), or it multiplies the counter values by 4 (for the 1:4 setting). Frequencies up to 16 MHz can be measured with the 1:1 prescale setting providing 1 Hz resolution, and up to 50 MHz with the 1:4 prescale setting yielding 4 Hz resolution.

Operation as an A/D Controller

As shown in the detailed schematic of the QuickieLab, a popular and inexpensive analog-to-digital converter is wired to the SX chip's I/O pins. The IOX software is able to initiate A/D conversions and read the resultant 8-bit data representing the analog signal on the ADC inputs. So if the host processor commands the SX chip to read the A/D (command 80), the I/O Expander initiates an A/D read cycle, awaits data conversion completion, and returns the 8-bit value to the host in response. The host then needs to process that value ranging from 0-to-255 into some meaningful data within its own program.

Operation as a Digital Pot Controller

In a similar manner, a very useful chip called an NV Trim Pot is wired to other I/O pins on the SX chip. When the host sends command 90 followed by another byte ranging from 0-to-99, the IOX software "moves the wiper" of that digital pot to that specified position (corresponding to percentage of rotation of the pot). In this way the host processor can easily control the gain of an amplifier, for example, if the digital pot is wired into the feedback loop of an op-amp.

Operation as a Keypad Processor

The IOX software running in the SX chip may be commanded by the host to read a 4 row by 3 column keypad in one of two ways. First, command 100 instructs the IOX software to merely return the current state of the keypad. If a key is pressed, a binary value in the range of 0-to-12 corresponding to that key is returned to the host as a response byte. But if no key is currently being pressed, a response value of 255 is sent back to the host.

A more conventional mode, initiated by the host sending command 101 to the SX chip, instructs the IOX software to send a key code whenever a key is pressed. This asynchronous operation of sending unsolicited data back to the host is useful in the respect that key presses can initiate operations while the host software is off doing something else. Note that some host processors might be better suited to operating in this manner, as compared to the BASIC Stamp (for example) that doesn't have a vector-based hardware interrupt structure. However if your host controller can be interrupt driven, this is like having 12 user-selectable interrupts and is a powerful addition to the hardware/software developer using the I/O Expander.

Standard Serial Port Talks to IOX

Because commands and data are exchanged over a standard asynchronous serial port, almost any host processor can be easily interfaced to the IOX chip. Digital levels (TTL) are available on the SX chip for connection directly to the Rx and Tx pins of many host processors, or if an RS-232 serial port is desired (as when using a PC as the host controller), a MAX232 level translator can easily be added to the SX serial data line.

The baud rate of the IOX serial port is hard coded to be 2400 baud because the test implementation of IOX was accomplished using a BASIC Stamp controller, which is relatively slow. The rate can be increased to a maximum of 19.2 Kbps with a simple change to the IOX source code, enabling it to efficiently connect with some fast RISC host processors. (Future versions of IOX software may be able to automatically detect and adjust to the host processor's baud setting.

Go Forth and Expand (your I/O)

By using the I/O Expander, you can easily control more hardware peripheral devices than possible with just a PIC, Stamp or 8051 microcontroller. An even more attractive feature is that the software is simplified too – you needn't worry about A/D conversion, frequency measurement or LCD coding intricacies … it's all there in the SX chip for you. The IOX source code is provided on the project's website (www.njqrp.org/ioexpander) and you can add/change routines in support of your own favorite peripheral. Any way you look at it, it's easy to "go forth and expand your I/O"!

Technical Support

If you have any questions, feel free to send an email to George Heron, N2APB (n2apb@amsat.org). Also, check the IOX website for common answers posted on the Frequently Asked Questions page.

Keep an eye out for software updates that you could download and use to program the SX chip with an appropriate SX-Blitz or SX-Key programmers' cable. Otherwise, we will gladly reprogram your SX-18 chip for you – just send your chip to us in a suitablely-padded, anti-static bag. We'll program it with the latest version and mail it back to you right away at no charge. For this service, send your chip to:

George Heron, N2APB
2419 Feather Mae Ct
Forest Hill, MD 21050

IOX DATASHEET

~ Version 1.0 ~

Communications link to Host

- IOX utilizes a standard 8N1 asynchronous 2-wire serial protocol to exchange command/data with the host processor. Data is "true" (non-inverted), as RS-232C line drivers are usually not required.
- This IOX version is optimized to interoperate with the BS2 BASIC Stamp from Parallax.com. Hence a link speed of 2400 bps is hard-coded into the IOX software, as are various internal delays required for successful operation with the BS2 host. Later versions will have a programmable means to adjust link speed and a more robust ACK-response mechanism to better accommodate variable IOX timing dependencies.
- IOX communicates with the host using a command/response application layer protocol. IOX interprets the incoming byte of $FE as a "command", and waits for another byte from the host which indicates the specific command being issued.

LCD Display

- IOX treats all data less than $FE as displayable ASCII data and sends the LCD as characters to be displayed at the current cursor position.
- LCD Commands include: clear display, clear 1st/2nd line, blank/unblank display, show/hide cursor, and set cursor to specific position on 1st/2nd line.

Frequency Counter

- IOX provides a raw counter "readback" capability. The three 8-bit counting registers can be read and further manipulated by the host.
- IOX also provides a 6-digit BCD "readback" capability, useful to the host to directly display measured frequency string in debug window, or to send back to IOX for display on LCD.
- Two prescaler settings can be commanded by the host: 1:1 and 1:4
- A single timebase of 1 second is provided
- The combination of all the above (3 counting registers, direct frequency display, prescaler and timebase) allows IOX to measure and directly display (i.e., without computation) frequencies ranging from 1 Hz to 50 MHz.
- The "low" frequency range is with the 1:1 prescaler setting, and measures/displays signals up to 16,777,216 Hz, with 1 Hz resolution
- The "high" frequency range measures signals up to 50 MHz with 4 Hz resolution. (NOTE: The host will need to multiply the counting registers by 4 for actual readings, and the 8-digit BCD frequency readback string displays only 1/4 the actual frequency. Later software versions may have IOX internally multiply the BCD values before sending the string, thus enabling a direct string representation like with the "low" range.)
- Host commands include: Set_1:1_prescale, Set_1:4_prescale, Measure_Frequency, Readout_Counter_Regs, Readout_Frequency_String.

Keypad

- IOX provides two commands to read the 12-key Keypad: Read_Keypad and Wait_Keypad
- The Read_Keypad command reads the immediate value of the Keypad and sends the binary value of the key to the host as an 8-bit value (0-9, $0A for the star_key, and $0B for the pound_key)
- The Wait_Keypad command waits for the user to press a key, then then sends the key code to the host as above.

A/D Converter

- The ReadADC command returns a single byte representing the 8-bit reading of the ADC0831 analog-to-digital converter.

Digital Potentiometer

- Two commands are provided to control the Dallas Semiconductors DS1804 Digital Pot chip.
- The SetPot [num] command presents a binary number (0..99) specifying the desired set point for the wiper on the potentiometer.
- The PotInc [num] command presents a binary number (1..99) specifying the number of steps by which the pot wiper should be incremented.
- The PotDec [num] command presents a binary number (1..99) specifying the number of steps by which the pot wiper should be decremented.

IOX System

- IOX responds to the Ping command with an immediate ACKnowledge byte [$01] being sent to the to the host. This is a convenient way for the host to determine if IOX is operational and responsive.
- The Reset command restarts the IOX software and returns all conditions to default values.

TABLE 1: I/O Expander Command-Response Structure

COMMAND	FUNCTION	RESPONSE
LCD:		
1	Clear entire display	
2	Clear 1st line & home cursor	
3	Clear 2nd line & home cursor	
8	Blank LCD (retains data)	
12	Hide cursor	
14	Show cursor	
128+n	Position cursor at the nth character of 1st line	
192+n	Position cursor at the nth character of 2nd line	
FREQ COUNTER:		
65	Measure Frequency	
66	Readout Counting Registers	3 Bytes ($00-$FF)
67	Readout Frequency String	6 BCD Byte (range: each $0-$9)
68	Set 1:1 Pre-scale	
69	Set 1:4 Pre-scale	
A/D:		
80	Read A/D	Byte ($00-$FF)
DIGITAL POT:		
90, n	Set wiper to n (0-to-99)	
91,n	Increment wiper n steps	
92,n	Decrement wiper n steps	
KEYPAD:		
100	Read Keypad	Byte ($00-$0B)
101	Wait Keypad	Byte ($00-$0B)
SYSTEM:		
200	Reset IOX software	ACK

