OWL2pe 1.4
technical manual

Contents

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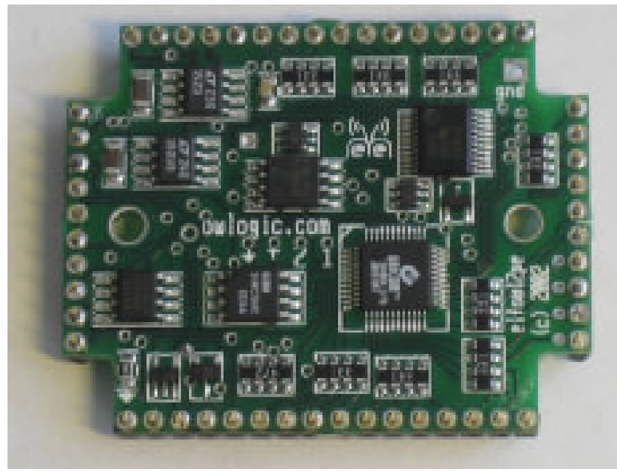
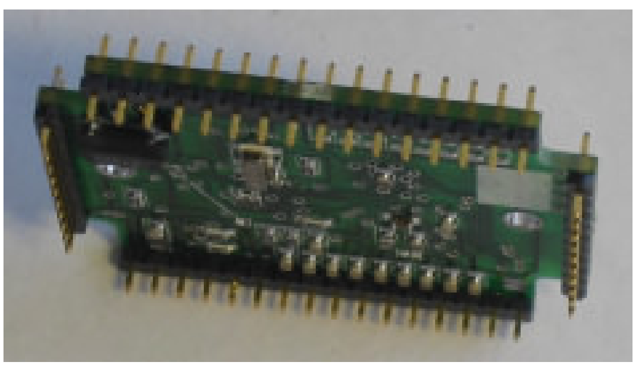
elfOWL data logger, model OWL2pe

The OWL2pe "elfOWL" data logger is built around the popular and versatile BASIC Stamp™ 2pe micro-controller from Parallax Inc. This technical guide is written to describe the operation and capabilities of the elfOWL core for engineers and programmers who want the technical details.



Another elfOWL document, Program Guide, describes a menu driven data logging program of the sort that allows for easy field setup of commonly used sensors and schemes. For field use, the elfOWL is always plugged into an breakout board that provides terminals for the connection of sensors, along with other electronic and mechanical functions, and fits to a standard enclosure with a power supply and provision for cable egress. Those expansions and systems are described in their own topboard or custom system guides. A great deal of additional information, tutorials, and links can be found on EME Systems' web site <http://www.emesystems.com>. This includes information on how to connect specific types of sensors to the elfOWL and how to offlod the data and transfer it to an analysis and graphing program like Excel™.



BASIC Stamp microcontrollers have a well deserved reputation for being easy to use, even for beginners. Professionals value them because projects can move quickly from concept to implementation, and changes that lead "back to the drawing board" are not so much to be dreaded. The elfOWL is capable of running widely different types of programs, unlike some data loggers that allow programming of only a narrow range of parameters. Not everyone wants to program at that level, but this document is for those who do. It describes elfOWL features and how to make use of them from within PBASIC. It helps if you already know something about the BASIC Stamp, but on the other hand, that is not necessary—The elfOWL can serve as a kit of the essential ingredients to learn the BASIC Stamp and put it to work.

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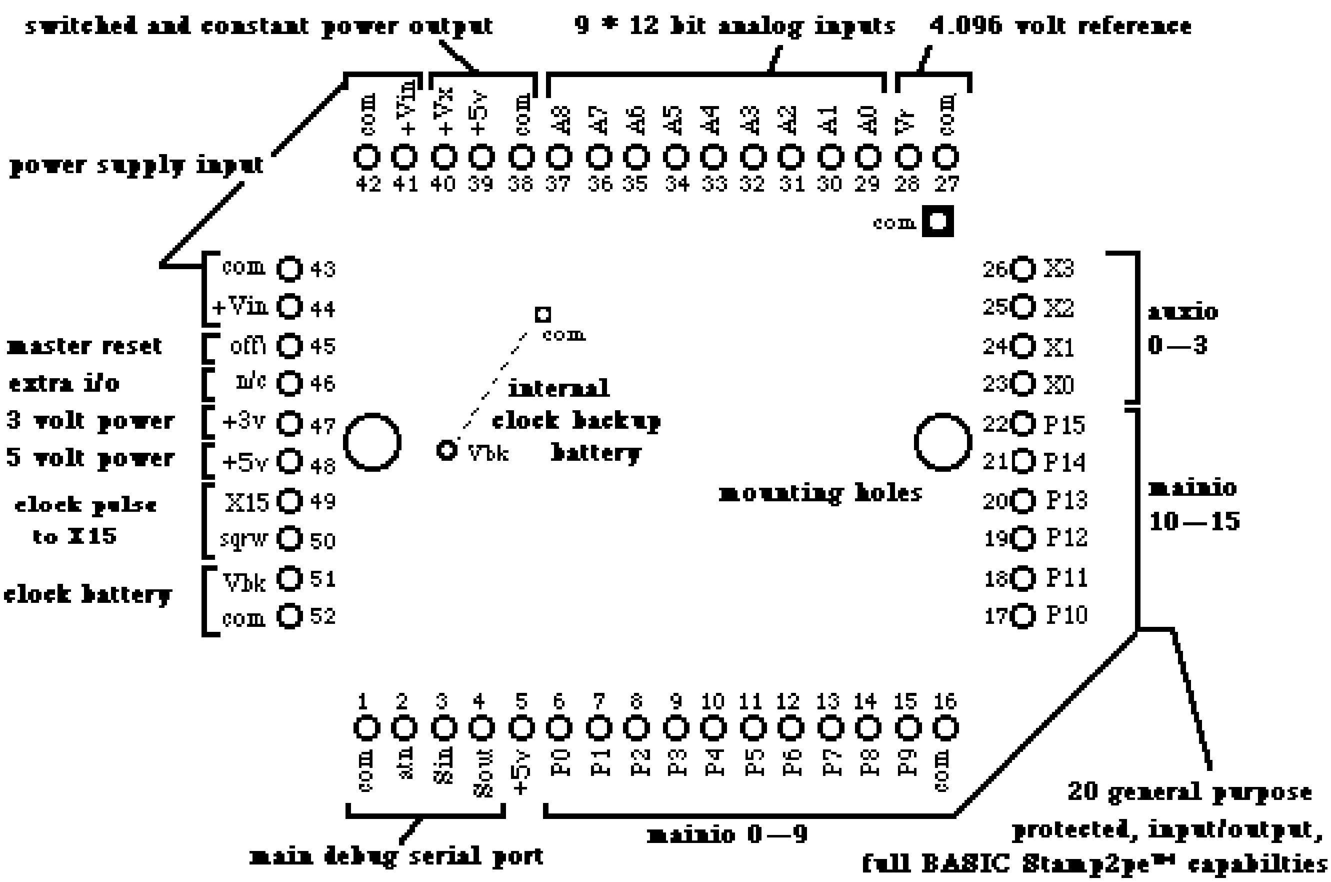
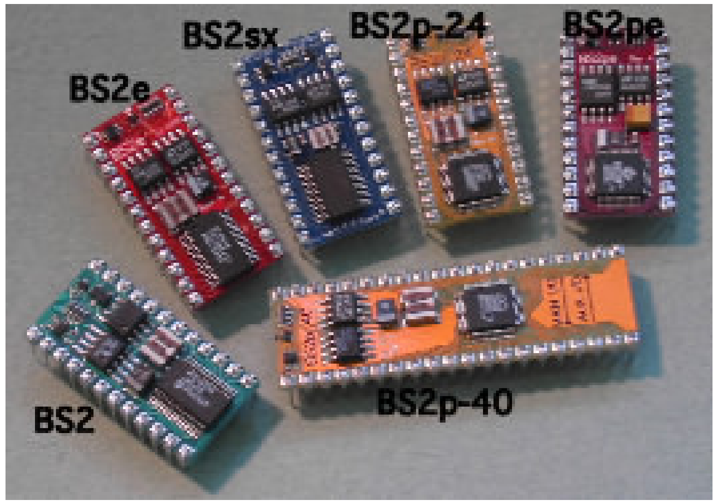
Features:

• BASIC Stamp 2pe built in, best BASIC Stamp for data logging, with all the latest commands,
• All components rated for extended temperature range, -20 °C to +85°Cm orbetter,, silicone resin conformal coating.
• Runs programs like any BASIC Stamp using the Parallax STAMPW.EXE development environment.
• 20 Stamp multi-function I/O available for user applications; mainio P0 to P15. auxio X0 to X3.
• 52 pin module; 2" x 1.5" ; surface mount technology; low profile headers 0.1" x 0.025" top & bottom
• 32 kbytes program & configuration memory on Stamp (16 banks of 2k) (24WC256)
• 512kbytes (1/2 megabyte) of non-volatile dataflash logging memory, plus 528 byte RAM buffer. (AT45DB041)
• Real time clock with 56 byte RAM memory, heartbeat pulse, and 10yr battery backup. (DS1307)
• 9 external analog to digital channels, precision 4.096 volt reference., 12 bits, 1 millivolt per bit (TLC2543)
• Power supplies
  5 volts constant at 200 ma, low dropout (LT1521-5)
  switched voltage (5.5 volts, standard) switched under program control (LT1521)
  3.3 volts, 50 ma, switched under program control (LT1761-3)
  4.096 volts precision reference (low current) switched under program control (LT1790-4)
  Low power consumption SLEEP and POLLWAIT modes, 50 microamps
• power supply voltage monitor , Vin, 0 to 25 volts, and temperature -25 to +85Celsius. (LM50)
• RS232 system programming and debugging interface, just like a standard BASIC Stamp, addressed as P16
• I/O protection (330Ω) on all pins, protection from mis-wiring, short circuit and ESD
• widely supported micro, see http://www.parallax.com & http://www.owlogic.com



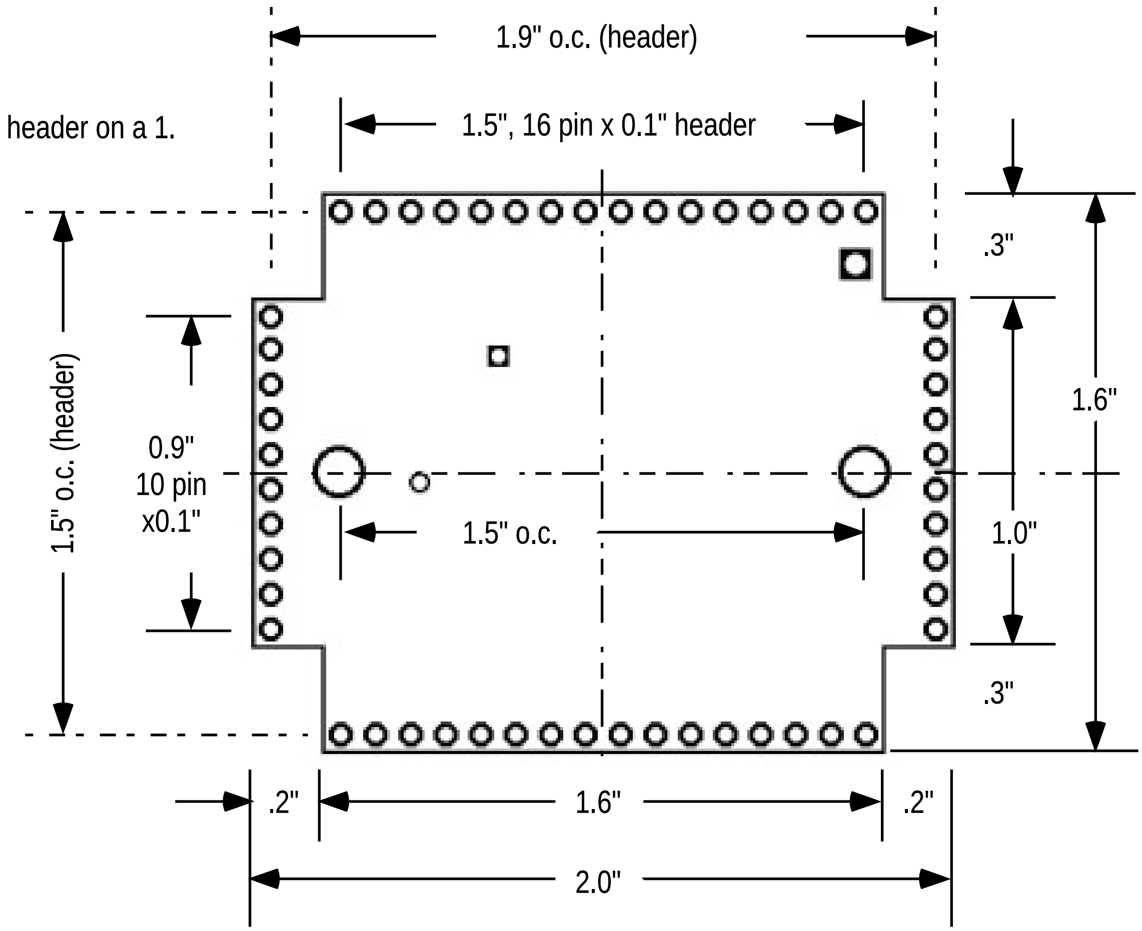
BASIC Stamp 2pe, special features

The BASIC Stamp 2pe is the 5th stage in the evolution of BASIC Stamps from Parallax, and it is one particularly well suited for data logging. The evolution has progressed toward more memory and a more powerful command set, and versions of the chip that trade off speed and power consumption.

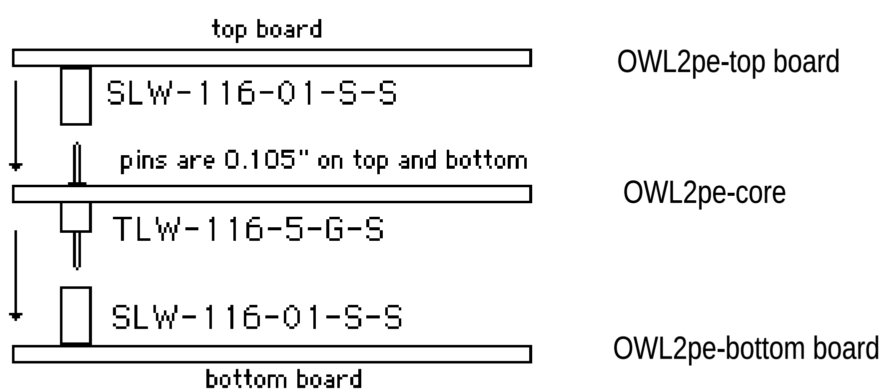


The the OWL2pe is based on the 32 i/o versions of the BS2pe. EME Systems purchases directly from Parallax the 48 pin interpreter chips seen at the lower end of the dark red BS2pe in the picture to the right, and we incorporate it on our own circuit board with the additional components that turn it into a self contained data logger. Here are features that distinguish the BS2pe from the other BASIC Stamps:

1) It has 16 kbytes of program memory, organized into 8 banks of 2kbytes each, and it has an additional 16kbytes of data and configuration memory. It can READ and WRITE the full extent of that 32k bytes from within any of the program banks, using the new STORE command. This is an indispensable advantage when writing long data intensive programs. The original BASIC Stamp II has only 1 bank of program/data memory, 2k, and that's it. The extra program banks and cross-bank access to data make much more full featured programs possible.
2) The BS2pe has 127 bytes of scratchpad RAM available for storing parameters and variables. The OWL2pe programs use this intensively and for accumulated data in transit to the logging memory.
3) The BS2pe, like the BS2p, is based on an SX48 microcontroller operated in turbo mode. However, the BS2pe is clocked at 8 megahertz, while the BS2p is clocked at 20 mhz. This affects operating current, 15 milliamps vs 40 milliamps.
4) In addition to all of the commands that are available on the earlier Stamps, the BS2p and the BS2pe have i/o commands that allow easy interface to I2C and one-wire protocol smart chips and standard LCD screens. The real time clock in the elfOWL uses the I2C protocol, as do a number of easy to use interface chips from Phillips, Maxim, Dallas and others.
5) When a Stamp wakes up from an interval of Sleep, the i/o pins briefly become inputs, even if they had been configured as outputs. This glitch can be a problem in systems where the pins have to maintain definite levels even while in the sleep state. On the BS2pe those glitches are much shorter and therefore easier to filter out than those of any of the other Stamps. 0.15 millisecond, versus 16 milliseconds, a factor of 100 improvement.
6) Due to the short wakeup interval described in (4), the BS2pe draws less current that other stamps during the sustained sleep mode.
7) The BS2pe has a kind of a polled interrupt command, called POLLWAIT, that allows the processor to sleep until there is activity on a pin. The OWL software uses this command and the heartbeat pulse from the clock chip to achieve low current while still maintaining accurate timing.
8) TheBS2p amd BS2pe are built with the Ubicom SX48 microprocessor and supports 32 inputs and outputs. The earlier BASIC Stamps were limited to 16 i/os. On the elfOWL, 12 of the i/o pins are used for internal functions, leaving 20 pins for external connections.



Mechanical diagram of the 52 pins on the elfOWL module, 1.6" x 2.0" overall two rows of 16 pins are 1.4" apart and two rows of 10 are 1.9" apart, all fitting on a 0.1" grid. The pins are 0.025" square and extend out from both the top and from the bottom of the module for flexibility in mounting and for stacking. The headers are low profile, with mating pin length of 0.1". The OWL core mates on either side with low profile socket strips in the TLW series from Samtec, with a board to board spacing of 0.2" on top and 0.25" on the bottom. Mounting holes on the board center line, 1.5" o.c., pass #4 or M3 screws. The spacing of the mounting holes as well as the outline of the circuit board matches a specific Rose NEMA4 rated weatherproof enclosure.



External pins on the OWL2pe module

Parallax' BASIC Stamp has 32 general purpose i/o pins, and 20 of those are available externally on the elfOWL module. Those are known as p0 to p16, and x0 to x3. Those are the same names they have on all BASIC Stamp modules and application boards from Parallax.

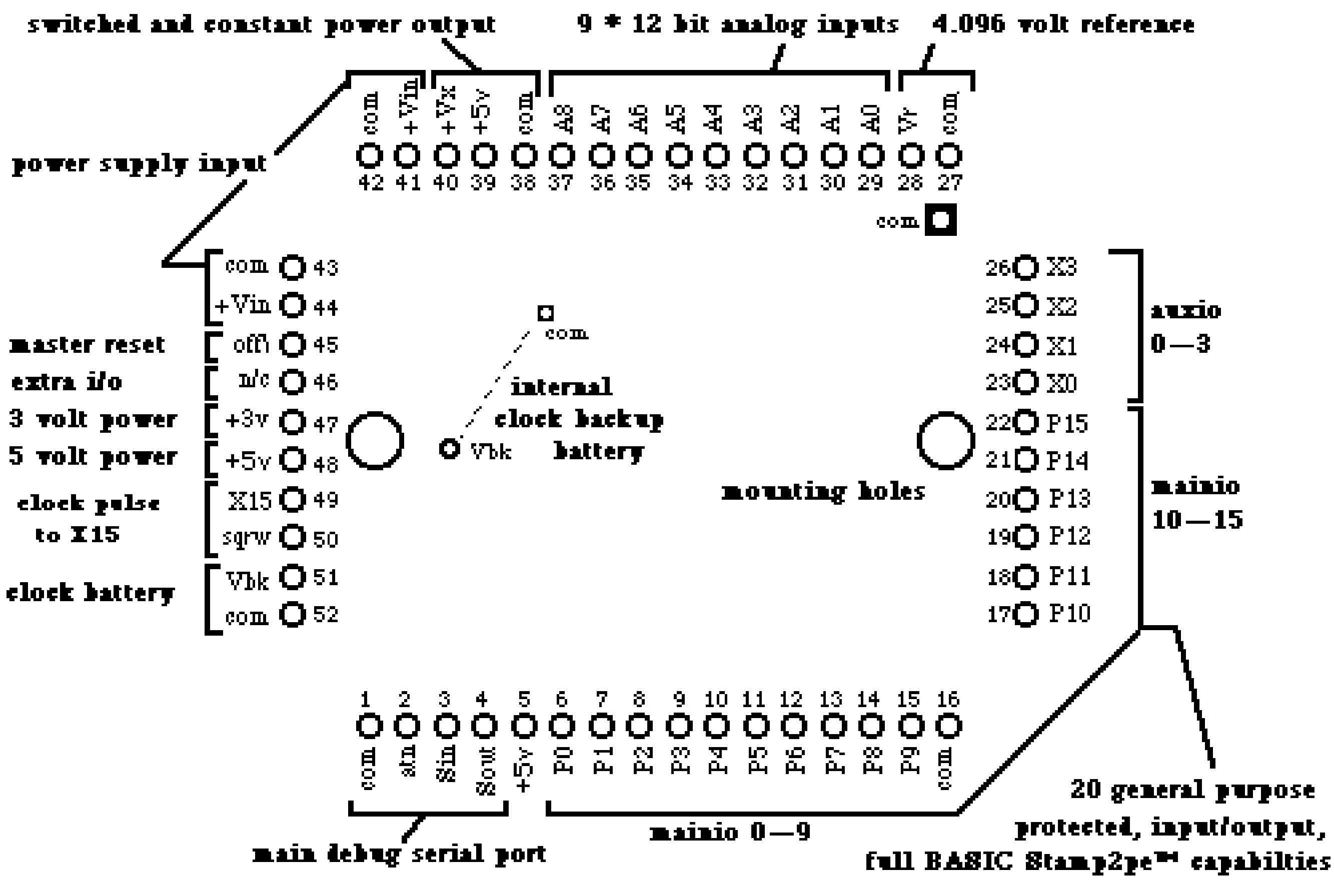
Logical pins P0 to P9 are along the bottom edge on the physical pins labeled 6 to 15, while p11 to p15, and x0 to x4 are to be found on physical pins 17 to 26 along the right edge. All these i/o's are are connected through a 330Ω protection resistor to BASIC Stamp pins of the same designations. These pins have exactly the same capabilities as all their BASIC Stamp 2pe counterparts.

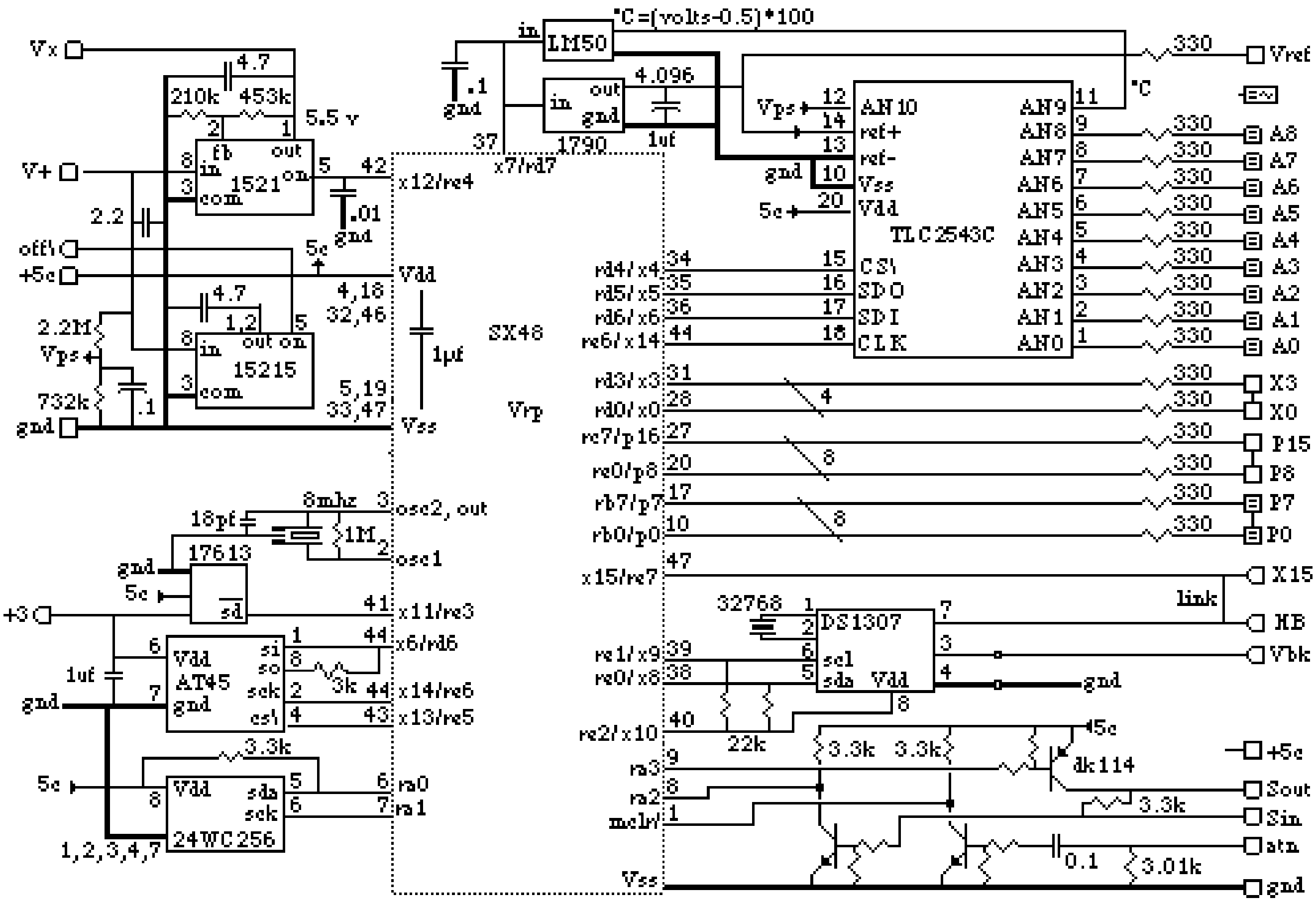
Nine analog inputs are indicated as a0 to a8, connected to pins 29 to 37 on the module. These inputs are protected also by a 330Ω resistors. The analog inputs have no counterpart on the regular BASIC Stamp and are unique to the OWL2pe. The capabilities of these inputs are described elsewhere in this document. Next to analog input on module pin 28 is Vr, the 4.096 volt reference. The analog inputs cover the range of 0.000 to 4.096 volts at one millivolt per bit.

Power supply inputs for 6 to 18 volts DC are found on module pins 41 and 44. The 5 volt regulated power is available on pins 39, 48 and 5. Switched power output is available on pin 40. The switched power is available for sensors and other external circuits. The switched supply is 5.5 volts standard, but it can be set at the time of ordering to any level from 5 volts to 14 volts. Ground or common connections are found at the corners as well as on module pin 38

A standard BASIC Stamp programming interface, addressed as p16 or by the DEBUG command, is provided on physical pins 1 to 4. This will normally be brought out to a DB9S connector, with
Sout from OWL on pin 4; Sin to OWL on pin 3; ATN reset to OWL on pin 2, common on pin 1.

Additional i/o is located on the left edge, including a heartbeat pulse to auxio pin x15, the clock backup battery, the system low power reset input, and the 3 volt switched and 5 volt constant power supplies.





Schematic diagram, overview

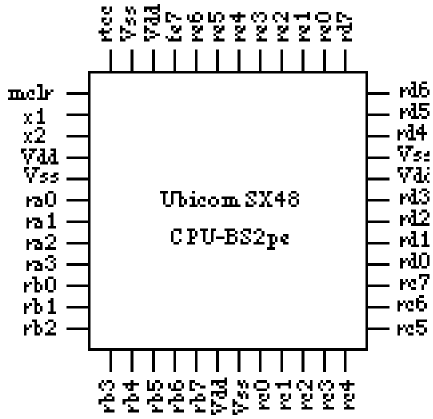
The OWL2pe core, version 1.4. The BASIC Stamp 2pe is in the center, surrounded by the on-board peripheral chips and the terminals that connect it to the outside world. Starting from 12 o'clock:

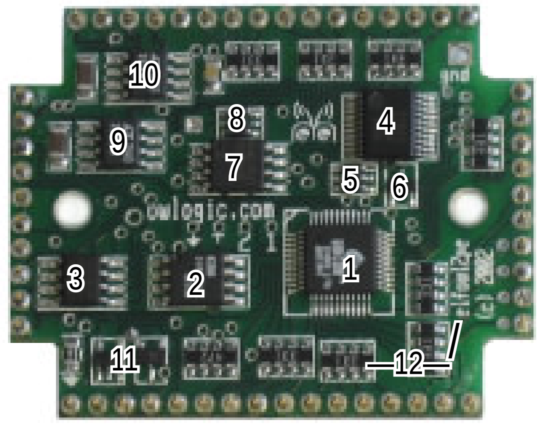
LM50 temperature sensor.
LT1790 precision 4.096 volt reference
TLC2543 analog to digital converter
DS1307 real time clock, with HB (hearbeat) output
main RS232 and debug interface, with inverting transistor buffers.
24WC256 BASIC program eeprom, 32 kbytes
AT45DB041 flash logging memory, 1/2 megabyte, 3 volt power
LT1761-3.3 voltage regulator (3.3 volts) switched
8mhz CPU crysta
5 volt LT1521-5 main voltage regulator
connection via 2.2MΩ:732kΩ voltage divider to power monitoring (4:1 ratio)
auxiliary LT1521 regulator, switched power to external circuits.

This symbol, , at some of the terminals (p0 to p7 and a0 to a8) indicates that there is provision on the circuit board for a capacitor from that position to ground. The capacitors are not installed by default, but can be installed later depending on the application.

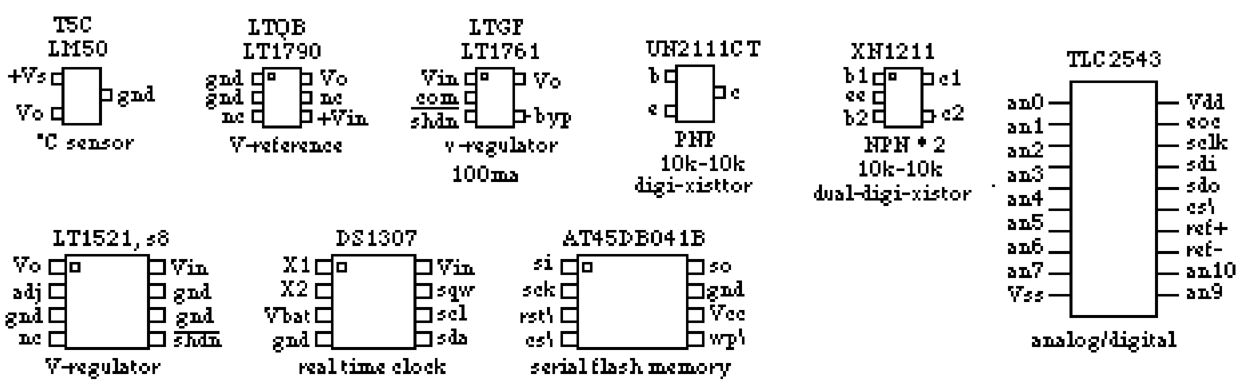
The OWL2pe uses the highest grade industrial parts for wide temperature range and greatest accuracy.

The following are the pinouts of some of the chips on the OWL2pe circuit.and a synopsis of their function.





1) BASIC Stamp, based on Ubicom SX48 microprocessor, clocked at 8 mhz.
2) 24WC256 32 kbyte eeprom holds tokenized BASIC program and data.
3) DS1307 real time clock, with heartbeat pulse and 56 bytes ram & batter backup, I2C.
4) TLC2543 analog to digital converter: 11 channel, 12 bit, SPI.
5) LT1790 precision 4.096 volt reference ±0.1% for analog converter.
6) LM50 temperature sensor: °Celsius=Volts/0.01+50 ±3 °C.
7) AT45DB041 512 kbyte flash memory for data logging, SPI.
8) LT17613 voltage regulator (3.3 volts), for logging memory and external power.
9) 5 volt LT1521-5 main voltage regulator, for elfOWL and external power.
10) adjustable LT1521 regulator, switched power to external circuits.
11) UN2111 PNP and XN1211 dual NPN digi transistors for main RS232 and debug interface.
12) 330Ω resistor networks for i/o protection.



Programming the OWL2pe; the programming/debug port

The OWL2pe is programmed just like any BASIC Stamp and follows the guidelines in the Parallax documentation. It can be programmed using any of the following means:

- Parallax software, STAMPW.EXE. This is the integrated development environment (IDE) that runs under Windows (95 and up). This includes a text editor, the compiler, and the debugger. For the OWL version 1.4 use STAMPW.EXE version 2.1beta1 or later, first released on 11/26/2003. Earlier versions of the IDE are not aware of the existence of the BASIC Stamp 2pe.

- Parallax "objectloader.exe", allows programs to be easily updated by email or by field personnel who do not have access to the full programming language. The object loader can be created by STAMPW.EXE main program, but once created, it can be separated from the IDE as an executable or as an small object file. Subsequently people can load the program into a BASIC Stamp or OWL2pe system without need to open the more complicated and bulky IDE. Great for field updates or updates via email.

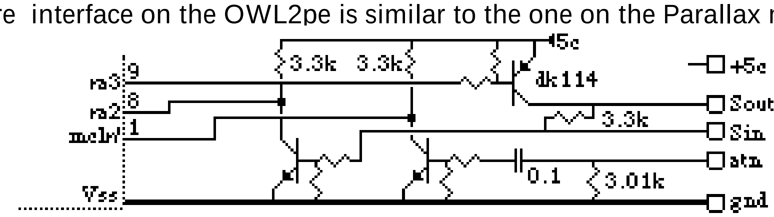
- EME Systems Stache, field programming module. This is a small battery powered module that be loaded with Stamp programs. Carried to a field site, those programs can be loaded into the OWL2pe with the press of a button. See http://www.emesystems.com/stache.htm.

Most BASIC Stamp modules sold by Prallax and others have a DB9S connector, wired DCE. A straight through cable ("modem cable") can connect between the PC and the system for programming and debugging. There are four wires, which carry three signals referenced to a common ground:

DB9 pin	signal		OWL2pe pin	signal
5	gnd	-------	1	gnd
4	DTR	----->	2	ATN
3	txd	----->	3	Sin
2	rxd	<-----	4	Sout

Often the OWL2pe module will be mounted in an enclosure of some kind, and the connection to the upload cable will be provided via the exterior panel.

The hardware interface on the OWL2pe is similar to the one on the Parallax modules.



The RS232 programming and debug interface consists of three transistors and resistors connected to SX48 pins ra2 and ra3. The interface inverts, isolates and shifts the level of the input and output signals to the RS232 line. Just as in Parallax BASIC Stamp ICs, this is a half duplex circuit that echoes all characters it receives.

The attention input (atn)connects to the master clear pin on the SX48. An external computer can initiate programming or cause the program running on the Stamp to start from the top by bringing the atn pin high. A capacitor blocks DC levels on that pin, so the reset will occur only on the positive edge of the atn signal. A resistor is provided from ATN to common, to improve noise immunity, and to improve the performance when connected to Palm and some laptop computers that put their serial port in a high impedance state.

Special function i/o internal to the OWL2pe

The BASIC Stamp from Parallax has 32 general purpose i/o pins. Of those, 20 are brought directly to the outside for use in applications. The other 12, commonly known as AUXIO x4 to x15, are used internally by the elfOWL2pe. The use of these 12 pins is summarized as follows

X15)	HB	sense real time clock heartbeat or frequency reference, always an input, needs a pullup resistor, which may be soldered directy to the OWL2pe circuit board between pins 48 and 49 or 50.
X14)	sclk	serial SPI clock for AT memory and for ADC leave this a low output when not in use
X13)	ATcs	chip select for AT45DB041 memory, active low should follow the 3 volt power, x11, except when chip is selected
X12)	Xpower	external switched power enable on module pin 40, LT1521, high=on, low=off open circuit will also leave the chip ON. see description.
X11)	ATpwr	3.3 volt power enable to AT45 memory and external circuits , high=on, low=off. ON to read/write the AT45 memory.
X10)	DSpwr	power to real time clock serial inteface High to access clock. (Clock continues to runs on battery even when this x10 pin is low.)
X9)	DSscl	I2Cserial clock for the DS1307 RTC chip with pullup to pin x10. Normally follows X10 except during I2C configure as input
X8)	DSdta	I2C serial data for DS1307 RTC with pullup to x10, normally follows X10 except during I2C. configure as input
X7)	Ipwr	pinternal ower to 4.096 volt reference and LM 50 °C sensor. high=ON. Have to turn this power on in order to read the ADC. The reference voltage is also available on pin 28 of the module.
X6)	ADsdo	serial data to TLC2543 and to/from the AT45DB041 logging memory leave as low output when not in use
X5)	ADsdi	serial data from TLC2543 to Stamp. leave this as low output when not in use.
X4)	ADcs	ADC chip select, active low to select TLC2543 for a/d conversion. leave this high when not in use

All of the above auxiliary pins are accessed by issuing the AUXIO command or the IOTERM 1 command. Subsequent commands will refer to the pins x0 to x15, until a MAINIO or an IOTERM 0 command sets the pin access back to the main group of 16, p0 to p15.

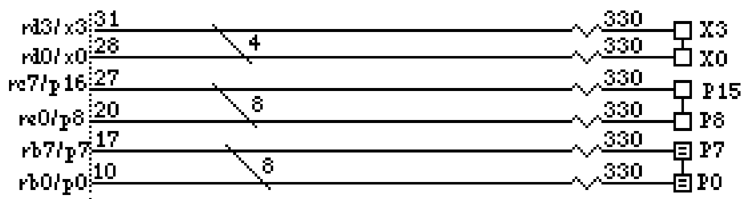
Needless to say, it is very important to understand what these pins do if you are to program the OWL2pe and make use of its special features. The sections to follow describe the the real clock chip, the analog to digital converter, the logging memory and the power supplies, and those sections go into detail about how to manage the relevant pins. Another section describes how those pins should be set in order to achieve the lowest possible current consumption. That can be an important concern in a data logging project.

When the module is first powered up all of the pins are inputs. That is fine to start. Nothing bad will happen if they are left as inputs. Also, the pins remain inputs unless a program tell them to do something else. It is often useful to write short test programs that manipulate a few of the pins or no pins at all. In such cases, the pins remain as inputs. That is fine, Run those programs without concern that anything bad will happen to the circuits connected to the pins x4 to x15.

All pins are inputs upon reset. In sleep modes (SLEEP, NAP, POLLWAIT and END) all pins briefly become inputs in between the sleep periods. On the OWL2pe, this input period is 0.15 millisecond. The switched power supply has a capacitor on its enable line that holds the power constant.

Pin x15 is brought to the outside of the header on pin 49, but it is connected there directly to the heartbeat output of the real time clock on pin 50. It is normally used for sensing the heartbeat pulse. It is brought out so that additional counting circuitry can be added externally. Normally we install a 1mΩ pullup resistor from x15/HB to +5 volts Vdd.

General purpose i/o pins on the OWL2pe module.



The BASIC Stamp 2pe from Parallax has 32 general purpose i/o pins. The previous page described how 12 of those are used for special purposes in the OWL2pe, to address the analog to digital converter, the real time clock, the data logging memory and the power supplies. That leaves 20 pins, which on the OWL2pe are brought to the header the edge of the module where they can be connected to external circuitry.

All sixteen of the pins known on the BASIC Stamp as MAINIO p0 to p15 are available, as well as 4 of the pins known as AUXIO. x0 to x3. Any or all of these pins can be used for any of the standard PBASIC commands, which are described in great detail elsewhere, including in the tutorials on the Parallax web site and on the EME Systems web site. The PBASIC instructions AUXIO and MAINIO will be used to switch back and forth between the two banks of 16 pins, p0 to p15, and x0 to x15.   Or, the commands IOTERM 0 and IOTERM 1.

All 20 of those pins are protected by 330 Ω series resistors. The resistors limit the current, in case a short circuit or an excess voltage is applied externally to the pins. The pins can also directly drive things like light emitting diodes, as the resistor act to limit the current to a safe level.

There is provision on the module for capacitors to be installed from the pin connection to ground on the pins of MAINIO p0 to p7, however, these capacitors are not installed by default. It depends on the application.

Each pin is rated for a maximum of 20 milliamps source or sink, and each group of 8 pins (p0 to p7, p8 to p15, and x0 to x3) is rated for a sum total of 50 milliamps.   The 330 ohm resistors limit the short circuit current to 15 milliamps per pin.

The switching threshold of the pins is TTL level, 1.4 volts. They are all high impedance sensing inputs. Unused inputs should be configured as outputs or else they should have a pullup or pulldown resistor installed, for lowest current consumption in the sleep modes. For running test programs, it is okay to leave them as inputs. Input is the default on power up.

All pins are inputs upon reset. In sleep modes (SLEEP, NAP, POLLWAIT and END) all pins briefly become inputs in between the sleep periods. On the OWL2pe, this input period is 0.15 millisecond.

Startup and low power sleep states for the pins

The following is a typical start-up state for the stamp pins. It comes up with the system ready to read the real time clock chip, and the 3 volt power to the logging memory turned on, as well as power to the ADC reference and temperature sensor and the external power .

There are many variations on this theme, depending on what the system is going to do and how frugal it needs to be with power. For example, it may not need to turn on the ADC reference power and the 3 volt power and the external power until the clock time is determined, and it is found to be time for data acquisition and logging activity.

The state of the external pins need to be determined by what those pins are assigned to do in a given application. If is pin is not used for anything, not connected to anything, then it should be configured as an output, either high or low. (Floating unconnected inputs lead to excess current drain.)

For running short test or developmental programs, it is not necessary to do anything with the pins. Just leave them in their default state, as inputs. The current consumption may be higher, but never dangerously so.

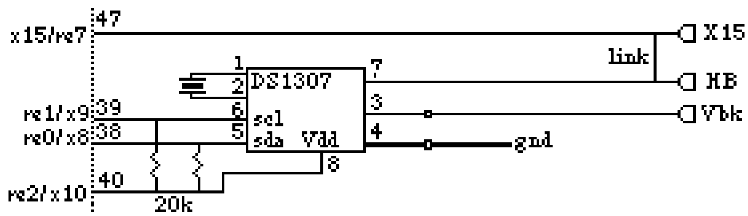
```
AUXIO
DIRS=%0111110011111111    ' $7cff
     'fedcba9876543210
OUTS=%0011110010010000    ' $3c90
' xf) input for rtc pulses with pull-up resistor
' xe) low to clock the AD converter and the AT45 memory.
' xd) high to deselect AT45 memory (power xb is also high)
' xc) high to turn on external sensor power
' xb) high to turn on 3 volt power to AT memory and to external 3 volt.
' xa) high to turn on power to DS1307 clock
' x9) input serial clock DSscl line high with pullup to xa
' x8) input serial clock DSdta line high with pullup to xa
' x7) high to turn on power to 4.096 volt reference & temperature sensor.
' x6) low, data to ADC and to/from the AT memory
' x5) low, data from ADC
' x4) high  to deselect ADC
' x3-x0) low to outside pins--depends on what is connected

MAINIO
OUTS= %0000000000000000
     'fedcba9876543210
DIRS= %1111111111111111
' all low outside pins, depends on what is connected
```

The following is a desirable state for the pins in sleep mode. Note that there is an additional step to be taken to power down the ADC. explained in the section devoted to it.

```
AUXIO
DIRS=%0111110011111111     ' $7cff
     'fedcba9876543210
OUTS=%0000000000010000     ' $0010
' xf) input for rtc pulses with pullup resistor
' xe) low clock for ADC and AT45
' xd) low to deselect AT45 memory (power line xb to chip is off)
' xc) low to turn off external power
' xb) low to turn off 3 volt power.
' xa) low to turn off interface power to DS1307
' x9) input serial clock line with resistor to xa
' x8) input serial clock DSdta line with resistor to xa
' x7) low to turn off power to reference & temperature sensor
' x6) low, data to ADC
' x5) low, data from ADC (tristate when not selected)
' x4) high  to deselect ADC
 x3 to x0) state shown LOW, depends on what is connected

MAINIO
OUTS= %0000000000000000
     'fedcba9876543210
DIRS= %1111111111111111
' all low outside pins, depends on what is connected
```

Remember that additional considerations may apply to the least significant 4 bits x0 to x3. and to all of the MAINIO pins p0 to p15. These are external pins on the OWL2pe module and their best state will depend on what is connected to them externally. If nothing, then make them either low or high outputs.

Real time clock



DS1307 real time clock—Dallas/Maxim semiconductor

The DS1307 maintains date and time even in the absence of the main power, at Vdd, so long as a 3 volt lithium battery is connected. There is provision on the OWL2pe circuit board to solder a 48 milliamp-hour CR1216 battery, At 500 nanoamp drain, this battery should last up to 5 years. (0.048/0.5E-6=96000 hours = 4000 days = 10+ years; = the shelf life of the battery due to self discharg). If the on-board battery is used, then the battery voltage will be available on the external pin Vb. Alternatively, if the battery is not installed on board the OWL2pe, an external battery can be used and applied to pin Vb. Do not use both an internal and an external lithium cell. Be careul when installing the battery, as reversing its polarity will destroy the DS1307 chip. If an external, user replaceable battery is used, please provide a diode or other means to insure against accidents.

The OWL2pe does not have provision to monitor the state of this battery, although this could be arranged through external circuitry to an ADC channel. The chip will not operate correctly unless the backup battery pin is connected to a voltage less than 3.5 volts. If a backup battery is not used, then the Vbk pin 3 must be connected to gnd pin 4. Other battery precautions: Do not overheat the battery, definitely not more that 85°C. The electrolyte will build up pressure and evaporate shortening its life. Do not short circuit the battery pins. Be sure the circuit board is clean, and seal near the contacts with a conformal coating if the OWL2pe will be subjected to high humidity, so the battery cannot find a leakage path across the circuit board. The crystal oscillator in the DS1307 is also sensitive to extra leakage paths across the board.

The serial I2C interface between the BASIC Stamp and the DS1307 is not active unless 5 volt power is supplied to the DS1307 Vdd pin 8. This power is supplied by pin x10 from the BASIC Stamp, and this power will only be turned on when the program needs to read the clock. This means that the clock chip wil normally be operating from the lithium cell, not from the Vdd power. The current drain at Vdd is about 200 µamps, which may not seem like much, but it is in relation to the OWL2pe micropower operation. The timekeeping from the lithium backup battery is only 0.5 microamp. Turning the Vdd power off from the BASIC Stamp does not stop the timekeeping, but it does save substantial operating current.

Pins x8 and x9 from the BASIC Stamp are connected to the RTC and have pullup resistors to pin X10. These pins should always be left as inputs, except through the action of the I2CIN and I2COUT commands. These pins x8 and x9 should never be made high outputs, especially when the power to the DS1307 is off, x10 low. Making them high can disturbp the clock operation.

The DS1307 pins sda (serial data) and scl (serial clock) communicate using I2C protocol with the microcontroller cpins x8 and x9. Here is a simple example program that sets the seconds to zero and then displays seconds until it reaches 30 seconds.

```
RTCsda      PIN 8
RTCscl      PIN 9
```

```
seconds      VAR byte
readclock:
  AUXIO
  HIGH 10
  I2COUT RTCsda,$D1,0,[0]       ' seconds=0
  DO
    I2CIN RTCsda,$D0,0,[seconds]
    DEBUG HEX2 seconds
    PAUSE 1000
  LOOP UNTIL seconds=30
  LOW 10
END
```
.

To read or write the chip, the x10 line from the BASIC Stamp is made high to provide power, and both sda and the scl follow suit, pulled high via the resistors. To power down, RTCsda and RTCscl are left as inputs and pin x7 is brought low to power down the chip. Sda and scl should never be made high outputs while the DS1307 pin8 is low. Doing so can temporarily stop the clock, so it would appear to lose time.

When the DS1307 is first powered up from the factory, it is in a state where the clock is not running at all. Bit 7 of the seconds register is high, and this bit must be set low in order for the clock to run. The above program does this (if it had not been down before) when it sets seconds to zero. This bit can be set high to stop the clock, to save power from the lithium battery during periods of storage and inactivity. The above demo program writes a zero into the seconds register, which will start the clock.

The clock memory includes 7 timekeeping registers, one heartbeat register, and 56 bytes of uncommitted RAM, as follow:
,

seconds	0–59	(bit 7=1 stops clock oscillator)
minutes	0–59	
hours	0–24	
day of week	0–7	
day	1–31	
month	1–12	
year	0–99	
heartbeat	see table below	
RAM (56 bytes)	0-255 for each byte	

The day of week register is updated modulo 7, but it is up to the programmer to initialize it to whatever day will be the zero reference. Note for computation that January 1st, 2001 was a Monday. Please seethe web site emesystems.com for date and time calculations.

The heartbeat register (location 7 in the clock RAM map) determines the action of pin 7 on the DS1307 chip. The heartbeat is an output from the clock chip that can be set to one of six different values, 1 hertz, 4096 Hz, 8192 Hz or 32768 Hz, or low, or high. The output is an open drain transistor, and an external resistor is necessary to pull the level up to +5 volts. This signal is fed both to an output from the OWL2pe module pin 50, and it is also it fed back into pin x15 of the BASIC Stamp micro-controller. This allows the heartbeat signal to be used as a frequency or timing reference for the controller. The operation of the heartbeat signal is set in a read/write configuration register in the clock chip. When the heartbeat output is set for 1 Hertz, the high to low transition is synchronous with update of the clock registers. Examples are shown in programs below.

x0010000	HB 1 Hertz	x = dont't care
x0010001	HB 4096 Hz	
x0010010	HB 8192 Hz	
x0010011	HB 32768 Hz	
00000000	HB always low	
10000000	HB always high	

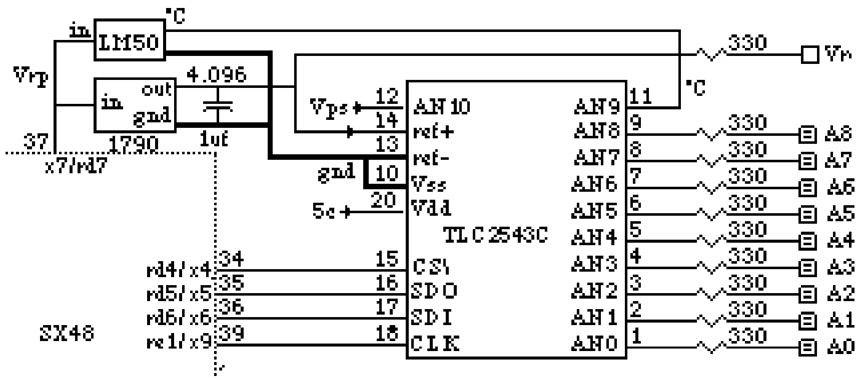
Here is an example program that sets the clock to midnight on Jan. 1, 2001, starts it running, and then displays the date and time at one second intervals. It sets the heartbeat for a 1hz output, and uses that to synchronize the display to the second. The program also increments a counter and stores it in the extra clock memory. This counter is backed up by the battery as is the running clock. so that it can survive resets and the disconnection of the system power.

```
{$PBASIC 2.5}
{$STAMP BS2PE}
' demo program to read DS1307 real time clock on OWL2pe
' (c) 2003 EME Systems
' sets and reads time, uses heartbeat, tests RAM
RTCpwr      con 10      ' high here turns on DS1307 serial interface
RTCsda      con 8       ' I2C data for RTC
RTCscl      con 9       ' I2C serial clock for RTC

DSHB1       con $10     ' configure DS1307 1 Hz heartbeat
DSHB4       con $11     ' configure DS1307 4096 Hz heartbeat
DSHB8       con $12     ' configure DS1307 8192 Hz heartbeat
DSHB32      con $13     ' configure DS1307 32768 Hz heartbeat
DSHBL       con $00     ' configure DS1307 constant low non heartbeat
DSHBH       con $80     ' configure DS1307 constant high non heartbeat

DSconfig    con 7       ' config register
DStime      con 0       ' location of seconds register
DSram       con 8       ' start of general purpose RAM

ww          var word    ' four general purpose word variables
wx          var word
wy          var word
wz          var word
pointer     VAR word    ' example of storage in RTC RAM

idx         var mib           ' index

second      var ww.byte0
minute      var ww.byte1
hour        var wx.byte0
dow         var wx.byte1      ' day of week (e.g. 0=Sunday)
day         var wy.byte0
month       var wy.byte1
year        var wz.byte0


Top:
  AUXIO
  HIGH RTCpwr
  GOSUB Read_time
  if second.bit7=1 them GOSUB Init_clock
  GOSUB Start_Heartbeat
```

```
Main:
DO
  GOSUB Read_time
  GOSUB Retrieve_pointer
  pointer=pointer+1
  GOSUB Save_pointer
  LOW RTCpwr            ' turn off RTC power
  debug cr,"20",hex2 year,"/",hex2 month,"/",hex2 day
  debug rep 32\8,hex2 hour,":",hex2 minute,":",hex2 second
  debug rep 32\8, "pointer=", dec pointer
  POLLMODE 2            ' ready to pollwait
  POLLIN 15,1           ' wait for high on x15
  POLLWAIT 3            ' using 0.125 second increment
  POLLIN 15,0           ' wait for low on x15
  POLLWAIT 3            '
  HIGH RTCpwr           ' power on to RTC serial interface
LOOP

Init_clock:       ' there are more condensed ways to do this!
  second=0 : minute=0 : hour=0
  dow=0 : day=0 : month=1 : year=1
  I2COUT DSdta,$D0,DSram,[STR second\7]   ' save time & date
RETURN

Read_time:
   I2CIN DSdta,$D1,DStime,[STR second\7]  ' read 7 bytes, time & date
RETRUN
:
Retrieve_pointer:       ' retrieve pointer from RTC RAM
   I2CIN DSdta,$D1,DSram,[pointer.byte0, pointer.byte1]
RETURN

Save_pointer:           ' save pointer to RTC RAM
   I2COUT DSdta,$D0,DSram,[pointer.byte0,pointer.byte1]
RETURN

Start_heartbeat         ' set one second heartbeat on x15
   I2COUT DSdta,$D0,DSconfig,[DSHB1]
RETURN
```

This program uses only the clock chip. Note that it stays exclusively with the AUXIO pins and never has need to switch to MAINIO. The routines like Read_time are very short, so in some programs it will be efficient to code them directly in line instead of as subroutines. .If you are unfamiliar with the I2C protocol, please refer to the DS1307 data sheet, or the the emesystems.com or the the www.parallax.com web site for tutorials and example programs.

The Analog to Digital Converter



TLC2543 analog to digital converter—Texas Instruments
    11 input channels, single ended, 12 bits, SPI interface, 4µamp sleep mode
LT1790-4.096 precision voltage reference—Linear Technology
    0.1% accuracy over temperature range, 2 mA output current
    OWL2pe input range, 0 to 4096 millivolts, resolution 1 millivolt
    ±4 millivolts uncalibrated accuracy, ±1 millivolt with calibration.
    The reference output (via 330 Ω protection) is also available on an output pin.
LM50 temperature sensor—National Semiconductor
    millivolts output = 10 * Celsius + 250 ± 2%.

The TLC2543 is a 12 bit analog to digital converter, which has 11 input channels and an SPI serial interface to the microprocessor. In the OWL2pe, nine of the input channels (AD0 to AD8) are brought to the outside for general purpose application, on module pins 29 to 37. Two additional inputs are used inside the module, one, AD9, is dedicated to measure temperature from an on board LM50 Celsius sensor, and the other, AD10, monitors the power supply voltage, Vps.

The OWL2pe includes an LT1790 precision voltage reference, 4.960 volts ±0.05%. The input range for voltage conversion is 0 to 4.096 volts with a resolution of 1 millivolt.

The TLC2543 is powered by the system 5 volt supply. In operation, the TLC2543 draws up to 1 milliamp. A special instruction puts the chip to sleep, to a drain of less than 4 µamps. The reference and the temperature sensor are powered by pin x7 on the microcontroller AUXIO bank. Reading the AD converter will always be done when this pin x7 is at a high level. And x7 will be made low for minimum power drain.

External inputs are protected with 330 ohm resistors, which limit current in cases where the externally applied input voltage might exceed the power supply voltage. There is provision on the circuit board, indicated by this symbol on the schematicl: . to add capacitors to filter the input signals. Those capacitors are not present by default, but can be added if necessary for a given application.

The TLC2543 does not exhibit crosstalk when the analog inputs are out of range, that is, if one input exceeds the power supply voltage, it will read the maximum (4095) or minimum (0) count, but the neighboring channels will not be affected.

The SPI interface for this chip uses 4 microprocessor lines. The clock line is shared with the memory chip, as is the serial input line. The chip select lines determine which device will control the SPI serial bus. The TLC2543 can receive a command on its ADsdi input pin at the same time that it delivers data from the previous command on its ADsdo output, however, in the OWL2pe, the command and the result will always take two separate operations, because the BASIC Stamp microcontroller cannot both send a command and listen at the same time.

The short program below illustrates a standard method to read the analog to digital converter. It displays the temperature and the power supply voltage on the debug screen.

```
{$PBASIC 2.5}
{$STAMP BS2PE}
' demo program to read TLC2543 AD converter on OWL2pe
' (c) 2003 EME Systems
' reads temperature and power supply voltage, calling ADC subroutine
ipower      con 7       ' high here turns on reference & temp sensor.
ADcs        con 4       ' low level here selects TLC2543
ADsdo       con 5       ' data from TLC2543 to BS2pe
ADsdi       con 6       ' data from BS2pe to TLC2543
sclk        con 14      ' the serial clock is shared

ADoff       con $e      ' command to put TLC2543 to sleep
ADvolt      con $a      ' command to read temperature sensor
ADheat      con $9      ' command to read power supply volts (/4)
AD8         con $8      ' command to read external AD input 8
AD7         con $7      ' command to read external AD input 7
AD6         con $6      ' command to read external AD input 6
AD5         con $5      ' command to read external AD input 5
AD4         con $4      ' command to read external AD input 4
AD3         con $3      ' command to read external AD input 3
AD2         con $2      ' command to read external AD input 2
AD1         con $1      ' command to read external AD input 1
AD0         con $0      ' command to read external AD input 0

ADch        var nib     ' channel to select on the TLC2543
wx          var word    ' data from the converter

DO
  GOSUB ADinit          ' get ready to read ADC
  ADch=ADvolt
  GOSUB ADconvert
  result=result*4       ' convert to millivolts
  debug cr,"millivolts= ", DEC wx,tab
  ADch=ADheat
  GOSUB ADconvert
  result=result-500     ' convert to Celsius*10
  debug "Celsius=", REP "-"\wx.bit15,DEC ABS wx/10,".",DEC1 ABS wx
  GOSUB ADsleep
  NAP 6                 ' nap for about 1 second
LOOP                    ' do it again

ADinit:                 ' power on reference and ready to read ADC
  AUXIO
  HIGH ipower           ' turns on the reference power
  INPUT ADsdo     ' this Stamp pin receives data from TLC2543
```

```
  PAUSE 1         ' delay for reference to stabilize
RETURN

ADconvert:
  LOW ADcs              ' select the TLC2543 chip
    SHIFTOUT ADsdi,sclk,msbfirst,[ADch<<8\12]  ' note shift left 8 bits
    SHIFTIN  ADsdo,sclk,msbpre,[wx\12]
  HIGH ADcs
' arrive here with the result in variable wx
RETURN

ADsleep:
  LOW ADcs              ' select the TLC2543 chip
    SHIFTOUT ADsdi,sclk,msbfirst,[$e00\12]   ' power off command is $e
  HIGH ADcs             ' now powered down
  LOW ipower            ' turn off the reference power
  LOW ADsdo             ' assert the line level while sleeping
RETURN
```

The ADoff routine concludes by setting a couple of the microprocessor lines to levels that result in the lowest power consumption. The ADsdo line is brought to a low level, because the TLC2543 tristates its output when it is not selected. The line must be at a definite level to keep it from floating. Floating inputs result in unpredictable levels and excess current consumption.

It often happens in a program that several analog to digital conversions will be carried in a row. It is not necessary to run the initialization routine between each conversion, because all of the power and signal lines are already in the correct state.

There are many other ways to organize these instructions, of course, depending on program requirements for speed or efficiency.

The OWL2pe hardware does not have a connection to the "conversion complete" pin on the TLC2543. The converter is much faster than the BS2pe chip, and the conversion is always complete by the time the PBASIC program gets around to it.

The TLC2543 acts on instantaneous samples of the input waveform. If noise or 60 hertz pickup is present at the input, the readings will appear to fluctuate. This can be overcome by better design of the instrumentation, for example, with shielded cables or amplifiers by the signal source. Suppression of noise can be accomplished with a low pass filter at the input of the converter, by using an external RC circuit for example. Finally, digital filtering in software can remove stubborn fluctuations on quasi-static signals (See example programs at www.owlogic.com).

Tight program loops can read a single channel on the analog to digital converter at intervals of less than 5 milliseconds. The sampling scheme inside the chip generates a small pulse of current at the input at the start of each conversion cycle. If attempting a rapid conversion cycle, keep the RC time constant of any input filter well under 5 milliseconds, to maintain accuracy.

The reference output on the OWL2pe is brought to an external pin. That is via a 330Ω resistor for protection. The current available from this pin is limited, and it is not a good idea to load it with more than 1 milliamp.

The reference is important for the accuracy of the analog to digital converter. . We suggest the use of an external x1 butter amplifier to isolate the reference from any external signal it may have to drive. Due to the usefulness of the external reference voltage, the OWL topboards incorporate such a buffer between the reference pin and external loads. Note that the reference turns on and off by means of Stamp pin x7. Current for the reference is supplied by thatCPU pin.

Channel AN9 is dedicated to an on board LM50 temperature sensor. This sensor (along with the voltage monitor) serves as a check on the operation of the converter. Also, having the temperature of the logger recorded in the data file can serve as a sanity check and as an aid in troubleshooting field installations. Finally, the temperature sensor can help with temperature compensation of the real time clock.

The sensor has an output of 10 millivolts per degree Ceslsius, with 0 millivolts set at -50 degrees Celsius. The formulat to convert from millivolts to Celsius (*10) is:

```
degC = result/10-50
```

Or as the above program illustrates, convert to tenths for better resolution:

```
degC = result-500
```

`Channel 1`he seChannel 10 has a voltage divider that samples the input voltage to the module, the voltage on module pin 41. The resistors apply 1/4 of the Vin to the analog to digital converter, so a reading from that channel is converted back to millivolts as follows:

```
m Vin = result * 4       ' in millivolts
```

OWL2pe is put to sleep, using the command shown, then the first reading after it wakes up may be inaccurate. We suggest taking one throw-away reading to wake up the chip.

Memory resources on the OWL2pe

A) There are several distinct memory resources on the OWL2pe.

1) RAM that can be written an indefinite number of times

a) Main RAM for active PBASIC variables, 26 bytes, This is standard on every BASIC Stamp. and can be addressed with flexibility as words, nibbles or bits, or as arrays at any variable size. All zeroed at reset or power-up.

b) Really part of the main RAM are 12 bytes, 6 words, that contain the state of the i/o pins. 4 bytes (32 bits) for the binary state of the 32 inputs, 4 bytes for the state of the output latches, and 4 bytes for the directions, defining each pin as either an input or an output.

c) Scratchpad RAM, 127 general purpose bytes plus 9 special information registers. Our programs use this RAM as a buffer for less frequently needed variables and stack. Access with PUT and GET. All zeroed on reset of power-up.

d) Clock memory, 56 bytes plus 8 timekeeping registers, accessed wth I2Cin and I2Cout used for frequently changing memory pointers that need to be non-volatile. Battery backed, maintained through reset and power-up.

e) Buffers A and B on the AT45DB041 logging flash memory. Holds data in transit to and from the logging memory. Accessed with SHIFTIN and SHIFTOUT. Zeroed when the 3 volt power supply is turned off.

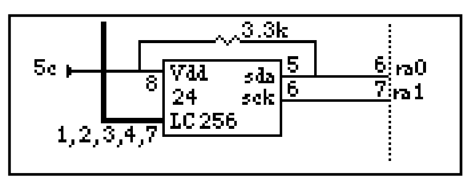
2) EEPROM or Flash memory that has a finite life for rewrites.

a) Data and program eeprom, 32kbytes on the BS2pe. Eeprom not used for program code can be used for DATA storage, Accessed using the READ, WRITE, and STORE commands.. Finite number of writes, >100000 per location. but non-volatile, maintains contents through resets and power-up.

b) Flash logging memory, 2048 pages of 264 bytes per page (=540672 bytes, 1/2 meg) Used primarily for data logging. Access via SHIFTIN and SHIFTOUT and the RAM buffers, (1d) above. Endurance 50000 writes per location.

c) PBASC interpreter. This is really not user memory. It is code that is permanently burned into the eeprom of the SX48 microprocessor, the code that runs the PBASIC program. Non volatile. This firmware is not normally changed during the life of the product, but if an upgrade in the Stamp firmware should become available, it is possible to do that with the programming pads provided on the OWL2pe circuit board.

2) A 24WC256 eeprom stores the tokenized PBASIC program. The PBASIC interpreter reads the program out of this memory and executes the program commands that it finds there. It is also possible to store data in this eeprom, both as compile time constants, and as data that can change at run time by the program action using the READ, WRITE commands. The 24WC256 is a 32k by 8 bit (32kbyte) eeprom. PBASIC organizes the eeprom into banks of 2k bytes each, and the development environment treats each of those 2kbyte banks as separate programs, which may be linked into a "project" and program control passed from bank to bank by means of the RUN command.



In addition to the 8 banks * of banked program memory, the 24WC256 has an additional 8 banks that can be used for data storage only (not RUN). The contents of the entire 32k can be addressed for READ and WRITE by using the STORE command to change the bank pointer.

The following are the memory resources common to any BASIC Stamp 2pe, both as it is found on the OWL2pe and on the product modules from Parallax. The BS2pe has more eeprom than any other Stamp.

- The 26 btes of main RAM, plus the 12 bytes of i/o mapped RAM, is used for the most important variables and for all calculations and operations.

- 127 bytes of Scratchpad RAM will be used for data buffers and for less important variables, and the 9 extra bytes of read only memory in the scratchpad area provide system status information for advanced programming.

- 32kbytes of Eeprom is for the application program and also parameters and data that does not need to change so often, and even for data logging in smaller (<32kbyte) projects

The original BASIC Stamp 2 had only 2kbytes of program eeprom, and no scratchpad RAM.

The following memory resources are not present on other BASIC Stamps:

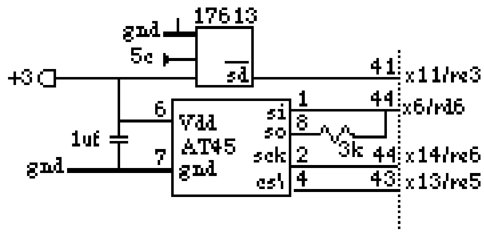
The AT45DB041—serial dataflash contains both flash memory and RAM.

a) 540672 bytes of flash memory (greater than 1/2 megabyte), is organized as 2048 pages of 264 bytes per page. This is primarily intended for logging lots of data. Even with smaller data sets, it allows backups to be maintained for a period of time. This chip has an advanced command set that needs to be implemented in PBASIC code,in order to write and read and to write to and from the memory pages. Flash memory is a little different from eeprom, because writes have to be done a whole page at a time.

b) In addition to the 2048 pages of flash memory, the AT45DB041 also has two pages of RAM memory. Data that is going to be stored in the flash memory will get there by way of one or the other of these RAM buffers, so that the writes can be done a whole 264 byte page at a time. When the RAM buffers are not busy passing data to the flash memory, they can be used for general purpose RAM storage.

The DS1307 real time clock chip contains not only the battery backed time and date functions, but also 56 bytes of battery backed RAM. This memory is very important for the OWL2pe systems, because it will hold important data logging pointers. It can also hold values and accumulations that need to survive main power outages.

The data logging memory



AT45DB041—serial dataflash—Atmel Semiconductor
- 540672 bytes of flash memory
- 0rganized as 2048 pages of 264 bytes per page.
- Plus two ram buffers, each 264 bytes
- Advanced command set
- operating voltage 2.7 to 3.6
- SPI/microwire serial interface, 5 volt tolerant inputs.
- 4 mA read, 2 µA standby, 40 mA peak page write/erase
- Endurance, 50,000 write cycles per page.

LT176133— voltage regulator, 3.3 volt—Linear Technology
- power for the flash memory and also for external devices
- 100 mA maximum current, 50 mA for external devices
- low power shutdown mode, 0.1 µamp, operating, 20 microamps quiescent.

The AT45DB041 is a 1/2 megabyte flash memory chip in an 8 pin package that connects via a three-wire SPI serial interface to the microprocessor. This memory is where data will be logged on the OWL2pe. This memory chip has an extensive command set. All writing to the flash memory is done via two 264 byte RAM buffers, that is, existing data on a page is read into one of the RAM buffers (either one), then new data is written into the RAM memory, then the whole 264 byte buffer is written back to the flash page. Data in the flash array can be read either directly, or it can be transferred 264 bytes at a time to either of the RAM buffers. While the contents of the flash memory are nonvolatile, the contents of the RAM are lost when the 3.3 volt power is turned off.

The 3.3 volt power comes from the LT176133 voltage regulator, which also supplies power to an external pin on the 52-pin module. The power can be used for external devices, however, care should be taken not to short circuit that power by any mistake, because the data logging memory depends on it. Limit external current to less than 50 mA. The 3.3 volt power is turned on by bringing pin x11 high. This pin is not used for anything else. When the 3.3 volt power is high, the chip select line, driven by Stamp pin x13, should also be high, unless a chip memory operation is underway. And when the 3.3 volt power is turned off, the chip select, x13, also should be brought low.

The data out signal line on the AT45DB041 is connected via a 3.01kΩ resistor to the data in signal line, ante then to OWL2pe Stamp pin x6. TheAT45 data output line will always be in a high impedance mode when the chip is receiving commands, then it will go into an active high/low state when it answers those commands and sends its data to the Stamp. The resistor avoids contention that might happen if both SO and the stamp pin happen to be opposite outputs.

The serial clock for the AT45DB041 is Stamp pin x14. That is also the serial clock for the analog to digital converter. Pin x6 and pin x14 are shared between the AT45DB041 memory and the TLC2543 analog to digital converter. This sharing of the data and clock lines is permitted by the SPI protocol. The chip select line will determine which chip is active.

Note that the AT45DB041, even though it runs from a 3.3 volt power supply, has what are called "5 volt tolerant inputs". The voltage level on its serial interface pins can safely be 5 volts. Those pins have a high impedance to 5 volts inputs, whether the 3.3 volt power is ON or OFF. Therefore, data can be exchanged with the ADC without the 3.3 volt power having to be turned on. There is no danger of damage to the AT45DB chip by doing this. Those pins act as a high impedance when not selected or when the power is off. The ATcs line is also 5 volt tolerant.

To use the AT45 memory, its power must first be turned on

```
AUXIO              ' peripherals are on auxiliary i/0 pins
HIGH 11            ' pin x11 turns on the LT1761-3.3 regulator
HIGH 13            ' chip select high to disable it.
PAUSE 20           ' ATMEL suggests  20 ms after power up, 5 is enough.
                   ' this might be part of ensuing program.
```

All exchanges between the microprocessor and the AT45DB041 start with the chip select pin x13 going from high to low, followed by a command from the BASIC Stamp, and then data flow to or from the AT45DB041. The data transfer may involve anywhere from none to thousands of bytes in one exchange. Finally, the chip select line is brought high again to complete the command. The following exchange writes a byte value 55 to location 72 of RAM buffer #1:

```
AUXIO
  LOW 13
    SHIFTOUT 6,14,MSBFIRST,[$84\8, 0\15, 72\9, 55\8]   ' 55 in loc 72 in ram #1
  HIGH 13
```

The command is $84, followed by additional 15 bits (don't care address) followed by the address (72 is in the range from 0 to 263) on the ram memory page, followed by the data byte 55.

The AT45DB041 has a command set with 26 different commands. While the commands are one byte each, tsome of the commands require additional clocking pulses. The following general purpose routine sends any command, and adds the necessary clocking bits that are required for completion. Long commands require either 8 of 32 bits of extra clocking.

```
sndcmd:
  AUXIO
  LOW ATcs
   ' send the byte address, (0 to 264)
   SHIFTOUT ATsd,sclk,MSBFIRST,[cmd\8,ATpage\15,ATadrs\9]
   SELECT cmd
     CASE $52,$68,$D2,$E8
       SHIFTOUT ATsd,sclk,MSBFIRST,[0\16,0\16]
     CASE $54,$56,$D4,$D6
       SHIFTOUT ATsd,sclk,MSBFIRST,[0\8]
   ENDSELECT
  RETURN
```

In general, the command byte is followed by the address of a page from 0 to 2047, contained in 15 bits, followed by an address within that page, from 0 to 263. That is it for most commands, athough specific read commands listed in the CASE statement require extra clocking bits.   Note that the command starts by bringing the ATcs line to a low level. The command will be finished by bringing that line back high. Usually another routine will call this subroutine to activate the command, return to do some business to read or write the memory, and then bring ATcs back high and to finish the task.

The command set of this chip is extensive and there are many possible ways to use it. Please consult the Atmel data sheet and application notes for a full exposition.

There are commands that read data from the AT45DBxxx that have two possible forms. The Stamp can use either form, so long as the MSBPRE or MSBPOST is entered correctly with the SHIFTIN statement.

if the following commands are SHIFTOUT
  $D2 read data bytes direct from flash page (cycles within page)
  $D4 read data bytes from RAM buffer #1
  $D6 read data bytes from RAM buffer #1
  $E8 read data bytes from Flash array (can cross page boundaries)
then use the form SHIFTIN ATsd,sclk,MSBPRE,[databytes…
] to capture the data bytes

if the following commands are SHIFTOUT
  $52 read data bytes direct from flash page (cycles within page)
  $54 read data bytes from RAM buffer #1
  $56 read data bytes from RAM buffer #1
  $68 read data bytes from Flash array (can cross page boundaries)
then use the form SHIFTIN ATsd,sclk,MSBPOST,[databytes…]
 to capture the data bytes

In the form that takes MSBPRE, the data is available right after the command byte is clocked out, but the form that takes MSBPOST requires one more clock pulse to shift out the first data byte. The Stamp can handle either form. It wil generally use one or the other in a program, not both.

The following demo program writes random data to one of the RAM buffer,s then transfers that to a flash memory pages, then powers off for a few seconds (which causes the chip to lose the contents of its ram buffers) then powers up again, and transfers the flash page contents to the other ram buffer, and then reads back the data and displays it. You can observe that the data going in is the same as the data coming out, or it certainly should be! The purpose of this is to illustrate the basics of using this memory. The details of how we use it in the OWL2pe data logger are in the separate document on the OWL2pe programming.

```
' {$PBASIC 2.5}
' {$STAMP BS2pe}
' This is for the version 1.4 OWL2pe
' -------- AT45 routines --------
' (c) 2002 Tracy Allen, EME Systems, http://www.emesystems.com
' test AT45DB041 memory on the OWL2pe v1.4 core
' 1) writes 12 random data words to RAM buffer
' 2) reads back and shows the 12 words (same?!)
' 3) writes the ram buffer (264 bytes) to a random flash page
' 4) turns off the 3.3 volt power to the memory (ram lost)
' 5) turn on the power, read back the flash page (still there?!)
' 6) do it again from step 1
' 2048 pages of 264 bytes per page = 540672 bytes
' ---------------------------------------
' AT45 command set...
' SPI mode 0, sclk low when ATcs goes low, MSBPRE for SHIFTIN reads
' Note the 1st 4 commands demand the MSBPRE form for SHIFTIN of data.
arraySO       CON $E8  ' read memory continuous across page boundaries
pageSO        CON $D2  ' read memory page (loops to start of page)
buf1SO        CON $D4  ' read from buffer #1
buf2SO        CON $D6  ' ditto buffer #2
statusSO      CON $57  ' read the status register
buf1SI        CON $84  ' fill buffer #1
```

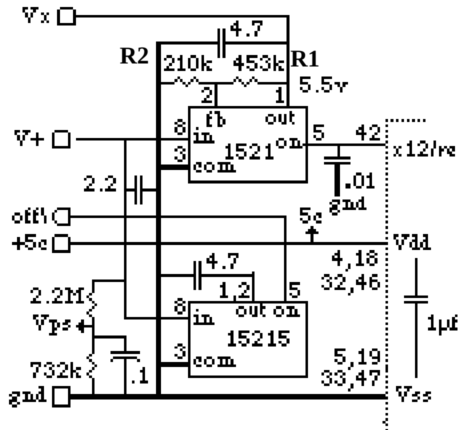
```
buf2SI        CON $87  ' ditto buffer #2
buf12pageE    CON $83  ' burn buffer #1 into memory page. erase page first
buf22pageE    CON $86  ' ditto buffer #2
buf12page     CON $88  ' burn contents of buffer #1, no erase first
buf22page     CON $89  ' ditto buffer #2
pageErase     CON $81  ' erase memory page
blockErase    CON $50  ' erase block.  There are 256 blocks of 8 pages
buf1SIpageE   CON $82  ' fill buffer #1 and write to page after erase.
buf2SIpageE   CON $85  ' ditto buffer #2
page2buf1     CON $53  ' transfer contents of page to buffer #1
page2buf2     CON $55  ' ditto buffer #2
pageXbuf1     CON $60  ' compare page to buf#1 (result in b6 of status)
pageXbuf2     CON $61  ' ditto buffer #2
autorewrite1  CON $58  ' auto rewrite page via buffer #1
autorewrite2  CON $59  ' ditto buffer #2
' -------------------------------------

' ---- program variables ----
who      VAR Word          ' for holding random numbers
cmd      VAR Byte          ' command to AT45 memory
ix       VAR Byte          ' general purpose index
ATpage   VAR Word          ' page 0 to 2047
ATadrs   VAR Word                ' address on page, 0 to 263
ATdata   VAR Word          ' data word to store/retrieve

' ---- pins for AT45DB041 on the OWL2pe
ATcs     PIN 13              ' chip select AT45, active low
ATsd     PIN 6             ' serial data for AT45
sclk     PIN 14              ' serial clock, shared with ADC
pwr33    PIN 11            ' 3.3 volt power, high=on

' ---- main demo program ----
initialize:
DEBUG BELL,CR,"top",CR
MAINIO
 OUTS=%0000000000000000
      'fedcba9876543210
 DIRS=%1111111111111111

AUXIO
 OUTS=%0010100000010000    ' $2810
      'fedcba9876543210
 DIRS=%0111110011111111
 ' turns on the 3.3 volt power and makes ATcs high
 ' also ADcs is high

main:
DO
  ' step 0...
  ' turn on the 3 volt power and make ATcs high to deselect chip
  HIGH ATcs
  HIGH pwr33
'  OUTS=OUTS|$2800      ' intpwr ON, ATcs high
```

```
                    ' same as high ATcs:high pwr33

  ' step 1...
  ' pick a bunch of random numbers
  ' and put them in ram buffer #1
  DEBUG CR,CR,"number:"
  FOR ix=0 TO 11
    RANDOM who         ' pick a number
    ATdata=who
    ATadrs=ix*2     ' address to store it on page
    DEBUG TAB,DEC who      ' show the random number
    GOSUB ATbuf1putword      ' store it in ram buffer #1
  NEXT

  ' step 2...
  ' now read back the contents of ram buffer #1
  ' the same numbers should still be there!
  DEBUG BELL,CR,"   ram:"
  FOR ix=0 TO 11
    ATadrs=ix*2            ' same addresses
    GOSUB ATbuf1getword    ' retrieve data
    DEBUG TAB,DEC ATdata         ' show it
  NEXT

  ' step 3...
  ' Now WRITE the buffer #1 into a page
  ATadrs=0          ' this zero for page write
  RANDOM who        ' pick a page at random
  ATpage=who/32     ' page 0 to 2047
  GOSUB writebuf1topage

  ' step 4...
  ' turn off the 3 volt power and bring ATcs low too
  ' note that ram buffer contents are lost when intpwr is off!
  ' turn the power back on, and chip select high too
  LOW pwr33 : LOW ATcs
  NAP 7             ' sleep for about 2 seconds
  HIGH ATcs : HIGH pwr33
  PAUSE 7    ' note delay for power up

  ' step 5...
  ' transfer the flash page to ram buffer 2, and show it
  GOSUB page2buffer2
  DEBUG BELL,CR," flash:"
  FOR ix=0 TO 11
    ATadrs=ix*2
    GOSUB ATbuf2getword
    DEBUG TAB,DEC ATdata
  NEXT

LOOP     ' main loop

' ---- start utility subroutines ----
```

```
' ------------------
' one word stored in ram buffer 1, uses ATadrs, ATdata
ATbuf1putWord:
  AUXIO
  LOW ATcs
  cmd=buf1SI : GOSUB sndcmd
  SHIFTOUT ATsd,sclk,MSBFIRST,[ATdata\16]   ' put word and autoincrement
  HIGH ATcs
  MAINIO
  RETURN

' ------------------
' retrieve one word from buffer 1, uses ATadrs, ATdata
ATbuf1getWord:
  AUXIO
  LOW ATcs
  cmd=buf1SO : GOSUB sndcmd
  SHIFTIN ATsd,sclk,MSBPRE,[ATdata\16]  ' get word from AT45 and autoincrement
  HIGH ATcs
  MAINIO
  RETURN

' ----------------
' write page, erase first, page in variable ATpage
' according to ATMEL, better erase always
writebuf1topage:
  cmd=buf12pageE : GOSUB sndcmd
  HIGH ATcs         ' finish command
  GOSUB waitready      ' wait for ready flag
  RETURN

' ----------------
' transfer contents of page ATpage into ram buffer #2
page2buffer2:
  cmd=page2buf2 : GOSUB sndcmd
  HIGH ATcs
  RETURN

  ' ------------------
ATbuf2getWord:
' retrieve word from ram buffer #2, uses ATadrs, ATdata
  AUXIO
  LOW ATcs
  cmd=buf2SO : GOSUB sndcmd
  SHIFTIN ATsd,sclk,MSBPRE,[ATdata\16]  ' get word from AT45 and autoincrement
  HIGH ATcs
  MAINIO
  RETURN

' ----------------
' ---- routine sends command
' ---- and adds extra clocking bits when required (data sheet)
' ---- use for all commands except status read
```

```
sndcmd:
  AUXIO
  LOW ATcs
   ' send the word address
   SHIFTOUT ATsd,sclk,MSBFIRST,[cmd\8,ATpage\15,ATadrs<<1\9]
     ‘ note: the shift left one (<<1) changes the word address to a byte address
   SELECT cmd
     CASE $D2,$E8   ' note command forms $52, $54, $56 and $68 will not be used
       SHIFTOUT ATsd,sclk,MSBFIRST,[0\16,0\16]
     CASE $D4,$D6
       SHIFTOUT ATsd,sclk,MSBFIRST,[0\8]
   ENDSELECT
  RETURN

  ' ----------------
' wait for the ready-busy\ bit (bit 7 of status register) to go high
' or for timeout error, variable ix is a timeout counter
waitready:
  LOW ATcs
  SHIFTOUT atsd,sclk,MSBFIRST,[$ae\9]    ' status command + 1 extra clock to get msb
                                 ' $ae is $57 status + shift in one more bit
  INPUT atsd          ' going to read the AT45 pin directly
  ix=15              ' timer
  DO
    PAUSE 2   ' short delay
    ix=ix-1
  LOOP UNTIL ATsd=1 OR ix=0
  ' DEBUG ?ix  ' about 10-20 milliseconds per write to flash
  HIGH ATcs            ' end of command
  IF ix=0 THEN error
RETURN

error:
 DEBUG BELL,CR,"AT flash write timeout error",CR
GOTO main
```

Power supply



The main 5 volt regulator is an LT1521-5, which has its voltage internally fixed at 5.0 volts. It is an advanced low dropout regulator that can supply full 5 volts, 300 ma output when the input is as low as 5.2 volts. The LT1521-5 quiescent current is only 12 microamps when the OWL is asleep.

.

LT1521I-5
5.0 ± 0.1 volts
-40 to +85 °C
300 mA maximum
0.2 watt maximum
maximum input voltage Vi = 18 volts

This LT1521 low dropout, micropower, linear voltage regulator has a fairly large filter capacitor, 4.7 µF. Even so, if there is a problem due to peak demands of the external circuitry, add an extra large value capacitor in parallel with the external circuitry. External circuits that use this 5 volt supply should not draw over about 100 milliamps, and care should be taken that the external circuits do not overload the supply or introduce spikes that could get back into the BASIC Stamp to cause resets or misoperation.

The OWL2pe itself draws a current that depends on its operational state . The BASIC Stamp 2pe draws 16 milliamps in full operation, and 50 microamps in full sleep state. Writes to the AT45DB041 flash logging memory will briefly kick the current demand up to as much as 50 milliamps total, during a block erase and write operation. The quiescent current in sleep mode goes to the voltage regulators and to the watchdog circuit on the BASIC Stamp, and a small amount to the analog to digital converter and to the batteryt monitoring circuits.

A second LT1521 voltage regulator is available on the OWL2pe to supply power to external sensors and circuits. This power is switched on and off under program control from BASIC Stamp AUXIO pin x12. Bringing this pin low will turn off the external power, while bringing this pin high will turn on the external power

The voltage output is set by a pair of fixed resistors on the OWL2pe circuit board. The default voltage is 5.5 volts switched, but the feedback resistor R2 can be changed to produce a any voltage from 3.75 volts to 12 volts out at up to 300 milliamps (withing the power restrictions also.) The formula for output voltage is:

$$V_{out} = 3.75 * (R_2/R_1 + 1)$$

The resistor R1 is fixed at 453 kohms, and the feedback current is 8.3 microamps.

volts out	R_1	R_{23}	
5	453k	150k	
5.3	453k	187k	
5.5	453k	210k	STANDARD OWL2pe
6.0	453k	274k	
6.9	453k	381k	
7.5	453k	453k	
8.0	453k	511k	
9.0	453k	634k	
10.0	453k	750k	
11.0	453k	887k	
12.0	453k	1.00M	
13.8	453k	1.21M	

Note that there is a capacitor connected to the shutdown pin on the regulator. The purpose of the capacitor is to hold the state of the voltage regulator either ON or OFF in case the BASIC Stamp briefly turns pin x12 into an input. This happens during execution of SLEEP or NAP or POLLWAIT instructions, or during a reset due to activity on the RS232 ATN pin. On the BS2pe, the interval is about 100 microseconds, so the capacitor is easily able to hold the regulator in the existing state. If that pin is left floating, the regulator will turn on after a fraction of a second due to leakage currents.

Also, once pin x12 is made high to turn the regulator is ON, then pin x12 can be turned into an input, and the regulator will stay on. If the regulator needs to stay on when the rest of the OWL2pe is in one of its SLEEP modes, leaving x12 as an input will save a few microamps of supply current.

The following program turns the external power ON for 10 seconds and off for 10 seconds, sleeping in between

```
powerON:
  AUXIO
  DO
    HIGH 12                    ' drives the regulator ON
    INPUT 12                   ' regulator stays on, lower current drain
    SLEEP 10
    LOW 12                     ' drives the regulator OFF
    SLEEP 10                   ' sleep some more
  LOOP
```

Try it with and without the INPUT 12 command to see the effect on the current drain, a difference of 50 microamps.

A third voltage regulator on board the OWL2pe is the LT1761-3.3 that supplies power to the data logging memory, the AT45DB041. The 3.3 volt power is also available on external pin 47. The external current is limited to 50 milliamps, and also subtracts from the amount of power available from the constant 5 volt supply. The 3.3 volts is turned ON by bringing AUXIO pin x11 high, and OFF by brining that pin low. Use this supply only for "safe" projects, because the logging memory also depends on the 3 volt power. Don't be tempted for example to send this 3 volts over a long cable to a remote instrument. In most applications, this 3 volt supply will be turned off except when it is time to access the AT45DB041 logging memory. The quiescent current for this regulator when shut down is only 0.1 microamp. However, if it is necessary to leave the 3.3 volt power turned on, for example, to power an external barometer, then the quiescent current will only increase by 20 microamps as a result. Note that when the 3 volt power is turned on, the chip select line for the AT memory should also be set high, except during a memory access cycle. The chip select should be made high at about the same time as the 3 volt power:

```
 HIGH 13       ' chip AT45, deselect
 HIGH 11       ' drives the 3.3 volt regulator ON
'
 ' LOW 11 : LOW 13   ' turn off, reverse order.
```

The 4.096 reference voltage is also available on the module external pin28, via a 330 ohm resistor for protection. This is next to the analog to digital inputs where it is most useful for accurate ratiometric con versions. The reference is switched ON and OFF by bringing AUXIO pin p7 high and low. The current available from the 4.096 reference output is limited\, and calculations have to take the 330Ω series protection resistor into account. We highly recommend using a buffer amplifier between the reference voltage and external circuits. The elfOWL top boards have such a buffer amplifier built in. Power for the temperature sensor also comes from Stamp pin x7. This pin should be made high only when it is time to read the analog to digital converter.

Within the OWL2pe module, the DS1307 clock interface receives its power from Stamp pin x10. That pin only supplies power to the clock interface circuitry, which draws about 200 microamps. The timekeeping function of the clock does not depend on the interface power. The timekeeping function and backup of the clock RAM is maintained by a 3 volt lithium coin cell. Pin x10 to power the DS1307 need only be made high when it is time to read or set the clock chip or the RAM. The 3 volt lithium cell can either be soldered directly to the OWL2pe circuit board (CR1612, 48 milliamp hours), or the 3 volts can come from an externally mounted coin cell. The three volt battery connection, an output or an input respectively, is available on pin 51 of the module. Be careful to avoid reversing the polarity of this battery, because doing so will ruin the DS1307 clock chip. If there is danger from a user-replaceable battery, please use a diode or a resistor (10kohm) in series with the battery. the current drawn by the DS1307 from the backup battery is only 0.5 microamp.

Input power to the OWL2pe module comes in on module pins 41 and 44. Those pins are internally connected in the OWL2pe module. There are two connections there for the sake of redundancy. The LT1521 voltage regulator is protected against damage from a reversed input voltage. However, voltages greater than 18 volts should never be applied to the Vin pin. That is the limit for the LT1521. For example, do not attempt to power the OWL from a 24 volt supply.

While the main voltage regulator can supply up to 300 milliamps, it also has power limitations. If the OWL has to operate continuously from a 15 volt power supply input, and the OWL runs at 5 volts, 17 milliamps, the power dissipated by the regulator will be 0.17 watt, and the regulator will get quite warm. We recommend operation of the system from a 6 volt supply, or at most, a 13.7 volt float charging supply.

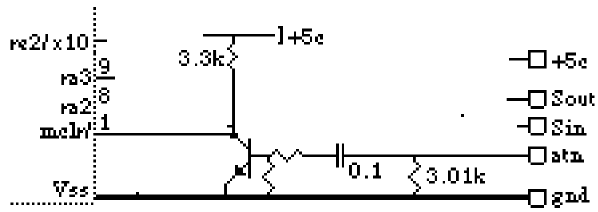
Applying a battery input in reverse to the OWL power pin will not normally have a bad effect, although of course the OWL will not operate until the power connection is right. The same is true for the switched power supply, an LT1521 adjustable regulator.

The OWL2pe inputs, both digital and analog, are protected from excessive currents by 330 ohm resistors. Those will prevent damage to the OWL2pe circuitry in case of a short circuit between the pins or between the pins and the power supplies, or in case of out of range input voltages up to a point.

An insidious condition arises when a voltage higher than 5 volts is applied to one of the regular inputs p0 to p15, or x0 to x3, or a0 to a8. The protection diodes divert excess current to the positive power supply. But if the OWL is asleep, those currents can cause the 5 volt supply to rise to a level dangerous to the OWL circuitry. That is because the LT1521 voltage regulator can source current, but not sink current. OWL topboards forestall that kind of error condition by shunting those currents to ground through an additional protection network.

Reset conditions

There is no direct connection on the OWL2pe module in to the master clear (MCLR\) pin on the SX48 microprocessor. In normal use, the reset will be done via the ATN, pin 2 on the module. This connects via a capacitor and inverting transistor to the SX48 active low reset pin. Bringing the atn input high causes a brief low going pulse that resets the BASIC Stamp so that it starts executing code at the top of program bank zero.



In many systems, this atn pin will be wired to pin 4 of a DB9 connector, and from there to the DTR signal line from a PC. The PC will toggle that line in order to reset the Stamp. For example, in the BASIC Stamp IDE, STAMPW.EXE, the debug screen has a "DTR" check box that can be clicked to toggle the state of that signal line and so reset the OWL2pe. In Hyperterminal, the "call" and "Disconnect" icons or commands serve this function, to bring the atn pin high or low respectively. A modem can reset the Stamp using this atn pin.

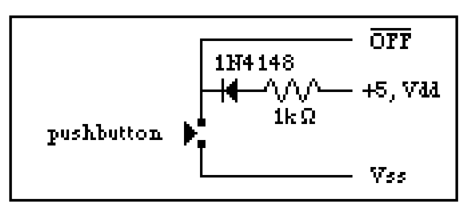
The atn pin also is used to initiate the download of new firmware into the OWL2pe, so it is important to provide that connection on any cable that is going to be used to reprogram the OWL2pe.

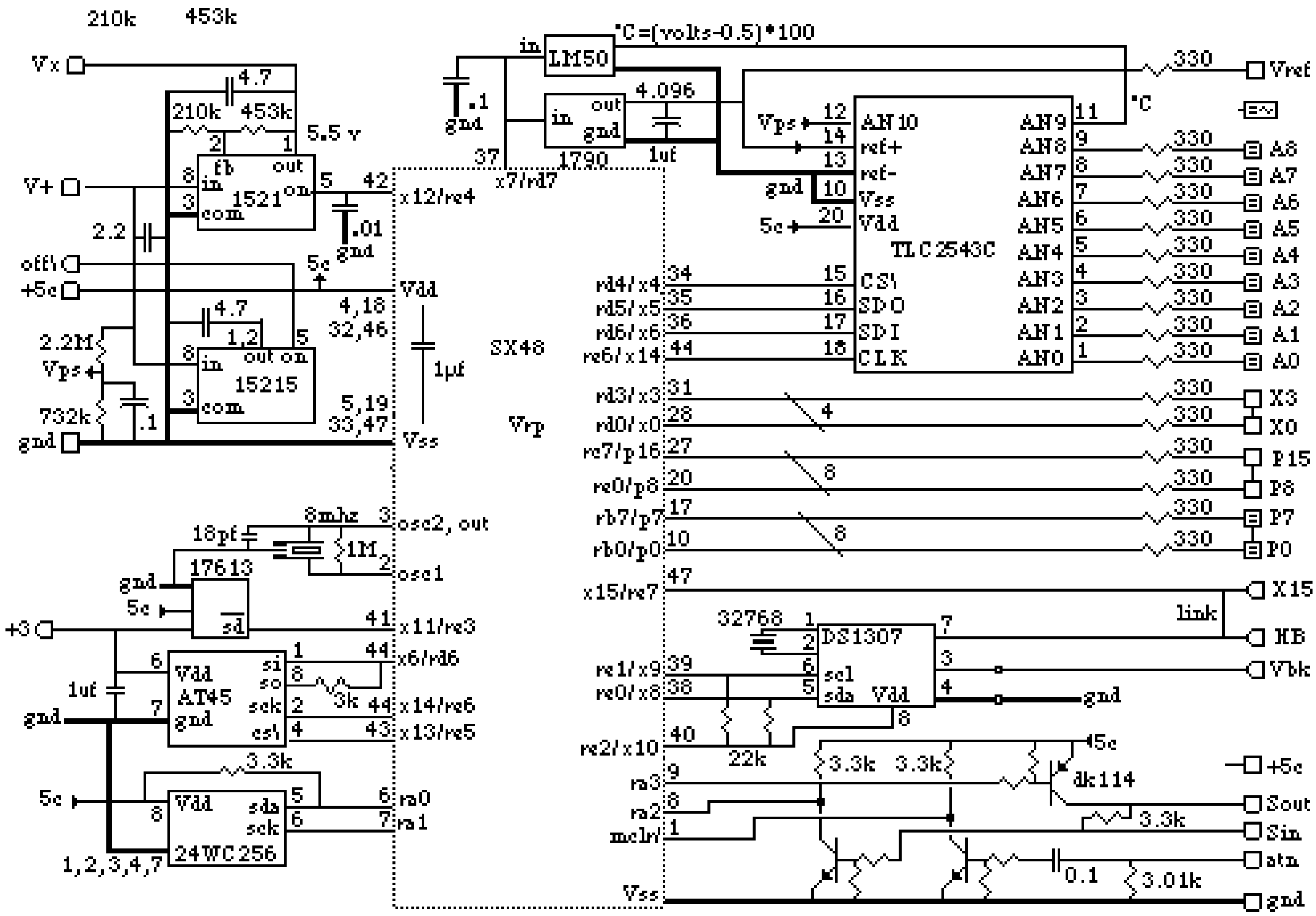
The atn input must be brought low and then high again in order to reset the Stamp. The 0.1 µf capacitor blocks DC levels. A 3.01 kΩ pulldown resistor is provided to sink current from some devices that require it (such as the Palm serial port and some laptops, which leave the serial port pins "floating" when they are turned off.)

The reset pulse may also be provided by a switch wired from the atn input to the +5 volt supply. When the user presses the switch, the positive edge on the atn input will reset the program to the top. Care must be taken when both the switch and the serial cable are connected to atn. If the serial port holds the line high, the pushbutton will not have an effect. An additional resistor (~200 Ω) is a good idea in series with a switch at that point in order to limit current contention between the serial port and the switch.

The resistor and capacitor network at the atn input sur presses noise that might be coupled in through the cable or through the atn pin. In extreme cases, it may be helpful to put additonal resistance or capacitance from atn to ground.

A additional shutdown pin is available on pin 45 of the OWL2pe module. It can be brought to a low level (Vss) to turn off the 5 volt power to the OWL2pe. This is the super-reset pin. When this pin is low, the power to the Stamp turns off completely and the current drain from the battery will be less than 7 microamps, only enough to power the LT1521 regulator. Note that the clock continues to operate on its own battery power. Bring module pin 45 high, or allow it to float, in order to turn the power back on and restart the BASIC Stamp. On the module, the pin 45 floats, and that is the condition for lowest current drain. The resistance from OFF\ to ground must be less than about 50 kohms, to turn off the regulator. On the other hand, to be sure that the regulator stays ON, be sure there is no chance of leakage from the OFF/ pin to ground. Observation: The reset condition on the BASIC Stamp is not a low power state--it draws about 15 milliamps when the MCLR\ pin is low. Much lower deep freeze current can be had by bringing the shutdown pin low on the main regulator, at pin 45 on the module. For best results, use the following pushbutton circuit. This circuit actively pulls down the 5 volt power so that sneak paths cannot keep the circuit in a partially on condition. (Most of our systems operate with no connection to the pin 45. They use the SLEEP, NAP and POLLWAIT commands to achieve average current that approaches 100 microamps or less.





OWL2pe schematic diagram, detail & narrative

The BASIC Stamp IIpe is a 48-pin Ubicon SX48 RISC microprocessor, with a BASIC interpreter burned into its internal flash program memory. The chip runs at 8 megahertz, set by the resonator on pins 2 and 3 of the SX48. There are a couple more components that define this as a BASIC Stamp system. The user application program is stored in an external eeprom, the 24WC256 connected to SX48 pins ra0 and ra1. And the RS232 programming and debug interface consists of three transistors and resistor network connected to SX48 pins ra2 and ra3. The interface invert, isolates and shifts the level of the input and output signals, to and from the RS232 line. Just as in Parallax BASIC Stamp ICs, this is a half duplex,circuit that echos all characters it receives. There is an attention input (atn)connected to the master clear on the SX48. An external computer connected to the port can initiate programming or cause the program running on the Stamp to start from the top. A capacitor blocks DC levels on that pin, so the reset will occur only on the positive edge of the atn signal.

Power to the BASIC Stamp and the associated components is regulated by a LT1521 low dropout regulator. This 5 volt power is also available at a pin on the edge of the OWL2pe module.

20 pins from the SX48/BASIC Stamp are connected to the external pins on the OWL2pe module. These are pins known as MAINIO p0 to p15, and AUXIO x0 to x3. The connection is made via 330Ω resistors for protection from short circuits and esd, and the resistor can be used as a current limiting resistor for things such as light emitting diodes.

With the above components, the OWL2pe is a functioning BASIC Stamp that can run any Stamp program that is compiled for the BS2pe, and that program can make use of the 20 Stamp I/O pins. The items to follow are features added to the BASIC Stamp, unique to the OWL2pe. These additional features make special dedicated use of SX48/BASIC Stamp pins AUXIO x4 to x15.

The TLC2543 is a 12 bit analog to digital converter with an SPI serial interface to the BASIC Stamp on pins AUXIO x4 (chip select), x5 (data from ADC to stamp), x6 (data from stamp to ADC) and x14 (serial clock). There are 11 analog input channels, one of which (ad10) is dedicated to reading the system power voltage via a 732kΩ & 2.2MΩ voltage divider (power voltage = 4 * reading), and one of which is dedicated to an LM50 temperature sensor (°C=(volts-0.5)*100. The other 9 input channels are available on pins on the edge of the OWL2pe module, and the pins are protected from miscues by 330Ω resistors. The reference for the analog to digital converter is a precision LT1790-4.096. a 4.096 volt reference, making the resolution 1.000 millivolt per bit. Both the reference and the temperature sensor are powered by a Stamp pin, x7, which only needs to be high when the ADC is active, to save power.

The real time clock is a DS1307, connected to the Stamp via an I2c interface on pins AUXIO x8 and x9 with pullup resistors to x10. Pin x10 supplies power to the interface and will normally be high only when the clock needs to be read, to save power. Timekeeping continues under power from a 3 volt lithium battery. even when pin x10 is low. The backup battery can either be soldered directly to the OWL2pe circuit board, or it can be attached to an outside pin. There is an external output from the clock chip which presents a square wave output, software selectable from 1 hz to 32khz. This output is connected internally to pin x15, to serve as a time and frequency reference. This pin is open drain and may need an external pullup resistor.

The AT45DB041 is the main logging memory, 512 kbytes of flash and 512 bytes of RAM in one 8-pin package. It connects to the Stamp via an SPI interface, using AUXIO pins x6 (data), x5 (chip select) and x14 (clock). Note that x6 and x14 are shared with the analog to digital converter. The AT45DB041 is powered by 3.3 volts, from an LT1761-3.3 regulator. That regulator is turned on by bringing AUXIO pin x13 high, when it is necessary to read or write the logging memory. The 3.3 volt power is also available on an OWL2pe external pin.

A second LT1521 regulator is available to supply power to external sensors and other devices. This power is turned on by bringing AUXIO pin x12 high. A capacitor on X12 can hold the ON or OFF state of the regulator in case the pin briefly becomes an input during a reset event.

PIN layout looking down on the top of the OWL2pe circuit board.