Serial Wombat 18AB Chip User Guide

Version 2.1.0_A (Corresponds to Serial Wombat 18AB firmware version 2.1.0)

An Open Source Project
Created by
Broadwell Consulting Inc.

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Overview

The Serial Wombat 18 chip family is designed to add smart I/O capability to Arduino, Raspberry Pi, PCs, MicroPython boards or other systems capable of communicating over I2C or UART. Each Serial Wombat 18AB chip adds up to 18 I/O pins. Each pin runs its own state machine 1000 times per second, allowing the chip to offload many common hardware interfacing tasks from the host.

The Serial Wombat 18AB firmware is open source under MIT license available here:

https://github.com/BroadwellConsultingInc/SerialWombat

The Serial Wombat 18AB chip is a peripheral chip that is commanded by a host device. It is not a device that runs downloaded user code directly. An Arduino C++ library is available to control the Serial Wombat 18AB chip from an Arduino host over I2C or UART through the Arduino Library Manager. Libraries are also available for C# and MicroPython which abstract the functionality of the Serial Wombat 18AB chip into easy to use interfaces. As much as technically possible, the Arduino, MicroPython and C# libraries implement the same interfaces, so example code and videos are typically applicable to all platforms.

The Serial Wombat communication protocol is available for users that wish to interface to the Serial Wombat 4B chip from other platforms.

The Serial Wombat 18AB firmware is heavily commented using Doxygen compatible commenting. The compiled Doxygen documentation is available here: https://broadwellconsultinginc.github.io/SerialWombat/sw18AB/index.html

The documentation embedded in the firmware exposes the internal workings of the Serial Wombat chip and its protocol. This documentation is typically not needed in order to use the Serial Wombat 18AB chip from Arduino, C# or MicroPython due to the availability of a wrapper library.

Each Serial Wombat pin runs an individual state machine every 1mS allowing that pin to solve common embedded systems problems. Pin modes can be mixed and matched (for example, two debounced inputs, an analog input, and a servo output).

The Serial Wombat 18AB chip supports the following pin modes:

SW18AB pin modes (All pins)

- GPIO Input or Output
- Button Debouncing (**SerialWombatDebouncedInput** class)

- Pulse Timing (**SerialWombatPulseTimer** or extended **SerialWombatPulseTimer_18AB** class)
- Digital Input (**SerialWombatChip.digitalRead()**) with optional Weak Pull Up or Pull Down
- Digital Output (**SerialWombatChip.digitalWrite()**) with optional Open Drain Mode
- Matrix Keypad (**SerialWombatMatrixKeypad** class)
- Protected Output (**SerialWombatProtectedOutput** class)
- PWM (**SerialWombatPWM** class, or extended **SerialWombatPWM_18AB** class)
- Pulse on Change (**SerialWombatPulseOnChange** class)
- Quadrature Encoder (**SerialWombatQuadEnc** class)
- Servo (**SerialWombatServo** class or extended **SerialWombatServo_18AB** class)
- Software UART TX/RX (**SerialWombatSWUART** class)
- TM1637 Display Driver (**SerialWombatTM1637** class)
- Ultrasonic distance sensing (**SerialWombatUltrasonicDistanceSensor** class)
- Watchdog (**SerialWombatWatchdog** class)

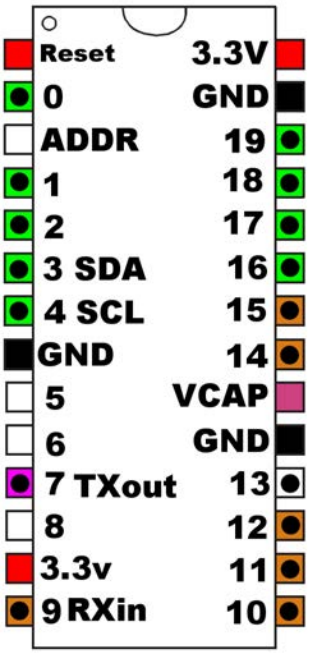
SW18AB Analog pin modes (pins 0,1,2,3,4,16,17,18,19)

- Analog Input (**SerialWombatAnalogInput** class or extended **SerialWombatAnalogInput_18AB**)
- Capacitive Touch (**SerialWombat18CapTouch** class)
- Resistance Input (**SerialWombatResistanceInput** class)

SW18AB Enhanced Digital pin modes (All pins except 5,6,8)

- High Frequency Servo (**SerialWombatHighFrequencyServo** class)
- Hardware UART (**SerialWombatUART** class)
- WS2812 Driver (**SerialWombatWS2812** class)
- PWM with enhanced frequency/resolution (**SerialWombatPWM_18AB** class)
- Servo with enhanced resolution (**SerialWombatServo_18AB** class)
- IBM PS2 Keyboard input
- VGA monitor output
- High Speed Clock Output
- High Speed Counter Input

The Serial Wombat 18AB chip is custom firmware running on the Microchip PIC24FJ256GA702 microcontroller. The capabilities of this microcontroller determine the capabilities and limitations of the Serial Wombat project.



Shown above is the pinout of the Serial Wombat 18AB chip. Pins marked in Green are capable of Analog input functions in addition to digital functions. Pins marked in brown can tolerate 5 volt digital inputs (input voltage to other pins should not exceed the chip supply voltage, typically 3.3V). Pins with circles are capable of enhanced digital functions.

The ADDR pin is used to set the I2C address or select UART operation:

ADDR Pin	Communication Interface
Open	I2C Address 0x6B. Pins 3 and 4 are used for I2C. Pins 7 and 9 are available for general use.
10k to GND	I2C Address 0x68. Pins 3 and 4 are used for I2C. Pins 7 and 9 are available for general use.
20k to GND	I2C Address 0x69. Pins 3 and 4 are used for I2C. Pins 7 and 9 are available for general use.
30k to GND	I2C Address 0x6A. Pins 3 and 4 are used for I2C. Pins 7 and 9 are available for general use.
Short to GND	UART communication at 115,200 bps, 8-N-1. Pins 7 and 9 are used for UART communication. Pins 3 and 4 are available for general use. Pin 9 is a 5V tolerant pin, so

	it is acceptable to receive data from a 5V host or UART connection

The Serial Wombat 18AB chip can be powered from 3.0 to 3.3v. Lower voltages are possible, but are not officially supported.

The I2C bus can run at any voltage between 3.0v and the Serial Wombat chip supply voltage. External pull-up resistors are required. 2200 ohm resistors are suggested. I2C clock frequencies up to 100kHz are supported. Preprogrammed chips are available that respond to I2C addresses 0x6C, 0x6D, 0x6E, and 0x6F. The Serial Wombat 18AB chip utilizes I2C clock stretching as defined in the I2C specification. Host systems controlling the Serial Wombat chip must support clock stretching (note that the Raspberry Pi built in I2C does not support clock stretching. The Raspberry Pi Pico Microcontroller does support clock stretching).

The Serial Wombat 18AB chip is open-source firmware running on a Microchip PIC24FJ256GA702. See the datasheet of that part for additional electrical specifications.

The Serial Wombat 18AB utilizes an internal phase-locked-loop RC oscillator to generate its internal clock. The nominal value of this clock is 32MHz, but may vary up to 2% based on manufacturing variation (variation may increase beyond 2% below 0 deg. C or above 60 deg. C). Since all timing done on the chip is based on this clock, absolute timing values such as PWM frequency, servo pulse, pulse measurement, UART bits, etc may vary by up to 2%.

Serial Wombat Trademark

The brand “Serial Wombat” is a registered trademark in the United States. See https://www.SerialWombat.com for usage.

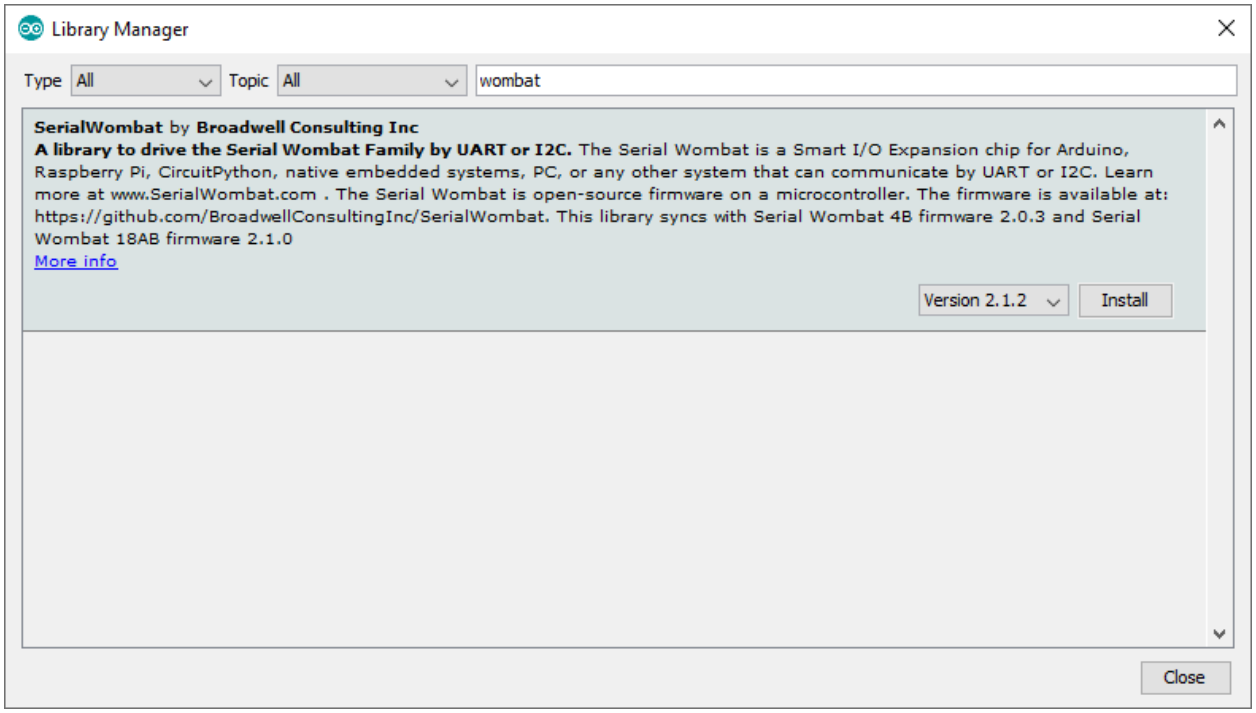
Arduino Library

An Arduino library is available that abstracts the communication protocol used by the Serial Wombat family of chips. The examples shown in this document assume that the Arduino library is used. The source code for the Serial Wombat Arduino library is available here: https://github.com/BroadwellConsultingInc/SerialWombatArdLib

The library is heavily documented using Doxygen in-line comment documentation. A compilation of this documentation is available here:

https://broadwellconsultinginc.github.io/SerialWombatArdLib/

The Arduino library can be installed using the Arduino library manager:



Some Arduino based interfaces are available directly from the SerialWombatChip class in the library, such as pinMode, digitalWrite, digitalRead, analogWrite, and analogRead. These provide a convenient way for Arduino programmers to get started quickly with the Serial Wombat 18AB chip. Over time, it is recommended that programmers transition to using the native Serial Wombat interfaces shown in the examples and videos.

A getting started video which includes the library installation procedure is available on YouTube:

https://youtu.be/mYTGZtJX6po

Python / MicroPython Library

A Python and MicroPython library is available which provides equivalent interfaces to the ones in the Arduino library. Most videos and examples shown are in C++ for Arduino, but are easily ported to Python.

The library is available here:

https://github.com/BroadwellConsultingInc/SerialWombatMicroPython

An introductory video is available here:

https://youtu.be/bbBO5n_Ef-I

C# library

A C# .Net llibrary is available which provides equivalent interfaces to the ones in the Arduino library. Most videos and examples shown are in C++ for Arduino, but are easily ported to C#.

The library is available here:

https://github.com/BroadwellConsultingInc/SerialWombatCsharpLib

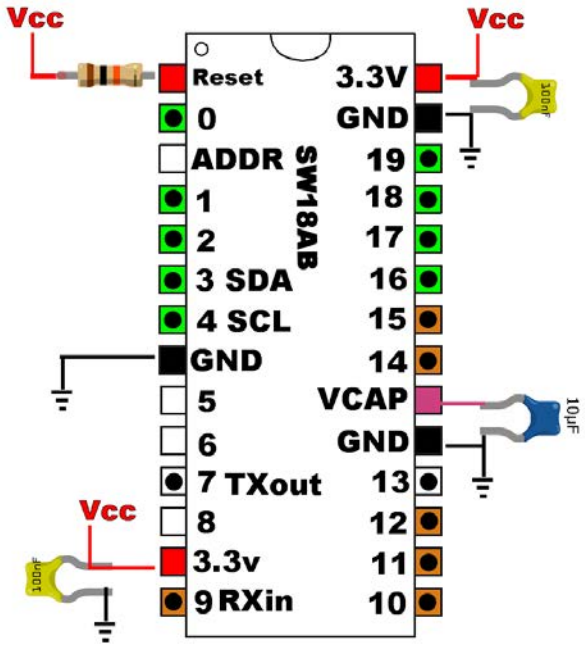
An introductory video is available here:
https://youtu.be/RgrjuJcJMmM

Circuit Construction

Before starting, consider subscribing to the Serial Wombat YouTube Channel:
https://www.youtube.com/@SerialWombat

and Instagram:
https://www.instagram.com/serialwombat/

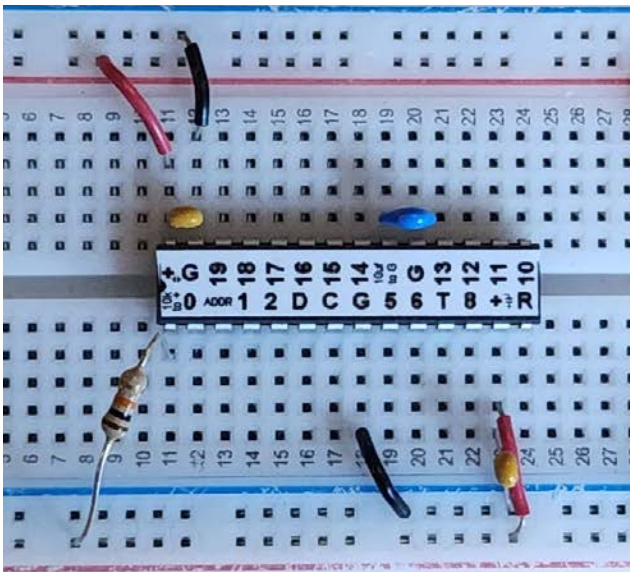
When bugs are discovered or fixed or new firmware or library updates are made available a post will be made on these platforms.



The Serial Wombat 18AB chip requires power and ground to be attached to the pins as shown in the figure above. Additionally, 100nF ceramic decoupling capacitors must be connected between each Vcc line and ground. A 10uF capacitor must be connected between VCAP and ground, and a 10k resistor must be connected between the reset pin and Vcc. Appropriate capacitors and resistors are included with the Serial Wombat 18AB kits created by Broadwell Consulting Inc. sold on Amazon. All resistors and capacitors shown must be installed and all connections to Vcc and Ground must be connected or the microcontroller may function erratically

An optional connection to the ADDR pin can be used to change the address or interface to the Serial Wombat chip as described prior in this document.

Serial Wombat 18AB kits created by Broadwell Consulting Inc. include user-applyable labels which indicate pin functions and provide a mini-schematic of the minimal resistor and capacitor connections. The labels are provided in a multiple-label strip. Using a rotary cutter or precision hobby knife to cut them apart is recommended, as scissors may not provide the precision needed to position the cuts perfectly.

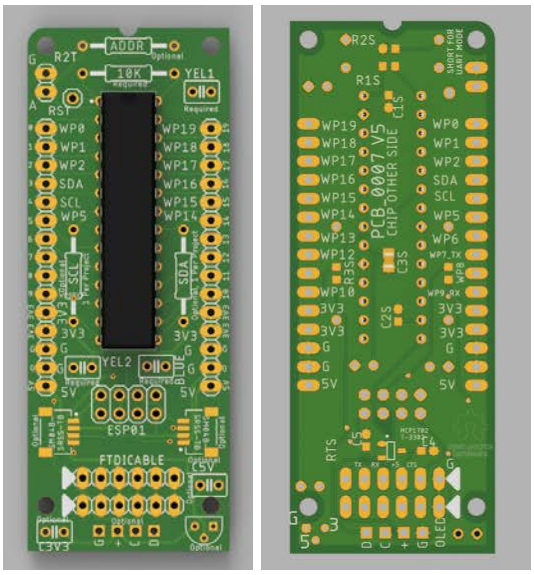


I2C lines should be pulled up with appropriate resistors. Appropriate values vary with application and clock speed. 2200 ohm pull up resistors are suggested as a starting point. Reliance on internal Arduino or other micros' pull ups instead of discrete resistors may cause communication errors.

Multiple Serial Wombat Chips can be used in the same circuit as long as they (and all other I2C devices) have unique addresses. The Serial Wombat 2-chip kit sold on Amazon includes a total of three 10k resistors so that one may be used to set the address pin if using both chips in the same circuit is desired.

The Serial Wombat 18AB chip requires a stable power supply to function properly. It is suggested that loads which may cause supply instability (such as relays, servos, motors, or other loads with large inductive or capacitive values) be powered from a separate power supply from that used for the Serial Wombat 18AB chip, as power fluctuations caused by these loads may trip the Serial Wombat 18AB chip's internal low-voltage reset circuit.

Serial Wombat 18AB PCB Board



The Serial Wombat 18AB PCB Board is designed to make the Serial Wombat 18AB chip convenient to use alongside other hobby electronics boards. It is designed to support a number of different use cases, including I2C connection, UART connection through an FTDI or similar USB to UART cable and standalone IOT board when combined with an ESP-01 ESP8266 module.

Basic Assembly

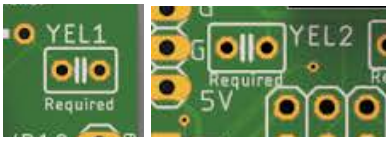
The Serial Wombat 18AB PCB board is designed to be used with the components included in the Serial Wombat 18AB kit sold on Amazon. This kit consists of:

2x Serial Wombat 18AB chips
2x Serial Wombat 18AB PCB Board
3x 10k through-hole resistors
2x 10uF through-hole capacitors (blue)
4x 100nF through-hole capacitors (yellow)
2x 2.2k through-hole resistors
Decal strip
Reference cards

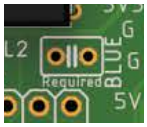
The Serial Wombat 18AB PCB board is designed to be self-documenting. Components are marked with functions on the top silkscreen. Assembly in the following order is suggested:

1. Solder the Serial Wombat 18AB chip into the PCB. ***Make sure that the chip is on the right side of the board, and that the chip is in the proper orientation.*** The Serial Wombat 18AB PCB board has a rounded corner which corresponds to the #1 pin of the microcontroller (often embossed with a dot), and a notch at the top of the board which mimics the notch in the microcontroller. When properly assembled the chip is inserted with the notched end matching the notch in the top of the board and the chip visible when the rounded corner of the board is in the upper left. Do not insert the chip on the side of the board that says “CHIP OTHER SIDE”.
2. Solder a 10k resistor over the image of a resistor that includes the marking “10K”. This resistor connects the reset pin to Vcc

3. Solder two yellow 100nF capacitors into the boxes marked “YEL1” and “YEL2”



4. Solder a blue 10uF capacitor into the box marked “BLUE”

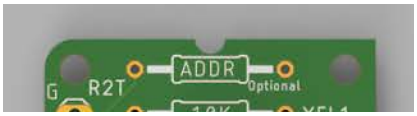


5. Trim leads as necessary to make the board nice and neat
6. Apply the chip decal if desired

In this configuration the ADDR line is left floating, and will result in the chip responding to I2C address 0x6B

Address Resistor (optional)

If an I2C address other than 0x6B is desired, a resistor can be soldered into the holes with the marking “ADDR” . This set of holes connects the ADDR pin and ground.



UART Mode (optional)

The Serial Wombat 18AB will respond to UART commands rather than I2C if ADDR is grounded. This can be achieved by using a wire in place of the ADDR resistor, or by using the UART jumper pins

The “G” and “A” pins in the upper left corner of the board are designed to allow addition of a 2-pin 0.1” header which can be optionally closed with a jumper. In this manner it’s possible to easily switch the Serial Wombat 18AB chip between I2C and UART mode. (A power cycle is necessary to re-evaluate the state of the ADDR pin).

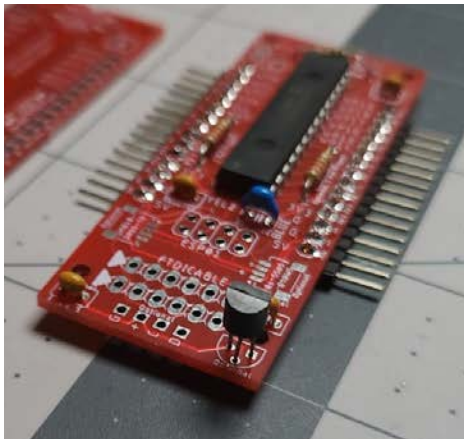
I2C Pull up resistors (optional)

The I2C bus requires pull-up resistors on SCL and SDA to function properly. If desired, these resistors can be soldered into the Serial Wombat 18AB PCB board in the “SCL” and “SDA” positions. The Serial Wombat 18AB kit includes two 2200 ohm resistors for this purpose. The user should evaluate their circuit to determine the best pull up resistance for their application. The pull up resistors typically only appear in one place across an entire application circuit (hence the inclusion of only one set of two resistors for two boards).

5V pins and traces

The Serial Wombat 18AB PCB board includes pins marked 5V for 5 volt power. This set of traces goes to the 5V pins on each side of the board, the FTDI connector holes, and the 3.3V regulator locations. Operation on 5V power requires addition of an additional regulator (not included).

5V to 3.3V LDO Regulator circuit (optional)



The Serial Wombat 18AB chip power supply should never exceed 3.6V (3.3V recommended). Therefore, it cannot be directly powered by a 5V supply. For convenience, the Serial Wombat 18AB PCB board incorporates options for adding a 3.3v regulator (not included). Mounting locations are available for either a TO-92 through hole part and input and output capacitors (C5V and C3V3, 0.1” pin spacing) or a SOT23-3 surface mount part and 0603 sized input (C4) and output (C5) capacitors.

The surface mount layout is designed with Microchip part MCP1702-3302 in mind. Note that the pinout for SOT23-3 regulators is not uniform across manufacturers. When using a surface mount regulator other than the MCP1702-3302 make sure it has an identical pinout.

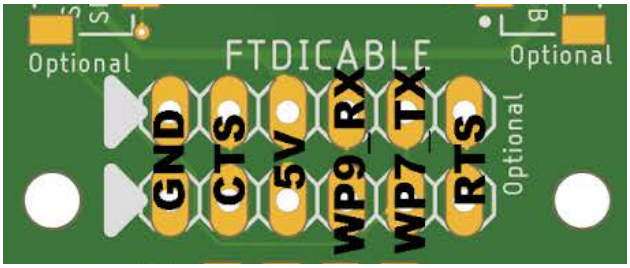
The throughhole option allows flexibility to use just about any TO-92 package regulator as it can be rotated and the pins flexed to attach to the Ground, 3.3V and 5V holes in the breadboard.

Capacitor recommendations for stable operation can vary depending on regulator selected and expected current draw. See your regulator’s datasheet for more information.

FTDI cable connector

The Serial Wombat 18AB PCB board supports connection of an FTDI or equivalent pinout USB to UART converter. This allows the Serial Wombat 18AB chip to be easily connected to a PC or other USB based device to allow direct data acquisition and control without the need for an Arduino or other board.

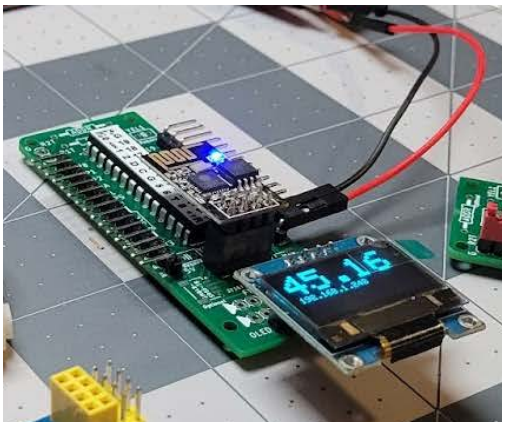
The RX pin of the Serial Wombat 18AB chip is 5V tolerant, so both 3.3v and 5v versions of FTDI cables can be used.



The pinout of the FTDI connector is shown above. The CTS and RTS lines are not used by the Serial Wombat 18AB PCB board. The dual row of headers is designed to make these lines accessible should the user want I/O lines that are controlled directly by the host rather than the Serial Wombat 18AB chip.

The User must verify that the pinout of a cable matches the PCB footprint before connecting the cable. Note that the WP9_RX pin is an input from the point of view of the Serial Wombat 18AB chip. This pin may be marked TX or similar on the FTDI pinout.

ESP-01 Module connector



ESP-01 modules with their onboard ESP8266 WiFi enabled SOC provide an exceptional value in terms of wireless connectivity and processing power for the price. However, they are lacking with regard to I/O capability. When combined with a Serial Wombat 18AB chip, the ESP-01 becomes a very reasonably priced IOT powerhouse.

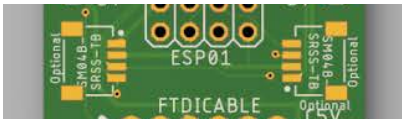
The Serial Wombat 18AB PCB board includes holes in which a 4x2 socket can be mounted which connects an ESP-01 board to the 3.3V, ground, and I2C lines of the PCB, allowing it to control the Serial Wombat chip.

The Serial Wombat 18AB PCB board is not designed to allow in-circuit programming of the ESP-01 chip through the FTDI interface. The chip must be externally programmed, then placed in the Serial Wombat 18AB PCB board.

Addition of an LDO regulator (see above) allows the system to run on 5V if desired.

Qwiic/Stemma Connector Pads

Pads are available to add Qwiic/Stemma connectors (not included) to the Serial Wombat 18AB PCB board. These connectors connect to the PCB's I2C, 3.3V and Gnd networks.



Part number SM04B-SRSS-TB is compatible with this footprint. Generic similar parts bought from online flea markets have also been compatible based on the author's experience.

OLED / I2C port

A 4 pin connector is available which connects to the PCB's I2C, 3.3V and Gnd networks. The pinout for this connector is designed to facilitate direct connection of the most common pinout of ubiquitous SSD1306 0.96" OLED displays to the 3.3V power and I2C bus. The Serial Wombat firmware does not drive SSD1306 displays. The port provides a convenient way to add an SSD1306 to the same I2C bus controlling the Serial Wombat Chip.

Surface mount Resistor / Capacitor alternate pads

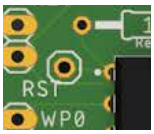
Many experienced electronics practitioners prefer surface mount components to through-hole due to the speed with which they can be manually placed. The Serial Wombat 18AB PCB board includes alternative 0603 surface mount pads for all throughhole resistors and 100nF capacitors on the back side of the PCB. An 0806 pad is available for the 10uF capacitor. Surface mount components are not included with the Serial Wombat 18AB kit.

Header Pin Connectors

The Serial Wombat 18AB PCB board includes standard 0.1” holes to mount typical headers. Straight header pins are included in the Serial Wombat 18AB kit, but other parts can be used. For instance, the author often uses boards with right angle pins due to the ease with which connections can be seen when shooting overhead video of a project.

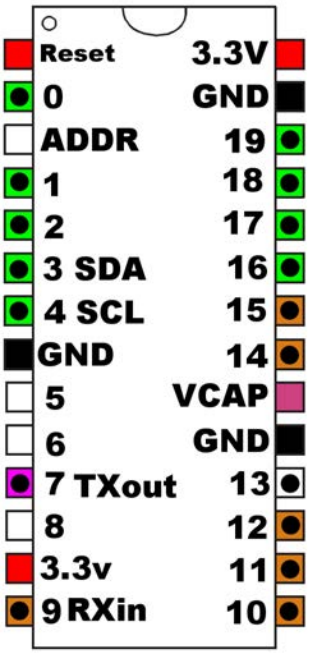
RST Pin

A hole is available for adding a pin which connects to the reset line of the Serial Wombat 18AB chip. This hole is primarily intended for use during firmware development to allow an ICD4 or similar debugger to connect to the reset line.



Pin Modes

There are multiple pin modes which can be selected for each pin. Many pin modes can run on any pin. Some pin modes require enhanced digital performance pins. Others require analog capable pins. A few pin modes require specific pin numbers to be used.



Shown above is the pinout of the Serial Wombat 18AB chip. Pins marked in Green are capable of Analog input functions in addition to digital functions. Pins marked in brown can tolerate 5 volt digital inputs (input voltage to other pins should not exceed the chip supply voltage, typically 3.3V). Pins with circles are capable of enhanced digital performance pin modes.

Many Serial Wombat pin modes (such as Analog Input pin mode or Pulse Measurement pin mode) provide an measurement value that varies depending upon the input. Many of these pin modes implement the Processed Input Pin Mode set of standardized signal measurement features for filtering, averaging, queuing, scaling, min/max tracking and outlier exclusion. See the Processed Input Pin Mode section for more information.

Many Serial Wombat pin modes (such as PWM output pin mode or Servo output pin mode) provide an output signal that varies depending on a value either written to that pin's public data value, or read from another pin's public data value. These pins implement the Scaled Output Pin Mode extension set of standardized output processing functions. The Scaled Output Pin Mode extension can scale the input value, invert the input, limit the rate of change of the output, filter the output, control the output via hysteresis, control the output via PID control, and scale the final output. See the Scaled Output Pin Mode section for more information.

Digital GPIO Input Pin Mode (0)

Pin Mode Name	GPIO (Input)
Pin Mode Firmware ID	0
Pin Type Required	Any
Available on Serial Wombat 4B chips	Yes
Serial Wombat 18AB Throughput consumed	Negligible
Arduino Class Documentation	https://broadwellconsultinginc.github.io/SerialWombatArdLib/class_serial_wombat_chip.html
Tutorial Video	Not Available
Implements Processed Input Functions	No
Implements Scaled Output Functions	No
Uses Timing Resource Manager resources	No

The Digital Input Pin mode allows the host to determine if the pin is logic high or logic low. Inputs are Schmitt Trigger inputs with a low value of 0.2 x System Voltage and high value of 0.8 x System Voltage. See the PIC24FJ256GA702 datasheet for more information on logic levels.

Digital inputs can be configured to use internal pull up resistors within the chip.

When public data is accessed for a Digital Input Mode pin, the result that comes back is either 0 for low or 0xFFFF (65535) for high. This is consistent with other Serial Wombat pin modes that scale their public data between 0 and 65535.

Digital Output Pin Mode

Pin Mode Name	GPIO (Output)
Pin Mode Firmware ID	0
Pin Type Required	Any
Available on Serial Wombat 4B chips	Yes
Serial Wombat 18AB Throughput consumed	Negligible
Arduino Class Documentation	https://broadwellconsultinginc.github.io/SerialWombatArdLib/class_serial_wombat_chip.html
Tutorial Video	Not Available

Implements Processed Input Functions	No
Implements Scaled Output Functions	No
Uses Timing Resource Manager resources	No

The Digital Output pin mode allows the host to set the pin high or low. The maximum current sunk or sourced per pin should not exceed 25mA. The maximum current sourced by the chip should not exceed 250mA. The maximum current sunk by the chip should not exceed 300mA. See the PIC24FJ256GA702 datasheet for detailed electrical specifications

Analog Input Pin Mode

Pin Mode Name	Analog Input
Pin Mode Firmware ID	2
Pin Type Required	Analog Capable
Available on Serial Wombat 4B chips	Yes
Serial Wombat 18AB Throughput consumed	TBD
Arduino Class Documentation	https://broadwellconsultinginc.github.io/SerialWombatArdLib/class_serial_wombat_analog_input__18_a_b.html
Tutorial Video	https://www.youtube.com/watch?v=_EKlrEVaEhg (Serial Wombat 4B chip equivalent pin mode)
Implements Processed Input Functions	Yes
Implements Scaled Output Functions	No
Requires Timing Resource Manager resources	No
Functions if Timing Resource Manager resources are unavailable	N/A

The Serial Wombat 18AB chip can measure up to 9 separate analog inputs in UART mode or 7 separate analog inputs in I2C mode, plus its own source voltage.

The Serial Wombat 18AB firmware makes a new 12-bit measurement every 1mS. The pin state machine implements the Processed Input Pin Mode set of standardized signal measurement features for filtering, averaging, queuing, scaling, min/max tracking and outlier exclusion. See the Processed Input Pin Mode section for more information.

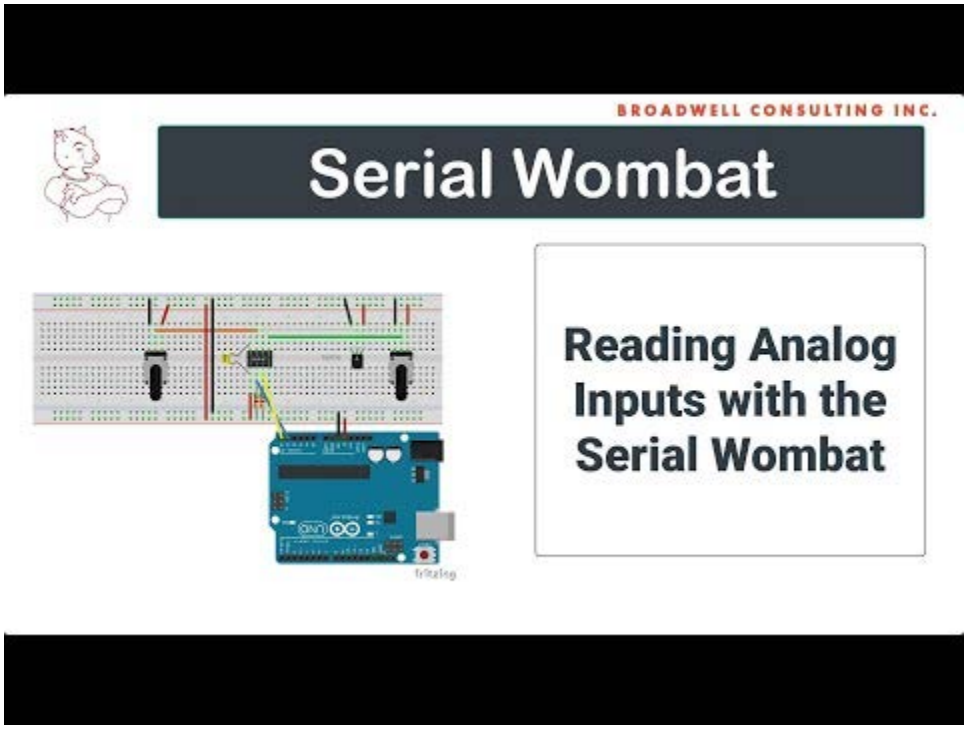
Serial Wombat analog measurements are ratiometric, ranging from 0 to 65535 where 0 means that the incoming voltage was equal (within the 12-bit resolution) to ground, and 65535 means that the incoming voltage was equal (within the 12-bit resolution) to the Serial Wombat chip's source voltage. Because 0-65535 represents a 16 bits of resolution but the Serial Wombat 18AB chip's A/D unit is only 12 bits, values will exhibit quantization in 16 count increments (e.g. the raw results can be 0, 16, 32, 48, 64, 32768, 51216 … but not 15, 45, 68, 32784, 51213, etc). In the case that the A/D reports a maximum value of 65520, this value is reported as 65535 (to be consistent with using that value to represent positive maximum scale).

An Arduino equivalent function .readAnalog() can be called directly from a Serial Wombat Chip instance. This function initializes a pin as an analog input, takes a reading, and scales it to a value between 0 and 1023 to correspond with the behavior of the Arduino Uno.

The Serial Wombat 18AB chip is capable of measuring an internal reference voltage which in turn can be used to infer the system voltage. The Arduino library has functions to retrieve the system voltage, as well as output A/D conversions in mV rather than counts using the measured system voltage as the high value for the ratiometric conversion.

Input impedance for A/D inputs should be 5 kOhm or less. See the PIC24FJ256GA702 datasheet for additional performance and electrical characteristics of the A/D converter circuit.

A video tutorial of the Serial Wombat 4B chip's analog capabilities, which are similar but less capable than the Serial Wombat 18AB's is available here:
https://www.youtube.com/watch?v=_EKlrEVaEhg



The Arduino class is documented here:
https://broadwellconsultinginc.github.io/SerialWombatArdLib/class_serial_wombat_analog_input.html

Here's an Arduino example of the using 3 pins to monitor two potentiometers and a TMP32 temperature sensor using the Analog Input pin mode:

```
#include <SerialWombat.h>

SerialWombatChip sw6B;    //Declare a Serial Wombat
SerialWombatAnalogInput leftPot(sw6B);  //5k linear Pot
SerialWombatAnalogInput rightPot(sw6B); //5k linear Pot
SerialWombatAnalogInput temperatureSensor(sw6B);
```

```
// This example is explained in a video tutorial at: https://youtu.be/_EKlrEVaEhg


void setup() {
  // put your setup code here, to run once:

  { //I2C Initialization
    Wire.begin();
    sw6B.begin(Wire, 0x6B); //Initialize the Serial Wombat library to use the primary I2C port,
SerialWombat is address 6C
  }
  leftPot.begin(0);
  rightPot.begin(1);
  temperatureSensor.begin(2,64,65417); // Wombat pin 2, average 64 samples, .5 Hz Low Pass filter
  Serial.begin(115200);
}

void loop() {

  Serial.print("Source V: ");
  uint16_t supplyVoltage = sw6C.readSupplyVoltage_mV();
  Serial.print(supplyVoltage );
  Serial.print("mV      Left Pot: ");
  Serial.print(leftPot.readCounts());
  Serial.print(" ");

  uint16_t leftVoltage = leftPot.readVoltage_mV();
  Serial.print(leftVoltage);
  Serial.print("mV      Right Pot:");

  Serial.print(rightPot.readCounts());
  Serial.print(" ");
   uint16_t rightVoltage = rightPot.readVoltage_mV();
   Serial.print(rightVoltage);

  Serial.print("mV      T:");

  Serial.print(temperatureSensor.readCounts());
  Serial.print(" ");
  Serial.print(temperatureSensor.readVoltage_mV());
  Serial.print("mV ");


  float tempSensor_mV = temperatureSensor.readAveraged_mV();

  //See datasheet for TMP36 Temperature sensor for conversion
   float temperature = (tempSensor_mV - 750) / 10.0 + 25;

  Serial.print(temperature);
  Serial.print(" deg C ");


  Serial.println();
  delay(200);
}
```

Servo Output Pin Mode

Pin Mode Name	Servo Output
Pin Mode Firmware ID	3
Pin Type Required	Any (degraded resolution on pins that are not enhanced digital performance)
Available on Serial Wombat 4B chips	Yes
Serial Wombat 18AB Throughput consumed	TBD
Arduino Class Documentation	https://broadwellconsultinginc.github.io/SerialWombatArdLib/class_serial_wombat_servo__18_a_b.html
Tutorial Video	https://www.youtube.com/watch?v=WiciAtS1ng0 (Serial Wombat 4B chip equivalent pin mode)
Implements Processed Input Functions	No
Implements Scaled Output Functions	Yes
Requires Timing Resource Manager resources	Yes
Functions if Timing Resource Manager resources are unavailable	Resolution of pulses degrades from sub-microsecond to 17uS.

The Serial Wombat 18AB chip can drive up to 18 standard RC servos simultaneously. Up to 6 servos can be driven with sub-microsecond precision, and the remaining 12 with 17uS precision. What pins are what precision depends on the order in which they are initialized. See the Timing Resource Manager section for more information.

The Servo pin mode outputs a pulse every 20mS. The minimum and maximum pulse lengths are specified when the pin mode is initialized (544uS and 2400uS maximum by default).

The host then provides a 16 bit value between 0 and 65535 which scales the pulse between minimum and maximum length.

A reverse option can be specified at initialization which causes 0 to generate a maximum length pulse, and 65535 to generate a minimum length pulse. This is useful to make operation intuitive in cases where the servo moves opposite of what “feels” like the natural direction for an increasing value.

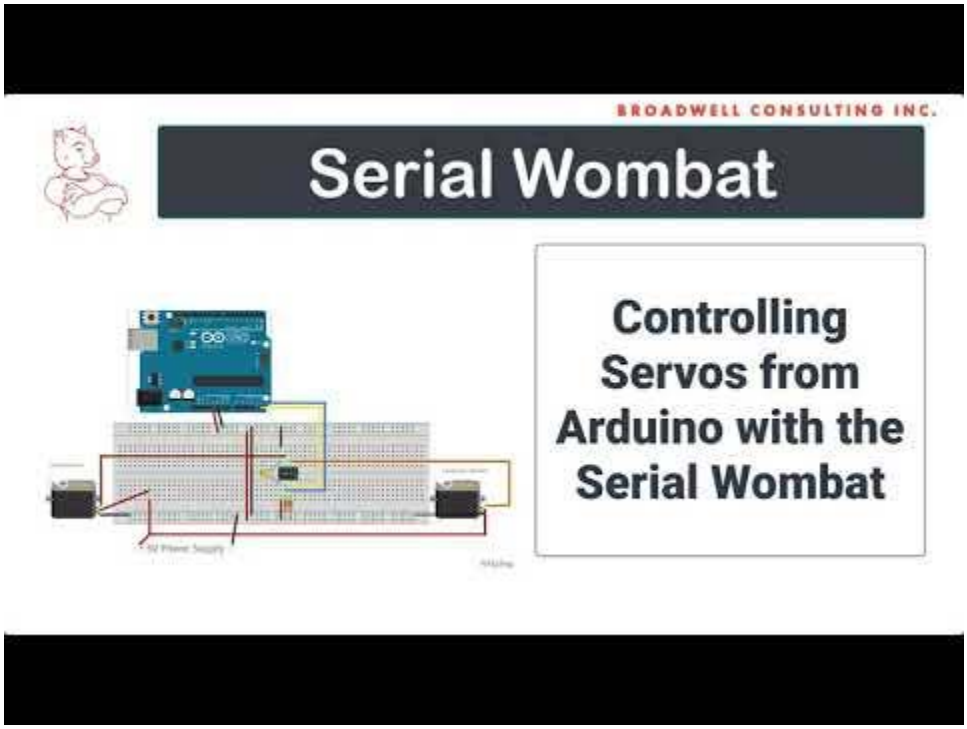
The Serial Wombat 18AB can position a servo based either on a position commanded by the host, or by constantly adjusting the servo input based on another Serial Wombat 18AB pin’s 16 bit Public Data.

The Serial Wombat 18AB Servo pin mode implements the Scaled Output Pin Mode extension set of standardized output processing functions. This is useful when adjusting the Servo’s

position based on another pin's Public Data value. The Scaled Output Pin Mode extension can scale the input value, invert the input, limit the rate of change of the output, filter the output, control the output via hysteresis, control the output via PID control, and scale the final output. See the Scaled Output Pin Mode section for more information.

The Arduino class which wraps this functionality also provides an Arduino compatible interface which takes a value of 0 to 180 rather than 0 to 65535 to scale between minimum and maximum pulses.

A video demonstrating the Servo pin mode on the Serial Wombat 4B is available here: https://www.youtube.com/watch?v=WiciAtS1ng0



Here's an Arduino example of the Servo pin mode from the Arduino library examples which declares two servos and controls one using the 16 bit interface, and the other using the Arduino compatible interface.

```
#include <SerialWombat.h>

SerialWombatChip sw;     //Declare a Serial Wombat chip
SerialWombatServo ContinuousServo(sw);  // Declare a Servo on pin 2 of Serial Wombat sw
```

```
SerialWombatServo StandardServo(sw);   // Declare a Servo on pin 3 of Serial Wombat sw

// A video tutorial is available which explains this example in detail at:
https://youtu.be/WiciAtS1ng0
void setup() {

  {//I2C Initialization
    Wire.begin();
    sw.begin(Wire,0x6B);  //Initialize the Serial Wombat library to use the primary I2C port,
This SerialWombat's address is 6B.
  }
  ContinuousServo.attach(2,500,2500,true); // Initialize a servo on pin 2, 500uS minimum pulse,
2500 us Maximum pulse, reversed
  StandardServo.attach(0);  // Initialize a servo on pin 0 using Arduino equivalent default
values

}

void loop() {

  // put your main code here, to run repeatedly:

  ContinuousServo.write(30);       // Takes a number from 0 to 180
  StandardServo.write16bit(5500);  // Takes a number from 0 to 65535:  Higher resolution
  delay(5000);
  ContinuousServo.write(140);
  StandardServo.write16bit(50000);
  delay(5000);

}
```

Throughput Consumer Pin Mode

Pin Mode Name	Throughput Consumer
Pin Mode Firmware ID	4
Pin Type Required	Any
Available on Serial Wombat 4B chips	No
Serial Wombat 18AB Throughput consumed	Varies with configuration
Arduino Class Documentation	https://broadwellconsultinginc.github.io/SerialWombatArdLib/class_serial_wombat_throughput_consumer.html
Tutorial Video	N/A
Implements Processed Input Functions	No
Implements Scaled Output Functions	No
Requires Timing Resource Manager resources	No
Functions if Timing Resource Manager resources are unavailable	N/A

The Throughput Consumer Pin mode exists primarily for firmware testing. It can be configured to waste a specified amount of time out of each 1mS frame (see the section on Serial Wombat 18AB Firmware Architecture). This allows simulation of scenarios where the various selected pin modes consume CPU time. The pin mode allows up to 16 different times to be configured in successive frames. The pin is low except when the pin mode is consuming CPU time, during which it is high. This allows viewing on a logic analyzer of when and how much CPU time is being wasted by the pin mode in each frame. See the section on Serial Wombat 18AB Throughput Management for more information.

Quadrature Encoder Input Pin Mode

Pin Mode Name	Quadrature Encoder
Pin Mode Firmware ID	5
Pin Type Required	Any
Available on Serial Wombat 4B chips	Yes
Serial Wombat 18AB Throughput consumed	TBD
Arduino Class Documentation	https://broadwellconsultinginc.github.io/SerialWombatArdLib/class_serial_wombat_quad_enc.html
Tutorial Video	https://youtu.be/_wO8cOada3w (Serial Wombat 4B chip Equivalent Pin Mode)
Implements Processed Input Functions	No
Implements Scaled Output Functions	No
Requires Timing Resource Manager resources	No
Functions if Timing Resource Manager resources are unavailable	N/A

The Serial Wombat Quadrature Encoder Pin Mode configures two pins on the Serial Wombat chip to work together to read quadrature encoder inputs.
By offloading the reading of an encoder to the Serial Wombat chip, it makes it easy for the host to track multiple encoders at once. The host need only periodically retrieve the net change in rotary encoder position from the Serial Wombat chip rather than monitoring for every signal change.

The Serial Wombat Quadrature Encoder Pin Mode is capable of running in either polled or DMA driven modes.
Polled mode is recommended for manual inputs such as rotary encoder knobs. It polls at 1 kHz which is fast enough for most applications.

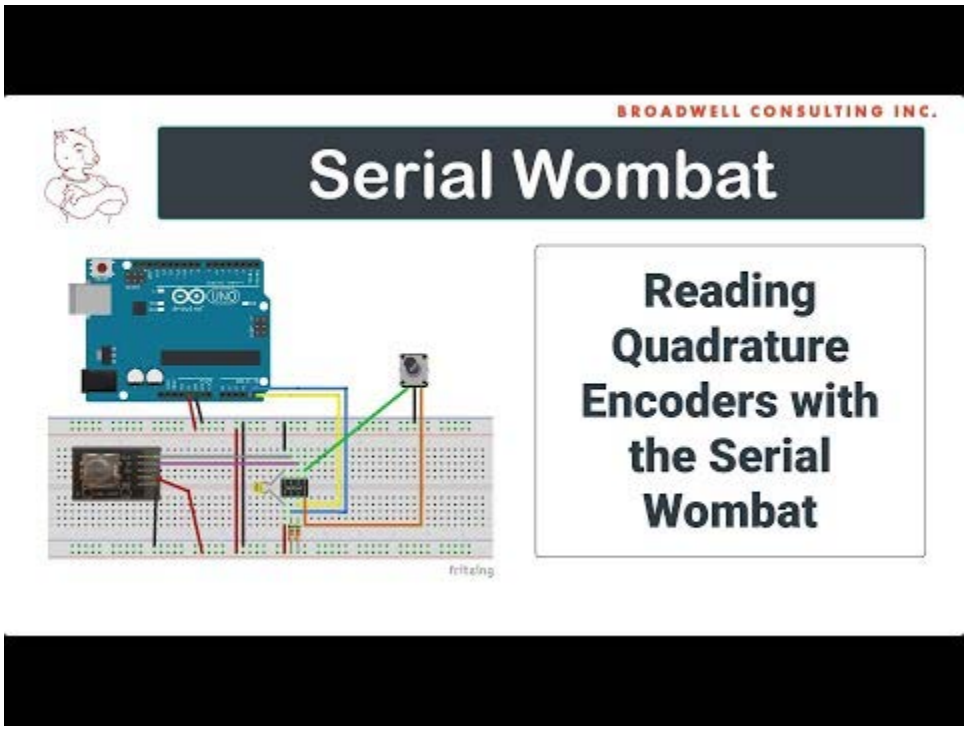
DMA driven mode on the Serial Wombat 18AB samples at 57600 Hz rather than 1 kHz and can decode pulse inputs from rapidly spinning encoders, but using DMA mode consumes much more CPU throughput on the Serial Wombat 18AB chip. When using DMA mode both pins must be on the same microcontroller port.

The Serial Wombat Quadrature Encoder Pin Mode can make use of the Serial Wombat chip's built in pull-up resistors to make connecting a rotary encoder knob very simple. Debouncing is available which prevents additional transitions from being measured for a specified number of mS after a transition.

Rotational direction measurement can be changed by switching the "pin" and "second pin" parameters in the begin call.

The reported position can be changed on low to high transitions of "pin", high to low transitions, or both transitions. This allows knobs that make and break connection on each click/detent and knobs that either make or break connection on each detent to report one change per detent to the host.
The default mode for simple initialization is to measure both, which will result in 2 increments per detent for encoders that make and break connection on each detent.

A video tutorial of the Serial Wombat 4B chip's Quadrature Encoder capabilities (Serial Wombat 18AB chips work similarly) is available here:



https://youtu.be/_wO8cOada3w

The following code shows Initializing two Quadrature/Rotary encoders on a Serial Wombat chip and reading them periodically.

```
#include <SerialWombat.h>

SerialWombatChip sw6C;     //Declare a Serial Wombat chip
SerialWombatQuadEnc qeBasic(sw6C);
SerialWombatQuadEnc qeWithPullUps(sw6C);

// This example is explained in a video tutorial at: https://youtu.be/_wO8cOada3w

void setup() {
  // put your setup code here, to run once:
```

```
  { //I2C Initialization
    Wire.begin();
    sw6C.begin(Wire, 0x6C); //Initialize the Serial Wombat library to use the primary I2C port,
SerialWombat is address 6C
  }
  qeBasic.begin(0, 1);  // Initialize a QE on pins 0 and 1
  qeWithPullUps.begin(2, 3);  // Initialize a QE on pins 2 and 3
  Serial.begin(115200);
}

void loop() {
  Serial.print(qeBasic.read());
  Serial.print(" ");
  Serial.print(qeWithPullUps.read());
  Serial.println();
  delay(50);
}
```

Watchdog Pin Mode

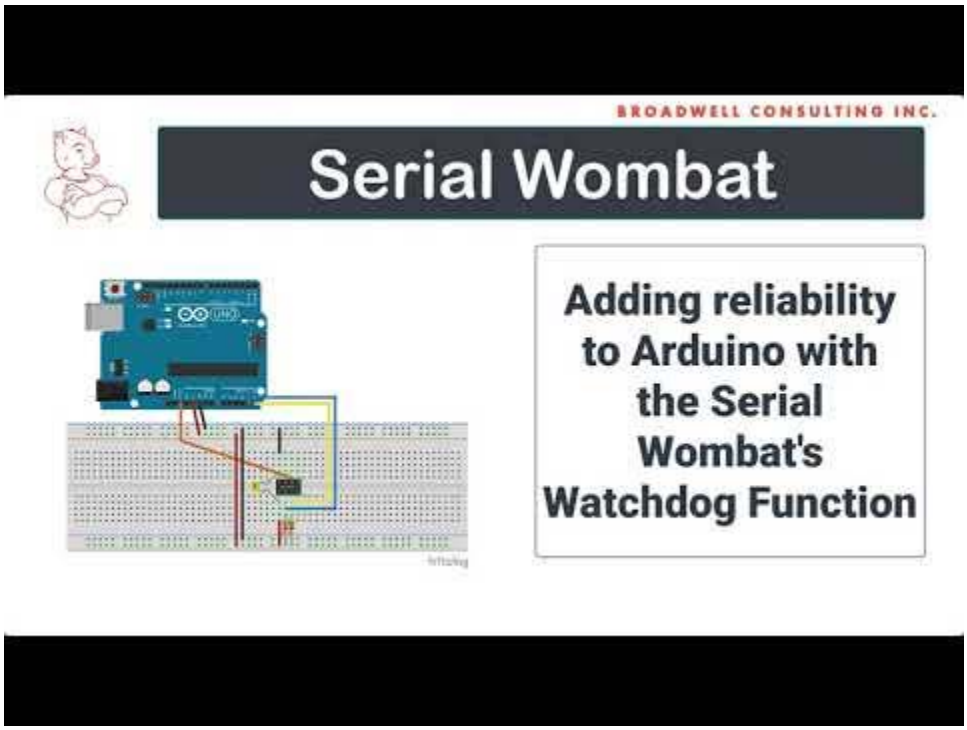
Pin Mode Name	Watchdog
Pin Mode Firmware ID	7
Pin Type Required	Any
Available on Serial Wombat 4B chips	Yes
Serial Wombat 18AB Throughput consumed	TBD
Arduino Class Documentation	https://broadwellconsultinginc.github.io/SerialWombatArdLib/class_serial_wombat_watchdog.html
Tutorial Video	https://youtu.be/fIObjmHmprY (Serial Wombat 4B chip Equivalent Pin Mode)
Implements Processed Input Functions	No
Implements Scaled Output Functions	No
Requires Timing Resource Manager resources	No
Functions if Timing Resource Manager resources are unavailable	N/A

The Serial Wombat Watchdog Pin Mode is designed to improve system reliability in case of communications loss with the host device. This may be because the communications lines are no longer functional (e.g. I2C bus locked up) or the host ceases to communicate (Such as when an Arduino malfunctions due to issues allocating string memory).

Once enabled, the Serial Wombat Watchdog will change its output and optionally other Serial Wombat outputs to predefined states and optionally reset the Serial Wombat itself if a new Watchdog feeding message isn't received within a period of time specified in the initialization.

The output can be used to reset the host, for instance when connected to an Arduino reset pin, or used to shut off an output. For instance, a motor controlled by a SerialWombatWatchdog pin could be configured to turn off if the host doesn't periodically feed the watchdog.

A video tutorial for the Serial Wombat 4B chip (Serial Wombat 18AB chips work similarly) is available:



https://youtu.be/fIObjmHmprY

Here's an example where pin 2 of a Serial Wombat 18AB chip is tied to the reset pin of an Arduino. The Arduino chip is designed to malfunction, leaving it stuck in a loop. Eventually, the Serial Wombat 18AB pin will pull the Arduino's reset pin due to not being serviced.

```
#include <SerialWombat.h>

SerialWombatChip sw;     //Declare a Serial Wombat chip
SerialWombatWatchdog Watchdog(sw);  // Declare a Watchdog pin

// A video tutorial for this example is available at: https://youtu.be/fIObjmHmprY
void setup() {

  {//I2C Initialization
    Wire.begin();
    sw.begin(Wire,0x6B);  //Initialize the Serial Wombat library to use the primary I2C port,
This SerialWombat's address is 6B.
  }
  Watchdog.begin(2,                              // Start the watchdog on pin 2.
                 SW_INPUT,                       // Make the pin Input for normal operation
                 SW_LOW,                         // Make the pin go low on timeout
                 10000,                          // Timeout is 10 seconds
```

```
                false);                         // The Serial Wombat won't self-reset on
timeout


  Serial.begin(115200);
  Serial.println();
  Serial.println("Setup Complete.");
}



// This flawed routine works well if A is a multiple of B, but
// acts badly otherwise because quotient is unsigned and rolls
// back to a big number if the subtraction goes negative.
// Some values, such as 60 / 7 eventually end up returning a
// (wrong) result as the rollover(s) end up eventually
// giving a number that is a multiple of B.
// others such as 60 / 8 stay trapped in the loop forever.
uint8_t DivideAByB( uint8_t A, uint8_t B)
{
  uint8_t C = 0;

  while(A > 0)
  {
    A = A - B;
    ++C;
  }
  return C;
}


int x = 1;
void loop() {

  // put your main code here, to run repeatedly:

   Serial.println();
   Serial.print("60 / ");
   Serial.print(x) ;
   Serial.print(" = ");
   Serial.println(DivideAByB(60,x));
   ++x;

   Watchdog.updateResetCountdown(10000); // Reset the watchdog clock to 10 seconds
   delay(1000);

}
```

Protected Output Pin Mode

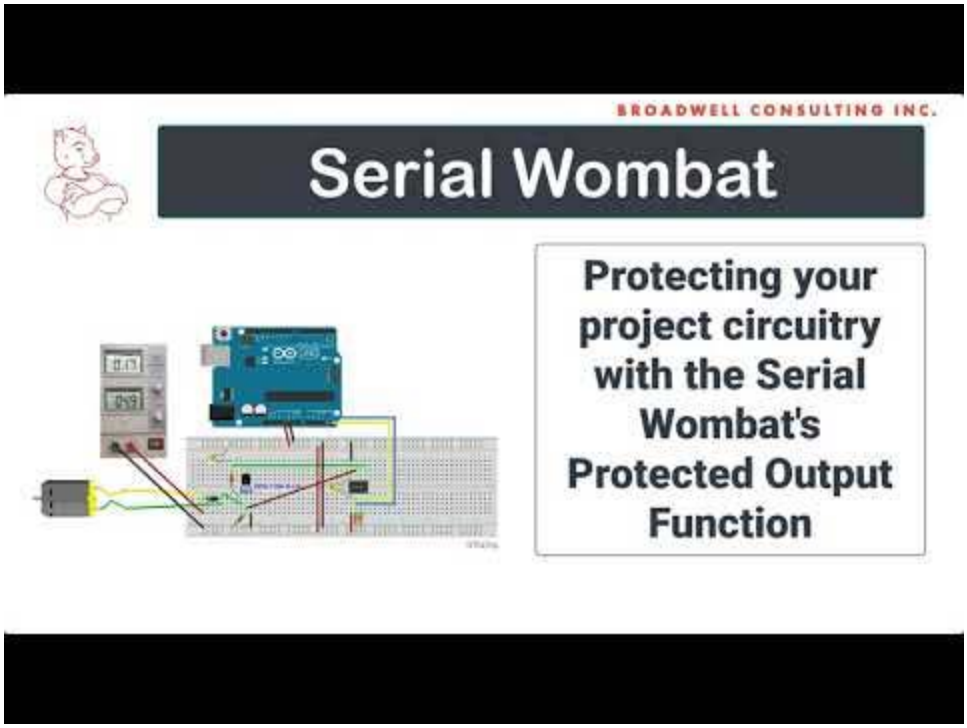
Pin Mode Name	Protected Output
Pin Mode Firmware ID	8
Pin Type Required	Any
Available on Serial Wombat 4B chips	Yes
Serial Wombat 18AB Throughput consumed	TBD
Arduino Class Documentation	https://broadwellconsultinginc.github.io/SerialWombatArdLib/class_serial_wombat_protected_output.html
Tutorial Video	https://youtu.be/p8CO04C1q_Y (Serial Wombat 4B chip Equivalent Pin Mode)
Implements Processed Input Functions	No
Implements Scaled Output Functions	No
Requires Timing Resource Manager resources	No
Functions if Timing Resource Manager resources are unavailable	N/A

The Serial Wombat Protected Output pin mode is assigned to a Serial Wombat output pin. It monitors another previously configured pin's public data, such as a digital I/O value or an Analog input. If the monitored value does not meet expectations, then the protected pin changes values to a configured state. This allows the Serial Wombat chip to constantly verify a condition without the need for constant polling from the host device.

Warning: The Serial Wombat 18AB chip's Protected Output Pin Mode is intended to help prevent accidental damage to hobby circuitry. The Serial Wombat chip and its associated libraries are not designed for use in Safety Critical applications. The Serial Wombat chip should not be used in situations where a malfunction or design defect could result in damage to property, economic loss, or harm to living people or creatures.

The period of time that a mismatch must occur before going to the safe state is configurable.

A video tutorial of the Serial Wombat 18AB chip's protected output capabilities is available here: https://youtu.be/p8CO04C1q_Y



The Arduino class is documented here: https://broadwellconsultinginc.github.io/SerialWombatArdLib/class_serial_wombat_protected_output.html

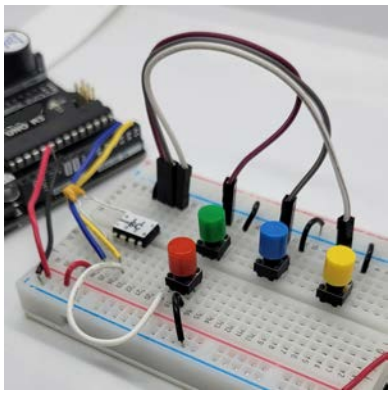
Here's an Arduino example where pin 0 is configured to monitor pin 1, which is configured as an analog input. The protected output pin is configured to be high unless pin one is higher than 8000 for 10 mS, in which case it latches low until reset by the host.

```
#include <SerialWombat.h>

SerialWombatChip sw;    //Declare a Serial Wombat chip

SerialWombatProtectedOutput swpo(sw);
SerialWombatAnalogInput Feedback(sw);

// This example is explained in a video tutorial at: https://youtu.be/p8CO04C1q_Y

void setup() {
  // put your setup code here, to run once:

  Serial.begin(115200);  //Initialize Arduino Serial Port for terminal use

  {//I2C Initialization
    Wire.begin();
    sw.begin(Wire,0x6C);  //Initialize the Serial Wombat library to use the primary I2C port, SerialWombat is address 6C.
  }

  swpo.begin(0,1);  // Controlling pin 0.   Feedback from pin 1.
```

```
  Feedback.begin(1);  // Begin analog reading on pin 1
}


int i;
void loop() {
      if(swpo.isInSafeState())
     {
      Serial.println("Protected Output Fault Detected, Output set to Safe State!");
     }
     if (i & 0x01)
     {
        swpo.configure(PO_FAULT_IF_FEEDBACK_GREATER_THAN_EXPECTED,8000,10,SW_HIGH,SW_LOW);
        Serial.println("On");
     }
     else
     {
        swpo.digitalWrite(LOW);
        Serial.println("Off");
     }

     delay(100);
     Serial.print ("counts at drain: ");
     Serial.println(Feedback.readCounts());
     Serial.print(Feedback.readVoltage_mV());
     Serial.println(" mV");
     Serial.println();

     delay(3000);
     ++i;
}
```

Debounced Input Pin Mode

Pin Mode Name	Debounced Input
Pin Mode Firmware ID	10
Pin Type Required	Any
Available on Serial Wombat 4B chips	Yes
Serial Wombat 18AB Throughput consumed	TBD
Arduino Class Documentation	https://broadwellconsultinginc.github.io/SerialWombatArdLib/class_serial_wombat_debounced_input.html
Tutorial Video	https://www.youtube.com/watch?v=R1KM0J2Ug-M (Serial Wombat 4B chip Equivalent Pin Mode)
Implements Processed Input Functions	No
Implements Scaled Output Functions	No
Requires Timing Resource Manager resources	No
Functions if Timing Resource Manager resources are unavailable	N/A



Debounced Input pin mode is designed to facilitate button and other switch style inputs which may oscillate before settling to a constant value.

The Debounced Input pin mode monitors an input pin 1000 times per second and reports back a value only after it has stabilized for a specified period of time.

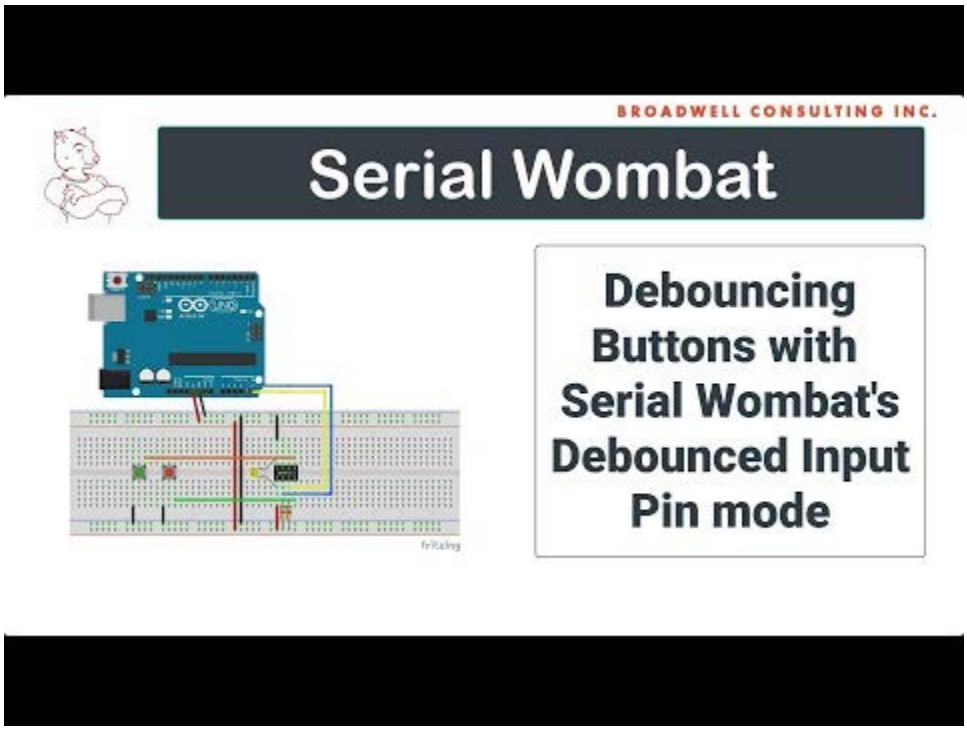
The Debounced Input pin mode also counts debounced transitions and records how long in milliseconds the pin has been in the present state. This allows easy creation of user interfaces or pulse counters without the need to constantly query the Serial Wombat chip.

The Debounced Input pin mode allows inversion of the signal so that inputs can report “true” when the input is low, such as when the pin is connected to ground through a button. This can make interfaces that produce a low input when active more intuitive to process.

The Debounced Input pin mode can enable an internal pull up resistor in the Serial Wombat chip which allows a typical button or switch to be used with no additional components when connected to ground.

A wrapper class is available on Arduino which can increment or decrement a variable at increasing speeds based on how long a button is held down.

A video tutorial on this pin mode is available here for the Serial Wombat 4B chip (the Serial Wombat 18AB chip implements equivalent functionality):
https://www.youtube.com/watch?v=R1KM0J2Ug-M



Here’s an Arduino example of the Debounced Input pin mode from the Arduino library examples:

```
#include <SerialWombat.h>

SerialWombatChip sw;     //Declare a Serial Wombat
SerialWombatDebouncedInput redButton(sw);
SerialWombatDebouncedInput greenButton(sw);


// This example is explained in a video tutorial at: https://youtu.be/R1KM0J2Ug-M
```

```
void setup() {
  // put your setup code here, to run once:

  {//I2C Initialization
    Wire.begin();
    sw.begin(Wire,0x6B);  //Initialize the Serial Wombat library to use the primary I2C
port, SerialWombat is address 6B.
  }

   redButton.begin(0);
   greenButton.begin(1);

   Serial.begin(115200);
}

void clearTerminal()
{
  Serial.write(27);       // ESC command
  Serial.print("[2J");    // clear screen command
  Serial.write(27);
  Serial.print("[H");     // cursor to home command
}

int greenTransitions = 0;
int redTransitions = 0;

void loop() {
    clearTerminal();

    redButton.readTransitionsState();
    redTransitions += redButton.transitions;

    greenButton.readTransitionsState();
    greenTransitions += greenButton.transitions;

    Serial.print(greenTransitions);
    Serial.print(" ");
    Serial.println(greenButton.readDurationInTrueState_mS());

    Serial.print(redTransitions);
    Serial.print(" ");
    Serial.println(redButton.readDurationInTrueState_mS());


    delay(50);

}
```

TM1637 Seven Segment Display Pin Mode

Pin Mode Name	TM1637
Pin Mode Firmware ID	11
Pin Type Required	Any
Available on Serial Wombat 4B chips	No
Serial Wombat 18AB Throughput consumed	5% (varies by configuration)
Arduino Class Documentation	https://broadwellconsultinginc.github.io/SerialWombatArdLib/class_serial_wombat_t_m1637.html
Tutorial Video	https://youtu.be/AwW12n6o_T0
Implements Processed Input Functions	No
Implements Scaled Output Functions	No
Requires Timing Resource Manager resources	No
Functions if Timing Resource Manager resources are unavailable	N/A

The TM1637 Pin Mode connects a TM1637 Seven-Segment Display to two Serial Wombat pins.

The pin mode is State Machine driven in firmware for a TM1637 Seven Segment LED Display.

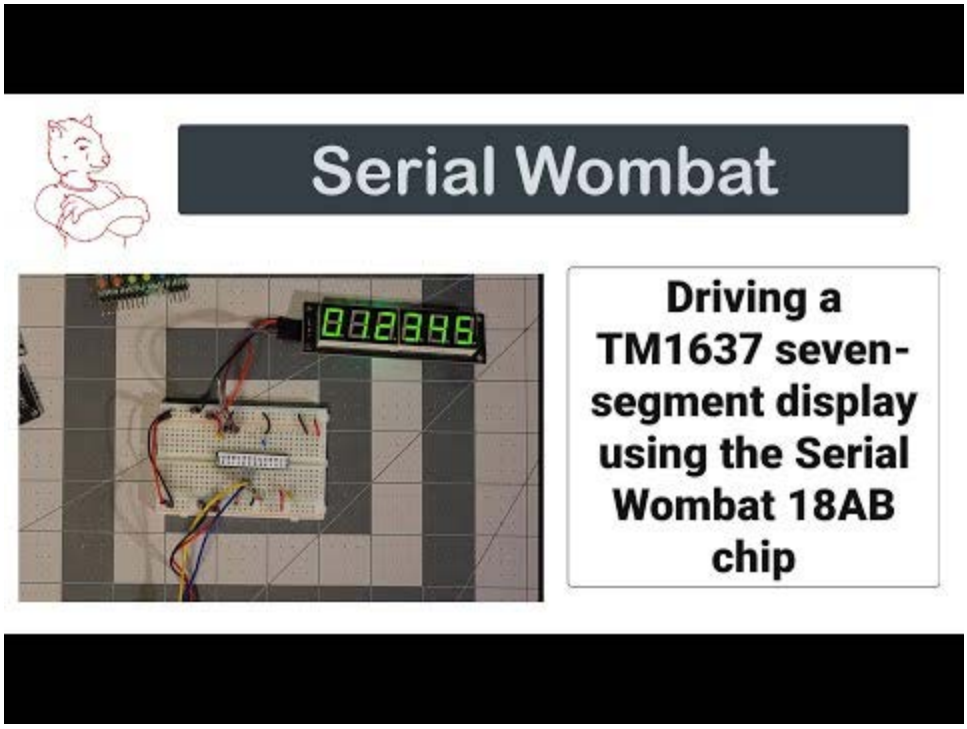
The Serial Wombat TM1637 driver can be configured in a number of ways:

- The Display shows the current value in Hex or decimal of a Pin's public data (including values written to the pin used to control the display)
- The Display shows an array of characters (as best they can be shown on a seven segment display) commanded by the host
- The Display shows raw 7-segment bitmaps commanded by the host
- The Display shows an animation downloaded to the Serial Wombat chip by the host.

See the available examples in the Arduino Library for usage.

Note: Different TM1637 displays behave differently based on how the manufacturer routed the LED matrix pins to the TM1637 outputs on the PCB. This can cause digits to be displayed in the wrong order, or cause decimal points or clock colons to malfunction. This is a display issue, not an issue with this library or the Serial Wombat firmware. Display order issues can be corrected with the orderDigits() command in the Arduino / Python / C# libraries.

A tutorial is available here:



https://youtu.be/AwW12n6o_T0

WS2812 RGB LED Pin Mode

Pin Mode Name	WS2812
Pin Mode Firmware ID	12
Pin Type Required	Enhanced Digital Performance
Available on Serial Wombat 4B chips	No
Serial Wombat 18AB Throughput consumed	5% (varies by configuration)
Arduino Class Documentation	https://broadwellconsultinginc.github.io/SerialWombatArdLib/class_serial_wombat_w_s2812.html
Tutorial Video	https://youtu.be/WoXvLBJFpXk
Implements Processed Input Functions	No
Implements Scaled Output Functions	No
Requires Timing Resource Manager resources	No
Functions if Timing Resource Manager resources are	N/A

Pin Mode Name	WS2812
Pin Mode Firmware ID	12
unavailable	

A pin mode for controlling a WS2812 or compatible RGB LED array from a Serial Wombat pin

This class is only supported on the Serial Wombat SW18AB chip.

This class controls a State Machine driven driver for a WS2812 compatible RGB LED string.

The Serial Wombat WS2812 driver can be configured in a number of ways:

- The driver lights up the LEDs one at a time in sequence (intended for initial testing and led sequence verification)
- The driver shows colors as commanded by the host
- The driver cycles through arrays of colors at a specified rate
- The driver shows a two-color bar graph based on a pin's 16 bit public data.

See the available examples in the Arduino/Python/C# Libraries for usage.

Note! Different WS2812 pcbs behave differently based on how the manufacturer routed the LEDs on the PCB Board. For instance a square 4x4 matrix may not light in the order expected. This is not an issue with the Serial Wombat pin mode.

Warning: An array of WS2812 LEDs can pull lots of current. Lighting multiple LEDs at full brightness may consume more power than your supply can provide, causing the system voltage to become unstable. An unstable system voltage can cause unreliable operation of the Serial Wombat chip.

The Serial Wombat WS2812 driver is extremely efficient in terms of processor time since it uses the PIC24FJ256GA702's DMA and SPI hardware to generate the WS2812 signal. This allows the Serial Wombat firmware to easily clock out WS2812 signals while doing other things. However, this method is very RAM intensive, requiring about 50 bytes of ram for each LED.

The RAM used for buffering this signal is stored in the User RAM Buffer, an array available for the user to allocate to various PIN modes' uses (see User RAM Buffer for more information). In Version 2.1.0 of the Serial Wombat 18AB firmware there is 8k of RAM allocated to User RAM Buffer, allowing about 160 LEDs to be used if all RAM is allocated to the WS2812 pin.

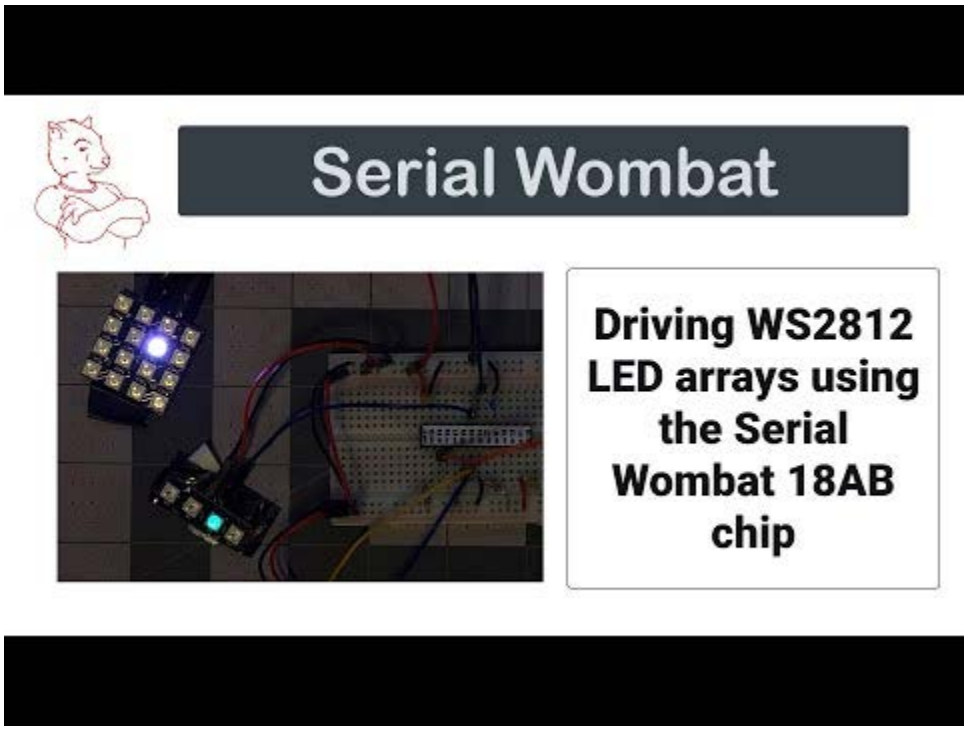
A number of frames to be shown in rotation with configurable delays in between can also be stored in the User Buffer. This is in addition to the rendering buffer. Each animation frame requires

2+3*NumberOfLEDs bytes.

The Update rate is variable with the number of LEDs so that rendering of colors into the User Buffer is spread across multiple Serial Wombat 1mS execution frames. The LEDs will be updated approximately every X mS, where X is the number of LEDs plus 20.

This pin mode requires access to the Serial Wombat 18AB's DMA Channel 5 and SPI internal peripherals. LED clock-out will be delayed if these resources are not available.

A tutorial is available here:



https://youtu.be/WoXvLBJFpXk

The following is an example of a Serial Wombat 18AB chip creating a "Stop Light" style animation on a 3 LED WS2812 LED strip. The Serial Wombat chip updates the LEDs automatically in a pattern without additional instructions from the host.

```
#include "SerialWombat.h"

/*
This example shows how to initialize an animation on a strip/board of WS2812b or equivalent LEDs.
This sketch uses
the SerialWombat18AB's SerialWombatWS2812 class to configure a pin to drive the LEDs.  The
selected pin must be an enhanced performance pin.

When executed this sketch will download 3 frames of 3 leds each to the Serial Wombat chip's user
buffer area.  It will cycle the frames
out to the WS2812 LED array and delay between each frame based on a specified per-frame delay.
In this example a Green/Yellow/Red
```

```
traffic light will be simulated, with red and green on for 5 seconds each, and yellow on for 1
second.

Change the WS2812_PIN below to fit your circuit.

A video demonstrating the use of the WS2812b pin mode on the Serial Wombat 18AB chip is available
at:
//TODO

Documentation for the SerialWombatTM1637 Arduino class is available at:
https://broadwellconsultinginc.github.io/SerialWombatArdLib/class_serial_wombat_w_s2812.html#deta
ils

*/


SerialWombat sw;
SerialWombatWS2812 ws2812(sw);

#define WS2812_PIN 15  // Must be an enhanced performance pin: 0,1,2,3,4,7,9,10-19
#define NUMBER_OF_LEDS 3
#define WS2812_USER_BUFFER_INDEX 0x0000  // Set this to an index into the on-chip user buffer.
Can't overlap with area used by other pins.


// Define colors.  prefix them with SW_ so we don't conflict with any other libraries, such as a
graphic display library.
#define SW_RED 0x000F0000   // Red, changed from 0x00FF0000 to reduce power
#define SW_GREEN 0x0000F00
#define SW_WHITE 0x000F0F0F
#define SW_YELLOW 0x000F0F00
#define SW_BLUE 0x0000000F
#define SW_OFF 0x00000000
#define SW_PURPLE 0x000F000F

#define NUMBER_OF_FRAMES 3

uint32_t Frames[NUMBER_OF_LEDS][NUMBER_OF_FRAMES] =
{
    {SW_OFF,SW_OFF,SW_GREEN},
    {SW_OFF,SW_YELLOW,SW_OFF},
    {SW_RED,SW_OFF,SW_OFF},
};

void setup() {
  // put your setup code here, to run once:
  Wire.begin();
  Serial.begin(115200);
  delay(500);

  uint8_t i2cAddress = sw.find();
  if (i2cAddress == 0) { showNotFoundError(); while(1){delay(100);}}

  sw.begin(Wire,i2cAddress);

  ws2812.begin(WS2812_PIN,  // The Pin connected to WS2812 array
    NUMBER_OF_LEDS,         // The number of LEDs being used
    WS2812_USER_BUFFER_INDEX);  // A location in the Serial Wombat chip's user RAM area where LED
output signals will be buffered

    int16_t offset = ws2812.readBufferSize();  // We have a second location in the Serial Wombat
chip's user buffer.  This is where
```

```
                                                // The animation frames are stored.  The
readBufferSize() method gets the length of
                                                // buffer used by the configured number of LEDs.

    ws2812.writeAnimationUserBufferIndex(WS2812_USER_BUFFER_INDEX + offset,  // Location in
memory to store the animation frames, after the main WS2812 buffer
                                        NUMBER_OF_FRAMES       // Number of frames
                                        );

    for (int i = 0; i < NUMBER_OF_FRAMES; ++i)
    {
       ws2812.writeAnimationFrame(i,Frames[i]);    // Transfer the frame to the animation buffer
on the Serial Wombat chip
       ws2812.writeAnimationFrameDelay(i,5000);// Initalize All Frames 5000 mS delay
    }

    ws2812.writeAnimationFrameDelay(1,1000);//Make the yellow frame (index 1 )  only 1000 mS
instead of 5000.

    ws2812.writeMode(ws2812ModeAnimation);

}


void loop() {
  // No code in here.  The Serial Wombat chip handles generating the LED sequence with no
additional
  // help from the Arduino.  In fact, you could unplug the I2C lines and it would continue
working until
  // powered down.
}
```

Hardware UART Receive and Transmit Pin Mode

Pin Mode Name	Hardware UART
Pin Mode Firmware ID	17 and 23
Pin Type Required	Enhanced Digital Performance
Available on Serial Wombat 4B chips	Yes
Serial Wombat 18AB Throughput consumed	Negligible
Arduino Class Documentation	https://broadwellconsultinginc.github.io/SerialWombatArdLib/class_serial_wombat_u_a_r_t.html
Tutorial Video	https://youtu.be/C1FjcaiBYZs (Serial Wombat 4B chip Equivalent Pin Mode)
Implements Processed Input Functions	No
Implements Scaled Output Functions	No
Requires Timing Resource Manager resources	No
Functions if Timing Resource Manager resources are unavailable	N/A

This pin mode allows use of the Serial Wombat 18AB chips's internal two UART hardware modules to send and receive data at standard baud rates in 8-N-1 format.

The Serial Wombat 18AB chip has a 64 byte transmit buffer and 128 byte receive buffer. Therefore, up to 64 bytes can be sent to the SerialWombatUART at a time. Attempts to send more than that will result in the write, print, etc command blocking until space is available on the SerialWombatUART to buffer the data.

Received data is buffered on the Serial Wombat chip until it is retrieved from the host.

Note: Due to the overhead of querying and retrieving data from the SerialWombatUART, data loss is likely when receiving streams of data greater than the buffer size at higher baud rates.

To minimize this possibility, read data frequently from the Serial Wombat chip.

This pin mode can Send, Receive, or both. Two instances of this pin mode can be used on the Serial Wombat 18AB chip by using the interface begin() call which takes a hardware indicator of 0 or 1.

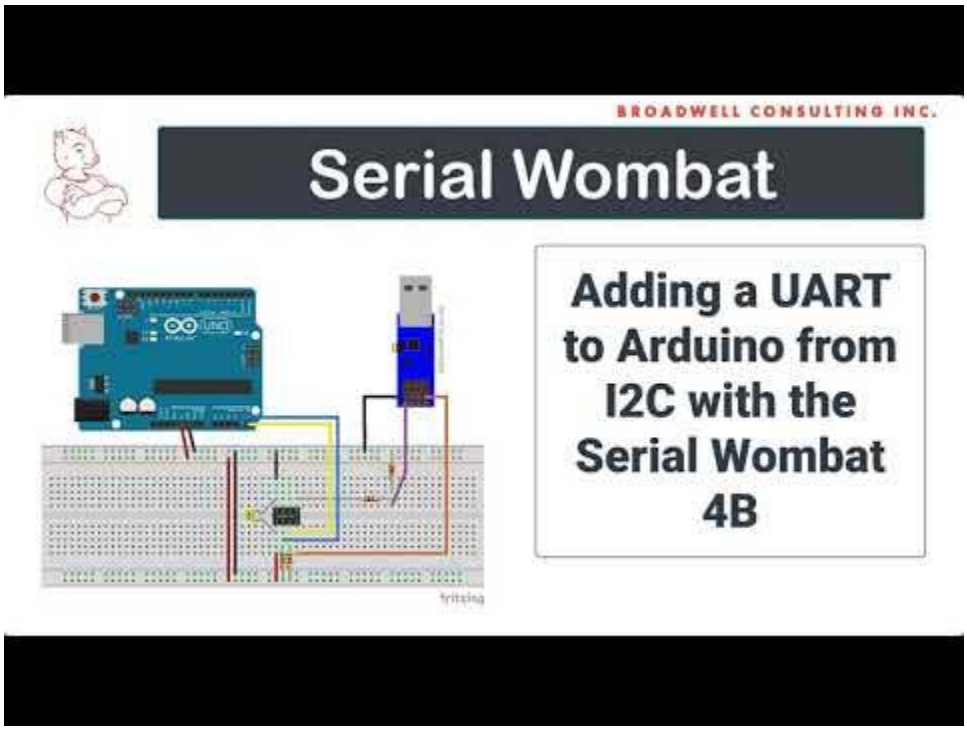
On Arduino the wrapper class for this pin mode inherits from the Arduino Stream class, so functions such as println() can be used once the UART is initialized.

A full Serial Wombat packet send / receive sequence (8 bytes in each direction) over I2C is necessary to query the status of the queues or to read or receive a byte of data. Therefore, the protocol becomes more efficient if multiple bytes are read or written using the readBytes or write(const uint8_t* buffer, size_t size) interfaces rather than read() or write(uint8_t data).

The class must be assigned to a pin. This may be either the receive or transmit pin.

Serial Wombat 18AB pins must be enhanced digital performance pins.

Available baud rates are:
- 300
- 1200
- 2400
- 4800
- 9600
- 19200
- 38400
- 57600
- 115200



https://youtu.be/C1FjcaiBYZs

Software UART Receive and Transmit Mode

Pin Mode Name	Software UART
Pin Mode Firmware ID	13
Pin Type Required	Any
Available on Serial Wombat 4B chips	no
Serial Wombat 18AB Throughput consumed	High - Varies with baud rate and send/receive frequency
Arduino Class Documentation	https://broadwellconsultinginc.github.io/SerialWombatArdLib/class_serial_wombat_u_a_r_t.html
Tutorial Video	N/A
Implements Processed Input Functions	No
Implements Scaled Output Functions	No
Requires Timing Resource Manager resources	No
Functions if Timing Resource Manager resources are unavailable	N/A

This pin mode allows pins to send or receive UART data via signal processing implemented in the Serial Wombat 18AB's firmware. This mode can be used when insufficient hardware based UARTs are available to meet user needs.

A queue in the User Buffer area is allocated for RX and one for TX prior to as part of begin for this mode. Size of these queues should be determined based on system needs. The User needs to ensure that the created queues do not overlap with other structures created in the User Buffer. See the section on User RAM Buffer Queues for more information

Warning: The Serial Wombat Software UART pin mode requires significant CPU utilization on the Serial Wombat microcontroller. This utilization increases as baud rates and bytes processed increase. The Serial Wombat chip is not capable of running the Software UART pin mode on all pins simultaneously due to processing power constraints. Exceeding more than the available CPU power may cause the Serial Wombat chip to malfunction. See the section on Serial Wombat 18AB Throughput management for more information.

Note: Due to the overhead of querying and retrieving data from the SerialWombat Software UART, data loss is likely when receiving streams of data greater than the buffer size at higher baud rates.

On Arduino the wrapper class for this pin mode inherits from the Arduino Stream class, so functions such as println() can be used once the UART is initialized.

A full Serial Wombat packet send / receive sequence (8 bytes in each direction) over I2C or the main UART is necessary to query the status of the queues or to read or receive a byte of data.

The protocol becomes more efficient if multiple bytes are read or written using the readBytes or write(const uint8_t* buffer, size_t size) interfaces rather than read() or write(uint8_t data).

The class must be assigned to a pin. This may be either the receive or transmit pin.

Available baud rates are:
- 300
- 1200
- 2400
- 4800
- 9600
- 19200
- 38400 (Transmit only, receive may be unreliable)
- 57600 (Transmit only, receive may be unreliable)

Processed Input Testing Pin Mode

Pin Mode Name	Processed Input Testing
Pin Mode Firmware ID	14
Pin Type Required	Any
Available on Serial Wombat 4B chips	no
Serial Wombat 18AB Throughput consumed	negligible
Arduino Class Documentation	https://broadwellconsultinginc.github.io/SerialWombatArdLib/class_serial_wombat_processed_input_pin.html
Tutorial Video	N/A
Implements Processed Input Functions	No
Implements Scaled Output Functions	No
Requires Timing Resource Manager resources	No
Functions if Timing Resource Manager resources are unavailable	N/A

The Serial Wombat 18AB Processed Input Testing pin mode implements the Processed Input Pin Mode set of standardized signal measurement features for filtering, averaging, queuing, scaling, min/max tracking and outlier exclusion. It does not output any signal on the pin. It is primarily designed to facilitate unit testing of the Processed Input functions. See the Processed Input Pin Modes section for more information.

Matrix Keypad Pin mode

Pin Mode Name	Matrix Keypad
Pin Mode Firmware ID	15
Pin Type Required	Any
Available on Serial Wombat 4B chips	no
Serial Wombat 18AB Throughput consumed	TBD
Arduino Class Documentation	https://broadwellconsultinginc.github.io/SerialWombatArdLib/class_serial_wombat_matrix_keypad.html And https://broadwellconsultinginc.github.io/SerialWombatArdLib/class_serial_wombat_matrix_button.html
Tutorial Video	https://youtu.be/hxLda6lBWNg
Implements Processed Input Functions	No
Implements Scaled Output Functions	No
Requires Timing Resource Manager resources	No
Functions if Timing Resource Manager resources are unavailable	N/A

The Serial Wombat SW18AB Matrix Keypad mode implements a state machine that uses multiple pins to scan matrix keypads up to 4x4

This class allows the user to declare up to 4 row and 4 column pins which are strobed continuously to read up to 16 buttons. The Serial Wombat chip's internal pull-up resistors are used so no additional hardware is necessary. Standard matrix keypads can be attached directly to the Serial Wombat chip pins.
All Serial Wombat 18AB chip pins can be used in any combination or order.

Results can be returned to the host as a binary 16 bit number indicating the state of 16 buttons, as an index indicating which button is currently pressed (0 for Col 0 Row 0, 3 for Col 3 Row 3 and 12 for Col 0 Row 3), or as ASCII values which assume a standard keypad layout.

Index mode:

```
|0  1  2  3 |
|4  5  6  7 |
|8  9  10 11|
|12 13 14 15|
```

With 16 being used for no current press, depending on mode setting

Ascii Mode:

```
|1 2 3 A|
|4 5 6 B|
|7 8 9 C|
|* 0 # D|
```

Note that the key indexes remain the same regardless of how many rows and columns are enabled.

The wrapper class under Arduino inherits from the Arduino Stream class, so queued keypad presses can be read like a Serial port.

The Serial Wombat 18AB firmware also keeps track of button transition counts and time since last transition for all 16 buttons. In this way each key of the keypad can be treated equivalently to a SerialWombatDebouncedInput class when encapsulated in a SerialWombatMatrixInput class. See the documentation on this class and Arduino examples for details.

The 16 Bit public data presented internally to other Serial Wombat pins and through the SerialWombatChip.readPublicData method can be configured to present the binary state of 16 buttons, the last button index pressed, the last button index pressed or 16 if no button is pressed, or ASCII of last button pressed. The Pulse On Change pin mode can be combined with the Matrix Keypad class to beep or blink an LED when a key is pressed.

A Tutorial video is available:

https://youtu.be/hxLda6lBWNg

The following is an example of a 16 key matrix keypad begin read in ASCII mode under Arduino:

```
#include <SerialWombat.h>

/*
This example shows how to initialize a 16 key, 8 pin 4x4 matrix keypad using the
Serial Wombat 18AB chip'sSerialWombatMatrixKeypad class.

This example shows how to treat the matrix keypad as a stream input
so that it can be treated as if keypresses are Serial Input

Note that firmware versions prior to 2.0.7 have a bug that may cause slow recognition of
button presses.

This example assumes a 4x4 keypad attached with rows connected to pins 10,11,12,13
and columns attached to pins 16,17,18,19 .  This can be changed in the keypad.begin
statement to fit your circuit.

This example uses default modes for the SerialWombatMatrixKeypad.  The default values
send ASCII to the queue assuming a standard

123A
456B
789C
*0#D

keypad format.   See the pin mode documentation (link below) for more information on the
possible buffer and queue modes It is assumed that the Serial Wombat chip is at I2C
address 0x6B.
```

```
A video demonstrating the use of the SerialWombatMatrixKeypad class on the Serial Wombat 18AB
chip is available at:
https://youtu.be/hxLda6lBWNg



*/
SerialWombatChip sw;
SerialWombatMatrixKeypad keypad(SW6B);

void setup() {

  Serial.begin(115200);
  Wire.begin();
  delay(100);
  sw.begin(Wire,0x6B);

  keypad.begin(10, // Command pin, typically the same as the row0 pin
  10, //row 0
  11, // row 1
  12, // row 2
  13, // row 3
  16, // column 0
  17, // column 1
  18, // column 2
  19); // column 3
}

void loop() {

  int i = keypad.read();  // returns a byte, or -1 if no value is avaialble
  if (i >0)
  {
    Serial.write((char)i);  // We got a keypress.  Dump it to the Serial Terminal
  }
}
```

PWM Pin Mode

Pin Mode Name	PWM
Pin Mode Firmware ID	16
Pin Type Required	Any (Enhanced Resolution on Enhanced Digital Capability pins)
Available on Serial Wombat 4B chips	yes
Serial Wombat 18AB Throughput consumed	TBD
Arduino Class Documentation	https://broadwellconsultinginc.github.io/SerialWombatArdLib/class_serial_wombat_p_w_m__18_a_b.html
Tutorial Videos	https://youtu.be/u4WihhoZnHA , https://youtu.be/Ab-H2pE9ZZk, https://youtu.be/Oqdvk5SoaU
Implements Processed Input Functions	No
Implements Scaled Output Functions	Yes
Requires Timing Resource Manager resources	Yes
Functions if Timing Resource Manager resources are unavailable	Degrades to 17uS resolution

The Serial Wombat PWM pin mode outputs a configurable duty cycle, configurable frequency PWM signal on a Serial Wombat 18AB pin. Unlike the Serial Wombat 4B chip, all PWM outputs can run at different frequencies.

Serial Wombat 18AB PWM outputs are driven either by hardware peripherals allocated by the Timing Resource Manager or by a DMA based software PWM scheme. Up to 6 hardware PWM outputs are available from the Timing Resource Manager on Enhanced Digital Performance pins. Simultaneously using other pin modes that use Timing Resource Manager resources may reduce the number of available hardware driven PWMs. Hardware capable pins can generate high resolution signals up to about 100kHz, at resolutions up to 16 bits depending on frequency.

DMA based output is limited to transitions every 17uS, so a 1kHz output will have about 6 bits of resolution and a 100 Hz output will have about 9 bit resolution.

The Serial Wombat 18AB PWM pin mode implements the Scaled Output Pin Mode extension set of standardized output processing functions. This is useful when adjusting the PWM's duty cycle based on another pin's Public Data value. The Scaled Output Pin Mode extension can scale the input value, invert the input, limit the rate of change of the output, filter the output, control the output via hysteresis, control the output via PID control, and scale the final output. See the Scaled Output Pin Mode section for more information.

Pulse Timer Pin Mode

Pin Mode Name	Pulse Timer
Pin Mode Firmware ID	18
Pin Type Required	Any (future firmware versions will perform better on enhanced digital performance pins)
Available on Serial Wombat 4B chips	Yes
Serial Wombat 18AB Throughput consumed	TBD
Arduino Class Documentation	https://broadwellconsultinginc.github.io/SerialWombatArdLib/class_serial_wombat_pulse_timer__18_a_b.html
Tutorial Video	https://www.youtube.com/watch?v=YtQWUub9gYw (Serial Wombat 4B chip Equivalent Pin Mode)
Implements Processed Input Functions	Yes
Implements Scaled Output Functions	No
Requires Timing Resource Manager resources	No (future improvements will use TRM resources to increase resolution)
Functions if Timing Resource Manager resources are unavailable	N/A (future versions will degrade to 17uS resolution)

The Serial Wombat Pulse Timer pin mode is useful for timing pulses such as RC Servo pulses, or reading PWM frequency and duty cycle.

The pin state machine implements the Processed Input Pin Mode set of standardized signal measurement features for filtering, averaging, queuing, scaling, min/max tracking and outlier exclusion. See the Processed Input Pin Mode section for more information.

The Serial Wombat chip can measure pulses in either millisecond or microsecond units. The user should select the correct units based upon pulse length. Measurements with a maximum value of less than 65535uS should use microsecond mode. Measurements with a maximum value longer than 65535 uS should use millisecond mode.

This pin mode has a 17uS precision and 2% accuracy (due to internal FRC variation from part to part).

A future improvement is intended that will microsecond precision when Timing Resource Manager resources are used.

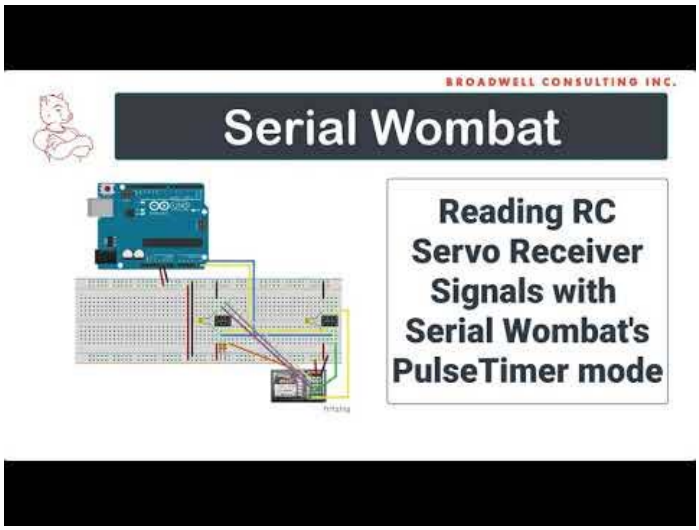
The Serial Wombat Protocol and Arduino library supports requesting both high and low times in a single transaction. This allows the most recent high and low times to be read together, which is important when calculating a PWM duty cycle. However, either the high time or low time may

be the most recently measured value depending on when the request is made which may cause variation in duty cycle or frequency calculation for quickly changing PWM values.

The number of measured pulses increments for each high/low combination. By reading this value twice over a given period of time, the host can calculate an approximate frequency of a signal. The measured pulses value overflows from 65535 to 0 without notice.

A video tutorial on this pin mode is available here (written for the Serial Wombat 4B, but similar for Serial Wombat 18AB):

https://www.youtube.com/watch?v=YtQWUub9gYw



Here's an Arduino example of the Pulse Timer pin mode from the Arduino library examples which reads the high time of 4 channels of an R/C servo receiver:

```
#include <SerialWombat.h>

SerialWombatChip sw;    //Declare a Serial Wombat chip
SerialWombatPulseTimer steering(sw);
SerialWombatPulseTimer throttle(sw);
SerialWombatPulseTimer button(sw);
SerialWombatPulseTimer thumbSwitch(sw);

// This example is explained in a video tutorial at: https://youtu.be/YtQWUub9gYw

void setup() {
  // put your setup code here, to run once:

  {//I2C Initialization
    Wire.begin();
    sw.begin(Wire,0x6B);  //Initialize the Serial Wombat library to use the primary I2C port,
SerialWombat is address 6B.
  }

   steering.begin(0);
```

```
   throttle.begin(1);
   button.begin(2);
   thumbSwitch.begin(19);

   Serial.begin(115200);
}

void clearTerminal()
{
    Serial.write(27);       // ESC command
  Serial.print("[2J");    // clear screen command
  Serial.write(27);
  Serial.print("[H");     // cursor to home command
}

int i;
void loop() {
    clearTerminal();
    Serial.println(steering.readHighCounts());
    Serial.println(throttle.readHighCounts());
    Serial.println(button.readHighCounts());
    Serial.println(thumbSwitch.readHighCounts());

    delay(50);

}
```

Frame Timer Pin Mode

Pin Mode Name	Frame Timer
Pin Mode Firmware ID	21
Pin Type Required	Any (one pin per chip can be allocated to this mode)
Available on Serial Wombat 4B chips	No
Serial Wombat 18AB Throughput consumed	Negligible
Arduino Class Documentation	N/A (pin mode is enabled from SerialWombatChip class method setThroughputPin)
Tutorial Video	N/A
Implements Processed Input Functions	No
Implements Scaled Output Functions	No
Requires Timing Resource Manager resources	No
Functions if Timing Resource Manager resources are unavailable	N/A

The Frame Timer Pin mode on the Serial Wombat 18AB chip is used to make individual 1mS frame utilization times visible externally. A pin in Frame Timer Pin Mode will go high while the Serial Wombat firmware is processing pin state machines and low when it is not. This allows the user to see how much of each 1mS frame is being utilized by pin mode processing. High time does not include processing time for any received communication packets. See the section on Serial Wombat 18AB Throughput management for more information. Only one pin per chip may be configured to this mode. A chip reset is required to disable this function once enabled.

Capacitive Touch (CapTouch) Pin Mode

Pin Mode Name	Capacitive Touch or CapTouch
Pin Mode Firmware ID	22
Pin Type Required	Analog
Available on Serial Wombat 4B chips	No
Serial Wombat 18AB Throughput consumed	TBD
Arduino Class Documentation	https://broadwellconsultinginc.github.io/SerialWombatArdLib/class_serial_wombat18_cap_touch.html
Tutorial Video	https://youtu.be/c4B0_DRVHs0
Implements Processed Input Functions	No
Implements Scaled Output Functions	No
Requires Timing Resource Manager resources	Yes
Functions if Timing Resource Manager resources are unavailable	No

This pin mode allows a metallic object with a thin insulating layer to be used as a capacitive touch surface. Items like a coin, PCB board, metal plate, etc can be connected directly to the pin and covered by a thin insulating layer. A finger touch can be detected by the change in capacitance caused by its presence.

The mode can output either analog or digital values back to the host and as public data to other pins. In analog mode the A/D reading at the end of a charge cycle is presented. This value gets smaller when a finger or item causes the capacitance of the sensor to increase. (Smaller A/D values when finger present, higher values when absent).

In digital mode the class is configured with a high and low limit which cause a digital change in hysteresis manner. This is useful when treating the touch sensor like a button. In digital mode the class implements the same interfaces as the SerialWombatDebouncedInput class so that physical buttons and cap touch inputs can be treated equivalently. Setting the high and low limits further apart will decrease the chance of false transitions but will also typically decrease the responsiveness of the sensor.

Output public data values for touched and not touched are configurable. This allows other pin modes to react based on touch. For instance, the touch and not touched values might be set to 0x4000 and 0xC000 so that a servo set to monitor that public data would move back and forth between 25% and 75% of its range depending on whether or not a touch is present.

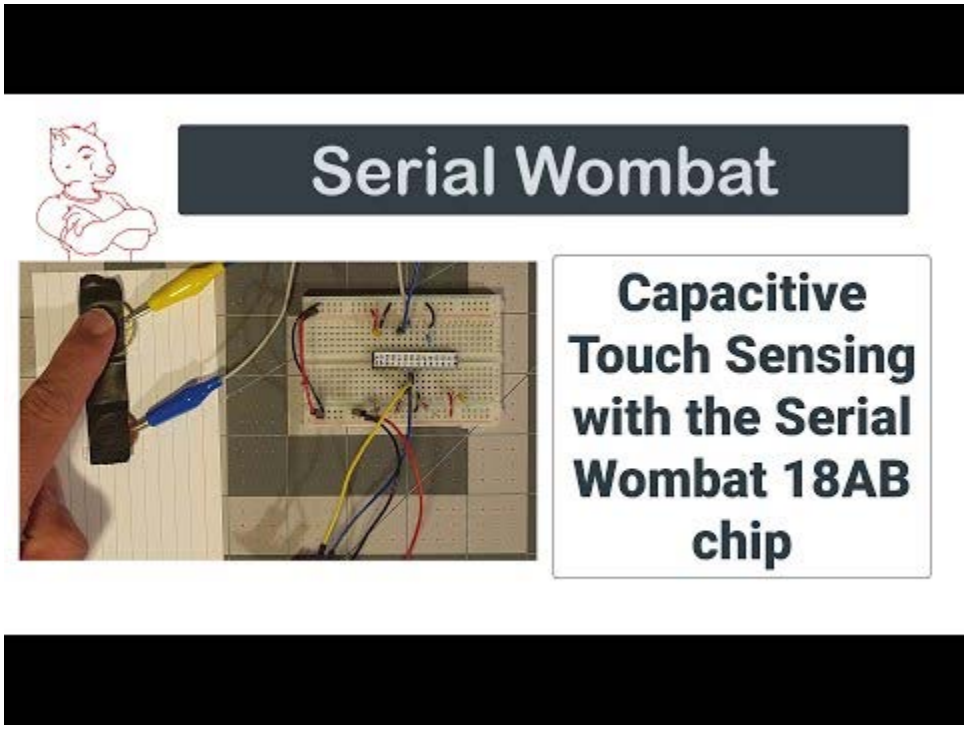
The final touch value is the result of 8 averaged samples in firmware remove noise.

For particularly noisy signals a debounce option is also available. This requires the specified number of samples to match before a transition is detected. This can help eliminate false transitions but makes the system less responsive in terms of time to transition after a touch is made or removed.

For good performance a CapTouch sensor needs to be calibrated. The response of the system is dependent on the capacitance of the plate, and the dielectric properties of the insulator. An example sketch is included in Arduino, Python, and C# that will calibrate a sensor. See the tutorial video for this procedure.

NOTE: The Cap touch pin mode in the firmware takes exclusive access to the Microcontroller's A/D hardware for a few milliseconds at a time. This isn't an issue for most users if the default 5ms delay between samples is used. However, it should be considered if multiple Cap Touch pins are being used simultaneously or if the delay is decreased as they may combine to starve other analog channels and make conversions sporadic, affecting filtering and averaging. This may also impact performance of real-time control pin modes run on the Serial Wombat chip such as PID control.

A Tutorial video is available:



https://youtu.be/c4B0_DRVHs0

The following example shows using two pins in CapTouch mode along with a wrapper class that allows a button, captouch, or matrix button input to increment a variable with increasing speed

the longer it is held. The calibration values in begin and makeDigital calls are based on a prior calibration using the calibration sketch in the library examples collection.

```
#include "SerialWombat.h"


/*
This example shows how to configure two Serial Wombat 18AB pins to Touch input and use the
SerialWombat18CapTouchCounter class to implement a two touch sensor interface to increment
a counter at various speeds by two different increments.

The example was created using a Serial Wombat 18AB chip in I2C mode with a Node MCU clone Arduino
and a penny and quarter both covered with electrial tape wired to pins WP16 and WP17.

When the penny is touched briefly the total will increment by 1 cent.  When the quarter is
touched
the total will increment by 25 cents.  If a finger is held on them then they will increment
slowly, then
more quickly, then very quickly.  This type of interface could be easily integrated into a
complete solution
for user configuration of parameters.

SerialWombat18CapTouch class documentation can be found here:
https://broadwellconsultinginc.github.io/SerialWombatArdLib/class_serial_wombat18_cap_touch.html#
details

A demonstration video of this class can be found here:
https://youtu.be/c4B0_DRVHs0

 */


#define I2C_ADDRESS 0x6B
#define PENNY_PIN 16  //Must be an Analog capable pin:  0,1,2,3,4,16,17,18,19
#define QUARTER_PIN 17 //Must be an Analog capable pin:  0,1,2,3,4,16,17,18,19

SerialWombat sw;
SerialWombat18CapTouch penny(sw);
SerialWombat18CapTouch quarter(sw);

SerialWombatButtonCounter quarterCounter(quarter), pennyCounter(penny);

long int moneyCount = 0;  //Place to keep track of total money count in pennies

void setup() {
  Wire.begin();  // Initialize I2C

  sw.begin(Wire,I2C_ADDRESS,false); //Initialize the Serial Wombat Chip

  Serial.begin(115200); //Initialize the UART

  delay(1000);

  VersionCheck();  //Check to ensure the Serial Wombat chip is responding (see other tab)

  // Initialize the Penny sensor
  //9000 based on previous calibration of this penny on this pin with this wire using the
Calibration example
  penny.begin(PENNY_PIN,9000,0);
```

```
  // Initialize the Penny sensor
  //9250 based on previous calibration of this quarter on this pin with this wire using the
Calibration example
  quarter.begin(QUARTER_PIN,9250,0);

  delay(500);

  penny.makeDigital(53985,57620,1,0,0,0);//Low and High limits based on previous calibration of
this penny on this pin with this wire
  quarter.makeDigital(54349,57792,1,0,0,0);//Low and High limits based on previous calibration of
this quarter on this pin with this wire
  delay(250);

  pennyCounter.begin(&moneyCount, //moneyCount is the variable we want to increment.
    1,  //Increment by 1
    500,//Every 500 ms
    2000, // for 2000ms, then...
    1,  // by 1
    250, // every 250ms
    5000, // for 5000 ms, then
    1,    // by 1
    100); // every 100ms

    //Initialization of the quarter Counter is the same, but incrments by 25.
   quarterCounter.begin(&moneyCount, 25,500,2000,25,250,5000,25,100);

   Serial.println("Touch or hold the penny or the quarter:");

}


long int lastCount = -1;  // A copy of moneyCount so we can send a Serial update on changes.
void loop() {
  quarterCounter.update();  //Service the counter periodically
  pennyCounter.update();    //Serivce the counter periodically

  if (lastCount != moneyCount)  // Did the counter change the moneyCount variable?
  {
    //Yes, the counter changed
    lastCount = moneyCount;  //Make a copy for comparison

    //Then build a string and send it.
    char moneyCountStr[20];
    sprintf(moneyCountStr,"$%ld.%02ld",moneyCount / 100, moneyCount%100);
    Serial.println(moneyCountStr);
  }
}
```

Resistance Input Pin Mode

Pin Mode Name	Resistance Input
Pin Mode Firmware ID	24
Pin Type Required	Analog
Available on Serial Wombat 4B chips	No
Serial Wombat 18AB Throughput consumed	TBD
Arduino Class Documentation	https://broadwellconsultinginc.github.io/SerialWombatArdLib/class_serial_wombat_resistance_input.html
Tutorial Video	https://youtu.be/c4B0_DRVHs0
Implements Processed Input Functions	Yes
Implements Scaled Output Functions	No
Requires Timing Resource Manager resources	No
Functions if Timing Resource Manager resources are unavailable	N/A

A Pin mode to make resistance measurements with the Serial Wombat 18AB chip.

The **SerialWombatResistanceInput** class is used to make resistance measurements on a given pin up to about 60 kOhm. The measurement must be between the pin and ground.

The pin state machine implements the Processed Input Pin Mode set of standardized signal measurement features for filtering, averaging, queuing, scaling, min/max tracking and outlier exclusion. See the Processed Input Pin Mode section for more information. The Serial Wombat Resistance Input mode makes 20 measurements per second per pin.

Declare and initialize a **SerialWombatResistanceInput** instance for each pin being used as a resistance input.

NOTE: The Resistance Input pin mode in the firmware takes exclusive access to the Microcontroller's A/D hardware for a few milliseconds at a time. This isn't an issue for most users if the default 5ms delay between samples is used. However, it should be considered if multiple Cap Touch pins are being used simultaneously or if the delay is decreased as they may combine to starve other analog channels and make conversions sporadic, affecting filtering and averaging. This may also impact performance of real-time control pin modes run on the Serial Wombat chip such as PID control.

A Tutorial video is available:

https://youtu.be/8ynBmxZSE_M

Pulse on Change Pin Mode

Pin Mode Name	Pulse on Change
Pin Mode Firmware ID	25
Pin Type Required	Any
Available on Serial Wombat 4B chips	No
Serial Wombat 18AB Throughput consumed	TBD
Arduino Class Documentation	https://broadwellconsultinginc.github.io/SerialWombatArdLib/class_serial_wombat_pulse_on_change.html
Tutorial Video	N/A
Implements Processed Input Functions	No
Implements Scaled Output Functions	No
Requires Timing Resource Manager resources	No
Functions if Timing Resource Manager resources are unavailable	N/A

The Pulse on Change Pin Mode monitors other pins' or public data in the Serial Wombat chip and generates a pin pulse on change. See the Section on Public Data for more information about public data.

Pulse on Change is useful to generate a pulse that can drive an interrupt on the host Arduino, or for creating user alerts such as LED pulses or buzzer tones that acknowledge data reception or human input.

For instance, a pulse could be generated when the output value of a rotary encoder state machine on other pins changes value. Or an LED could be pulsed to command traffic on the Serial Wombat chip by making it pulse when SW_DATA_SOURCE_PACKETS_RECEIVED changes.

Each Pulse On Change pin can monitor up to 8 other pins or data sources for changes. A pulse will be generated when any of the criteria (orNotAnd == 1) or all (simultaneously) of the criteria (orNotAnd == 0) are met. Criteria can be any of the following:

- Pin data or public data changed
- Pin data or public data increased
- Pin data or public data decreased
- Pin data or public data equals a fixed value
- Pin data or public data below a fixed value
- Pin data or public data above a fixed value
- Pin data or public data not equal to a fixed value

- Pin data or public data crosses a fixed value
- Pin data or public data crosses (ascending) a fixed value
- Pin data or public data crosses (descending) a fixed value
- Pin data or public data equals another pin
- Pin data or public data below another pin
- Pin data or public data above another pin
- Pin data or public data not equal to another pin
- Pin data or public data is within a range
- Pin data or public data is outside a range

The pin mode can be configured with regard to the length and polarity of the pulse produced. In addition, an active pulse condition can cause a PWM output. This is useful to drive a passive buzzer or speaker circuit.

High Frequency Servo

Pin Mode Name	High Frequency Servo
Pin Mode Firmware ID	26
Pin Type Required	Enhanced Digital Performance
Available on Serial Wombat 4B chips	No
Serial Wombat 18AB Throughput consumed	TBD
Arduino Class Documentation	https://broadwellconsultinginc.github.io/SerialWombatArdLib/class_serial_wombat_high_frequency_servo.html
Tutorial Video	https://youtu.be/sCQGRyau40g
Implements Processed Input Functions	No
Implements Scaled Output Functions	Yes
Requires Timing Resource Manager resources	Yes
Functions if Timing Resource Manager resources are unavailable	No

This pin mode adds support for a frequency/period setting and by changing the on-chip pin mode to one optimized for high speed servos.

Up to six High Frequency Servo pins may be assigned per Serial Wombat 18AB Chip. This pin mode claims and holds one of the 6 timing resources also used by PWM output, standard servo output, etc.

This mode creates rapid pulse outputs by using a PWM rather than pulse generation mode. This makes it well suited for fast updates, (200 Hz or better) but a poor choice for driving standard 50Hz servos as it will have worse resolution at low speeds than the standard mode.

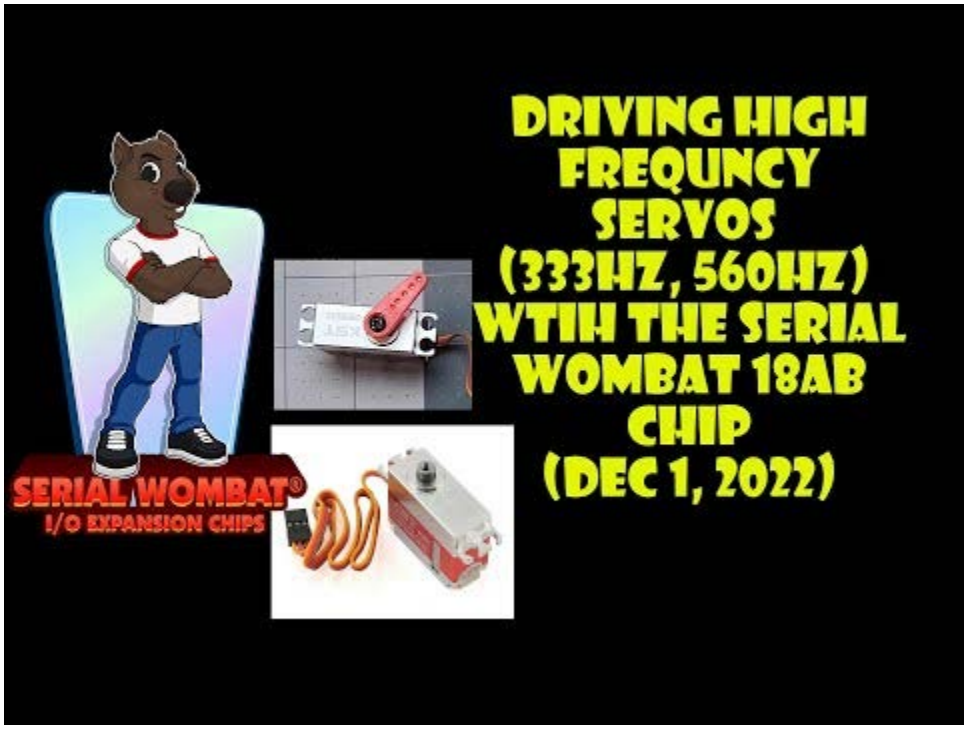
The Arduino / C# / Python class wrapping this pin mode inherits from the SerialWombatServo_18AB class, but the interface
void attach(uint8_t pin, bool reverse)
is not available in this mode, as it must be explicitly configured for minimum and maximum pulse width.
The pulse update rate can be set with writeFrequency() or writePeriod().

This class uses "attach" rather than "begin" to initialize servos to be consistent with the Arduino Servo native API.

This pin mode implements the Scaled Output Pin Mode extension set of standardized output processing functions. This is useful when positioning the servo based on another pin's Public

Data value. The Scaled Output Pin Mode extension can scale the input value, invert the input, limit the rate of change of the output, filter the output, control the output via hysteresis, control the output via PID control, and scale the final output. See the Scaled Output Pin Mode section for more information.

A video tutorial is available:
https://youtu.be/sCQGRyau40g



Ultrasonic Distance Sensor Driver

Pin Mode Name	Ultrasonic Distance Sensor
Pin Mode Firmware ID	27
Pin Type Required	Any (future versions will benefit from Enhanced Digital Performance)
Available on Serial Wombat 4B chips	No
Serial Wombat 18AB Throughput consumed	TBD
Arduino Class Documentation	https://broadwellconsultinginc.github.io/SerialWombatArdLib/class_serial_wombat_high_frequency_servo.html
Tutorial Video	N/A
Implements Processed Input Functions	Yes
Implements Scaled Output Functions	No
Requires Timing Resource Manager resources	No (future versions Yes)
Functions if Timing Resource Manager resources are unavailable	N/A (future versions reduced resolution)

The Serial Wombat Ultrasonic Distance Sensor pin mode combines 2 pins to drive an HC-04 or compatible Ultrasonic distance sensor, and provides the measured distance in millimeters as the pin mode's public data based on an assumption that the speed of sound is 343 m/S.

The pin mode can be set up to trigger a sensor reading pulse on command, or to trigger a new pulse immediately after the prior pulse completes. The number of pulses taken can be retrieved as a 16 bit number.

The pin state machine implements the Processed Input Pin Mode set of standardized signal measurement features for filtering, averaging, queuing, scaling, min/max tracking and outlier exclusion. See the Processed Input Pin Mode section for more information.

Liquid Crystal Character LCD Display Driver

Pin Mode Name	Liquid Crystal
Pin Mode Firmware ID	28
Pin Type Required	Any
Available on Serial Wombat 4B chips	No
Serial Wombat 18AB Throughput consumed	TBD
Arduino Class Documentation	https://broadwellconsultinginc.github.io/SerialWombatArdLib/class_serial_wombat_liquid_crystal.html
Tutorial Video	N/A
Implements Processed Input Functions	Yes
Implements Scaled Output Functions	No
Requires Timing Resource Manager resources	No
Functions if Timing Resource Manager resources are unavailable	N/A

This pin mode uses 6 Serial Wombat 18AB pins to connect to HD44780 / 1602 / 4002 / 2004 or similar interface Character LCDs. This pin mode is only used for connecting in parallel to a Character LCD. It is not applicable for LCDs that have an I2C interface

This pin mode has nearly identical interfaces to the classic Arduino LiquidCrystal library and can be used with similar parallel character LCDs. This pin mode is only intended for use with character LCDs that are connected in 4 bit parallel (E, RS, D4, D5, D6, D7) with the Serial Wombat chip. RW pin on the LCD must be grounded.

In addition to the classic LiquidCrystal interfaces, this pin mode has a more advanced mode available through the initializeBufferCopy() interface which allows displays to be updated from data stored in the Serial Wombat Chip's User Buffer. The Serial Wombat chip will handle getting the right data to the right location on the display. This is convenient for displays such as 20x4 displays which alternate lines when addressing. When combined with a shifting queue initialized with SerialWombatQueueType::QUEUE_TYPE_RAM_BYTE_SHIFT, the display can be treated like any other Stream Class under Arduino. See the Arduino examples directory for an example of this.

This class also supports buffer copying to large 40x4 character LCDs that have two E lines. These displays are essentially two 44780 controllers connected to a single piece of glass. See the example in the Arduino examples directory.

Multiple Liquid Crystal LCD displays may be attached to the Serial Wombat 18AB chip. E (and optional E2) lines must be exclusive to a single LCD display. If multiple LCDs are attached to a single Serial Wombat Chip then RS, D4, D5, D6, and D7 can be shared by multiple displays.

When in buffer mode the class updates one character per mS.

High Speed Clock

Pin Mode Name	High Speed Clock
Pin Mode Firmware ID	29
Pin Type Required	Enhanced Digital Performance
Available on Serial Wombat 4B chips	No
Serial Wombat 18AB Throughput consumed	None
Arduino Class Documentation	https://broadwellconsultinginc.github.io/SerialWombatArdLib/class_serial_wombat_h_s_clock.html
Tutorial Video	N/A
Implements Processed Input Functions	No
Implements Scaled Output Functions	No
Requires Timing Resource Manager resources	No
Functions if Timing Resource Manager resources are unavailable	N/A

A pin mode which outputs a high speed clock signal suitable for clocking other devices.
This pin mode provides a high speed clock (in the case of the SW18AB Chip up to 32 MHZ). The number of pins that support this mode and the resolution and frequency options will vary by base microcontroller.

In the case of the SW18AB chip only one pin may be configured to this pin mode, as the mode uses the hardware Reference Clock Output, and there is only one reference clock available on the PIC24FJ256GA702. The selected pin must be an enhanced digital capability pin.
The pin mode takes a 32 bit unsigned integer and outputs that frequency (or the chip's best approximation of it).

In the case of the SW18AB chip, the output frequency is determined by a hardware clock divider that either outputs 32MHZ or 32Mhz / 2 * an integer. So 32MHz and 16MHz are possible, but 24MHz (for example) is not. The divisor can range from 1 *2 to 32767 * 2, so the minimum output frequency is 32000000 / 32767 / 2 = 488 Hz
Note: The SW18AB uses an internal oscillator which has an accuracy of +/- 2 percent. So the accuracy of the output frequency can vary with the accuracy of the internal oscillator.
If assigning a new pin mode to a pin in HS Clock mode, call the disable method first.

High Speed Counter

Pin Mode Name	High Speed Counter
Pin Mode Firmware ID	30
Pin Type Required	Enhanced Digital Performance
Available on Serial Wombat 4B chips	No
Serial Wombat 18AB Throughput consumed	TBD
Arduino Class Documentation	https://broadwellconsultinginc.github.io/SerialWombatArdLib/class_serial_wombat_h_s_counter.html
Tutorial Video	N/A
Implements Processed Input Functions	Yes
Implements Scaled Output Functions	No
Requires Timing Resource Manager resources	No
Functions if Timing Resource Manager resources are unavailable	N/A

This class is used to measure the frequency or cycles of a high speed input. On the Serial Wombat 18AB chip this class can be used two times, as two clock inputs are available. An enhanced digital capability pin must be used.

This pin mode has been tested on inputs up to 4MHz on the 18AB.

For frequency measurements a number of counts is divided by a time. The time in mS can be specified. The frequency is updated every X ms. In order to get a good value, X should be an even divisor of 1000 (e.g. 1, 2, 4, 25, or 500, but not 3 or 15 or 300).

The counter can be retrieved and optionally be reset on reading.

The public data buffer for this pin mode can be based either on the count of cycles or the frequency.

Since the public data buffer is limited to 16 bits a divisor is available that's applied to the counter or frequency before it's copied to the public data buffer. That way a varying high speed frequency can still create a varying public data buffer rather than saturating at 65535.

When in frequency mode the pin state machine implements the Processed Input Pin Mode set of standardized signal measurement features for filtering, averaging, queuing, scaling, min/max tracking and outlier exclusion. See the Processed Input Pin Mode section for more information. The Processed Input Pin Mode functionality is only updated at the end of each frequency

measurement period, so the time required to average and the effect of filtering will vary depending on this period.

VGA Output Pin Mode

Pin Mode Name	VGA OUTPUT
Pin Mode Firmware ID	31
Pin Type Required	Enhanced Digital Performance, fixed pins 14, 15, 16, 17, and 18 must be used
Available on Serial Wombat 4B chips	No
Serial Wombat 18AB Throughput consumed	TBD
Arduino Class Documentation	https://broadwellconsultinginc.github.io/SerialWombatArdLib/class_serial_wombat18_a_b_v_g_a.html
Tutorial Video	https://youtu.be/AymDj_xVlV8 (Preview Video)
Implements Processed Input Functions	No
Implements Scaled Output Functions	No
Requires Timing Resource Manager resources	Yes
Functions if Timing Resource Manager resources are unavailable	No

This pin mode is designed to drive a VGA monitor RGB and H and V Sync lines. The output is essentially 1 bit, with the ability to change the color between 8 colors (including black) by horizontal line.

This pin mode is unusual among SW18AB pin modes because it requires specific pins to be used for certain things. Pins must be:

VGA VSYNC (VGA Pin 14) -> 100 ohm Resistor -> SW Pin 18
VGA HSYNC (VGA Pin 13) -> 100 ohm Resistor ->SW Pin 17
VGA Red (VGA Pin 1) -> 280 ohm Resistor -> SW Pin 16
VGA Blue (VGA Pin 2) -> 280 ohm Resistor -> SW Pin 15
VGA Green (VGA Pin 3) -> 280 ohm Resistor -> SW Pin 14

Thank you to Nick Gammon who published a very informative article on driving a VGA monitor here: http://www.gammon.com.au/forum/?id=11608

Note: This pin mode stretches the limits of what the SW18AB chip can do while still being able to do other things - some flicker / jitter is to be expected

The rate at which the display can be updated is slower than with a hardware connected LCD or OLED. The Serial Wombat protocol's 8 byte in / 8 byte out packet structure is not ideal for moving large blocks of data such as screen pixel data. This mode is better suited to data displays than real-time games, for example.

The pin mode is capable of limited color generation with the restriction that an entire horizontal line must be the same color. Colors are achieved by turning Red, Green, and Blue lines totally on or off in combinations.

This pin mode implements a 160x120 pixel output to a monitor in 640x480 mode with black bars around part of the screen. This was the best I could do using the chip's SPI in DMA mode.

The SerialWombat18ABVGADriver class (A separate Arduino Library) is designed to act as a wrapper between this pin mode and the AdafruitGFX library. See the Arduino examples for this pin mode for an example.

This pin mode uses a significant amount of SW18AB time that is not measured using typical methods due to the high number of interrupts it produces. These interrupts happen both during and outside of the main loop executive processing, so actual system utilization is higher than normal metrics indicate.

This pin mode should be considered experimental at this time, and may interact in unexpected ways with other pin modes. Users using the pin mode should ensure that the system works properly in their application.

PS2 Keyboard Input Mode

Pin Mode Name	PS2 Keyboard
Pin Mode Firmware ID	32
Pin Type Required	Any, 5V tolerant lines recommended
Available on Serial Wombat 4B chips	No
Serial Wombat 18AB Throughput consumed	TBD
Arduino Class Documentation	https://broadwellconsultinginc.github.io/SerialWombatArdLib/class_serial_wombat_p_s2_keyboard.html
Tutorial Video	https://youtu.be/YV00GfyxFJU
Implements Processed Input Functions	No
Implements Scaled Output Functions	No
Requires Timing Resource Manager resources	No
Functions if Timing Resource Manager resources are unavailable	N/A

A pin mode which receives input from IBM PS2 Keyboards.

The class inherits from the Arduino Stream class, so queued ps2 keyboard presses can be read like a Serial port.

Keys can also be read as PS2 key codes, or as a bitmap of currently pressed keys

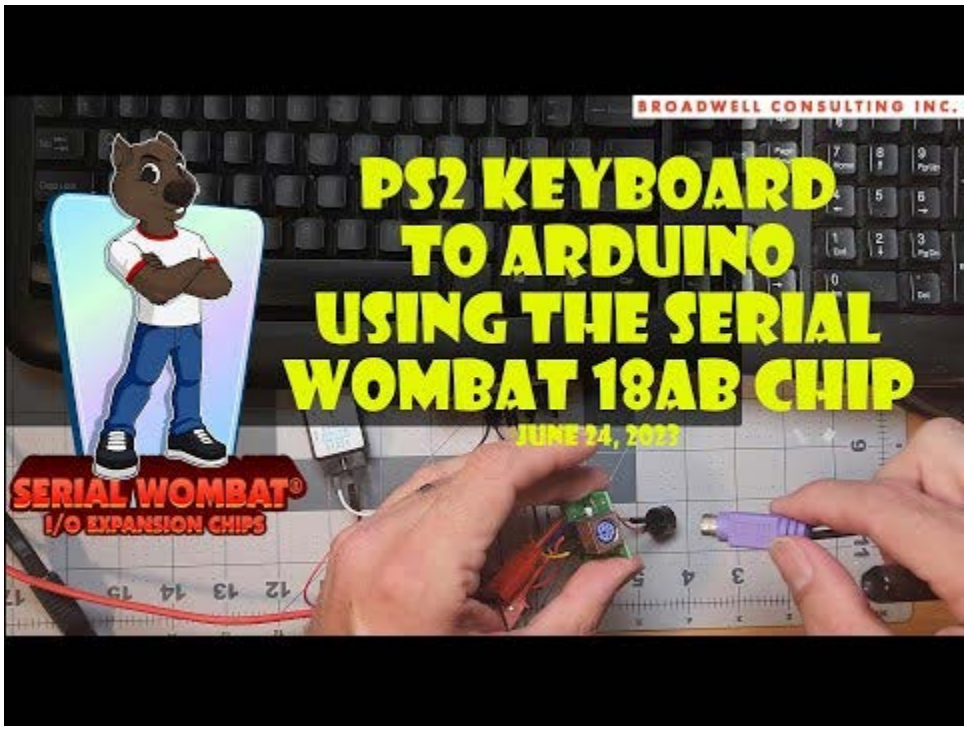
This class allows the user to declare a PS2 Keyboard. The PS2 Keyboard class is currently only supported on the Serial Wombat 18AB chip.

Note: The PS2 Keyboard pin mode requires 20 to 25% of the Serial Wombat 18AB chip's processor capacity. Assigning pin modes which together exceed available processing capacity causes malfunctions within the Serial Wombat chip.

The PS2 Keyboard pin mode requires a clock pin (to which this pin mode is assigned) and an additional data pin. Both should be tied high to 5v with a pull up resistor. I use a 5.1k.

Warning
The PS2 Keyboard inputs are 5V inputs. It is suggested that pins 9,10,11,12,14, or 15 on the Serial Wombat 18AB chip be used for PS2 Keyboard because they are 5V tolerant. Using other pins may damage the Serial Wombat chip.

A video Tutorial on this pin mode is available:



https://youtu.be/YV00GfyxFJU

Serial Wombat 18AB Pin to Pin interactions

The Serial Wombat 18AB chip is much more capable than other I/O expansion solutions due to its ability to do real time control. Each pin on the Serial Wombat 18AB chip does not exist in isolation. The pins are capable of interacting with each other.

For example, it is possible to control a servo from a potentiometer by allocating one pin as an analog input, and other pin as a servo output, and tying the pins together through the Scaled Output function of the servo output pin mode. This interaction is configured once by the host over I2C. Once this happens, the host need not interact any more with the Serial Wombat chip, and the servo will continue to respond to changes in the potentiometer. The host can query the Serial Wombat chip when desired to monitor the state of the analog input or servo, or to reconfigure the pin modes or take direct control of the servo output.

For another example, a rotary encoder can be configured to provide an input value. This value can be output to a TM1637 display without intervention by the host.

The Processed Input and Scaled Output functions available to some input and output pin modes provide much more flexibility, allowing values to be scaled, filtered, averaged, and more between pins. This allows, for example, a digital input such as a button to drive a servo between two predefined positions without real time assistance from the host.

The Scaled Output functions include PID and Hysteresis feedback control. A PWM pin configured to do PID control based on a frequency input can provide speed control to a motor with an encoder without real time interaction from the host. A temperature sensor on an analog input could control a heater attached to a digital output in hysteresis mode with configured on and off values to provide a thermostat system.

The pulse on change pin mode is very powerful with respect to monitoring changes in other pins' public data. It can provide a pulse or constant digital output when the data of another pin changes, increases, decreases, etc. It can also be configured to look for any of or a combination of conditions on other pins. This can be used to provide a digital interrupt or status signal back to the host, or to blink an LED or sound an acknowledgement tone. It is useful as an audio feedback to human interface inputs such as buttons, captouch inputs, rotary encoders, or matrix keypads.

In addition to public data provided by pin modes, the Serial Wombat chip has a number of public data variables that can be read as if they were pin outputs. Square waves, counts of received data packets, counts of errors, system source voltage, temperature, and other values are available. These variables are useful for diagnostic displays such as communication leds, system voltage, or error beepers. Outputs such as square waves are useful for offloading LED blinking from the host to the Serial Wombat chip.

Serial Wombat 18AB Public Data Sources

The Serial Wombat 18AB chip provides pin reading and writing and pin-to-pin interaction through unsigned 16-bit numbers (0 to 65535, or 0 to 0xFFFF in hexadecimal).

The concept of 0 to 65535 representing the full range of available variation is central to the philosophy and architecture of the Serial Wombat 18AB chip. By expressing all inputs and outputs in these terms (where possible) the Serial Wombat Chip abstracts inputs and outputs to all mean the same thing. Some values are represented in absolute units (such as temperature, resistance, time and voltage), but most others are proportional.

For instance, the position of a servo is represented by a range of 0 to 65535. 0 means the furthest possible location in one direction, and 65535 means the furthest possible location in the other. Different servos may require different pulse widths to reach their furthest operation in each direction, but that is abstracted at the lowest level when the pin mode is initialized. That way a standard 50Hz signal servo can be controlled in the same way as a high frequency servo that requires a 333Hz update rate, despite the fact that the pulse width for each is much different.

The ability to scale inputs and outputs through the Processed input and Scaled Output pin mode capabilities provides higher abstraction capabilities. For instance, a given servo may move 185 degrees when provided with a pulses that range from 500uS to 2500uS. However, the available range of motion may be reduced if this servo is installed as a “wrist” in a robot arm, in which case, the range of motion might be reduced to 110 degrees between 30 and 140 degrees. In this case, the servo’s Scaled Output scaling function could be used to scale a value of 0-65535 to 30-140 degrees, which would then be converted to appropriate pulse outputs. This would allow an analog potentiometer (which outputs from 0 to 65535) to control the robot arm’s wrist directly, using the full range of the potentiometer to control the robot wrist in only its range of motion.

In another example, a pin configured for pulse measurement mode and connected to an R/C receiver might read input pulses that range from 750uS to 2250uS. Using the input processing

This concept is why the Serial Wombat 4B and 18AB chips provide A/D conversion results in 0 to 65535 ranges rather than 0-1023 or 0-4095 for 10- and 12-bit conversions. This method has a number of interesting side effects:

1. A PWM output (with a duty cycle of 0-65535) will produce an analog input reading equal to the PWM setting if filtered and fed back to an analog input pin.
2. Serial Wombat 18AB a/d conversion and Serial Wombat 4B a/d conversion results are directly comparable. The SW18AB version is more precise, but scaled the same (assuming equal Vdd values).

Each pin outputs one 16-bit unsigned value as its public data. This value is updated by the pin mode's state machine. In some cases updates are as frequent as every 1mS, and in others updates come when new measurements are complete.
Some pin modes allow a choice of what measurement becomes that pin's public data. For instance, the pulse measurement mode can output the latest high time, low time, period, or frequency as its public data. Duty cycle would be relevant when reading a PWM signal, period would be relevant when reading the speed of a motor feedback, and high-time would be relevant when reading pulses from a servo controller or Radio Control radio receiver.

Other system wide pieces of public data are available in addition to public data provided by each pin state machine.

Public Data Sources:

SW_DATA_SOURCE_INCREMENTING_NUMBER(65)

An number that increments each time it is accessed.

SW_DATA_SOURCE_1024mvCounts(66)

The number of ADC counts that result from a 1.024V reading

SW_DATA_SOURCE_FRAMES_RUN_LSW(67)

The number of frames run since reset, least significant 16 bits

SW_DATA_SOURCE_FRAMES_RUN_MSW(68)

The number of frames run since reset, most significant 16 bits

SW_DATA_SOURCE_OVERRUN_FRAMES(69)

The number of frames that ran more than 1mS

SW_DATA_SOURCE_TEMPERATURE(70)

The internal core temperature expressed in 100ths deg C

SW_DATA_SOURCE_PACKETS_RECEIVED(71)

The number of incoming command packets that have been processed since reset (rolls over at 65535)

SW_DATA_SOURCE_ERRORS(72)

The number of incoming packets that have caused errors since reset (rolls over at 65535)

SW_DATA_SOURCE_FRAMES_DROPPED(73)

The number of times since reset that a frame ran so far behind that it crossed two subsequent 1ms boundaries, causing a permanent lost frame

SW_DATA_SOURCE_SYSTEM_UTILIZATION(74)

A number between 0 and 65535 that scales to the average length of pin processing frames between 0 and 1000mS

SW_DATA_SOURCE_VCC_mVOLTS(75)

The system source voltage in mV

SW_DATA_SOURCE_VBG_COUNTS_VS_VREF(76)

A/D conversion of VBG against VRef . Used for mfg calibration

SW_DATA_SOURCE_RESET_REGISTER(77)

Hardware dependent reset reason register contents

SW_DATA_SOURCE_LFSR(78)

A Linear FeedBack Shift register (32,7,5,3,2,1) based pseudo-random number generator

SW_DATA_SOURCE_PIN_0_MV(100)

The public data of Pin 0 expressed as mV. Only applicable to Analog Input mode
mode

SW_DATA_SOURCE_2HZ_SQUARE(164)

Square wave that alternates between 0 and 65535 every 256 frames

SW_DATA_SOURCE_2HZ_SAW(165)

Sawtooth wave that goes from 0 to 65535 to 0 every 512 frames

SW_DATA_SOURCE_1HZ_SQUARE(167)

Square wave that alternates between 0 and 65535 every 512 frames

SW_DATA_SOURCE_1HZ_SAW(168)

Sawtooth wave that goes from 0 to 65535 to 0 every 1024 frames

SW_DATA_SOURCE_2SEC_SQUARE(170)

Square wave that alternates between 0 and 65535 every 1024 frames

SW_DATA_SOURCE_2SEC_SAW(171)

Sawtooth wave that goes from 0 to 65535 to 0 every 2048 frames

SW_DATA_SOURCE_8SEC_SQUARE(173)

Square wave that alternates between 0 and 65535 every 4096 frames

SW_DATA_SOURCE_8SEC_SAW(174)

Sawtooth wave that goes from 0 to 65535 to 0 every 8192 frames

SW_DATA_SOURCE_65SEC_SQUARE(176)

Square wave that alternates between 0 and 65535 every 32768 frames

SW_DATA_SOURCE_65SEC_SAW(177)

Sawtooth wave that goes from 0 to 65535 to 0 every 65536 frames

Processed Input Pin Modes

The Processed Input Pin Mode system allows services to be applied to Serial Wombat inputs which inherit from it. These include Analog Input, Pulse Timer, Resistance Input, and UltraSonic Distance Sensor and will include others in the future. The result of the Processed Input system becomes a pin’s 16 bit public data, available for use by other pins.

This system allows various transformations and filters to be performed on incoming measurements within the Serial Wombat firmware using the Serial Wombat chip's cpu cycles. Since this class is processed every 1mS for each pin configured to an input class, it can do tasks like filtering or averaging much more quickly and consistently than could be achieved by sampling the value over I2C or UART and doing the computation on the host device. Minimum and Maximum measured values are also tracked for retrieval by the host

Additionally, this class is capable of limiting input (for example any value below 10000 is processed as 10000, and any value above 62331 is processed as 62331), scaling input (e.g. an expected input range of 3000 to 7000 is scaled linearly to the full Serial Wombat Range of 0 to 65535), mx+b linear transformations, exclusion of outlier data (e.g. any value over 50000 is ignored, and the previous valid measurement is substituted in its place).

Inputs can be inverted (scaled from 0-65535 to 65535-0 by substracting the raw value from 65535). This is useful for reversing the direction of things like analog measured potentiometers.

The final output of the SerialWombatAbstractProcessedInput operations can be queued in a User Memory Area queue on a periodic basis. This allows synchronous sampling and storage of input data for retrieval and processing by the host. This allows waveforms to be stored and processed. Sampling period is an enumerated type ranging from 1mS to 1024mS in power of 2 intervals. When multiple pins use the queue system with the same sampling period, all pins queue their data in the same frame, allowing further processing of channel differences on the host.

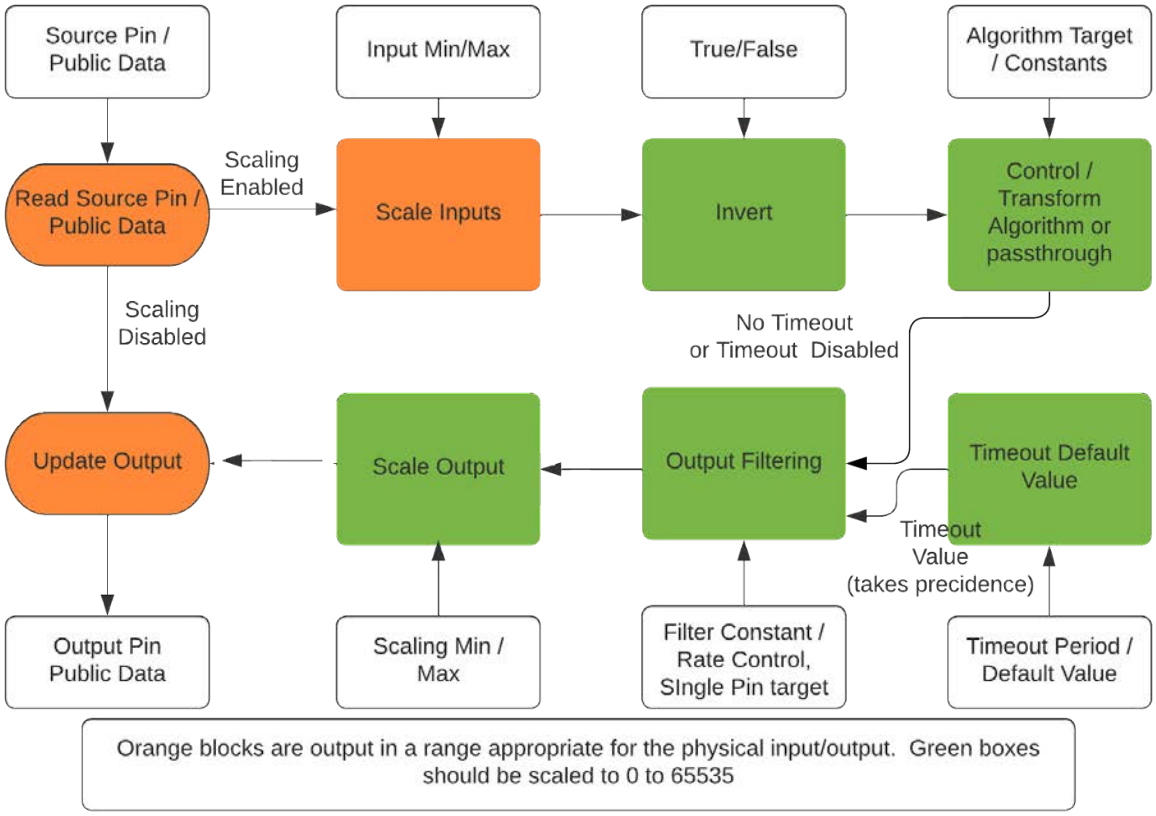
Data processing happens in the following order each 1mS for any enabled feature:

1. The pin mode measures the physical input
2. Any outlier values are excluded. if a value is excluded the last valid measured raw input is substituted in its place
3. Inversion of input (subtraction of value from 65535)
4. Transformation of output value (Scale of smaller input range (e.g. 8000-12000 to 0-65535) or mx+b linear transformation
5. Averaging and filtering of the result of prior steps and storage of averaged / filtered values for access by the host.
6. Selection of the result to be passed to the next steps. The unfiltered value, the averaged value, or the filtered value can be selected to be the pin's public data output
7. Updating the minimum and maximum recorded value for retreival by the host

8. Sampling the data into a queue in the user buffer
9. Placement of the value into the pin's 16-bit public data buffer for access by the host or other pin modes that react to a pin's public data buffer.

To use this class first configure the pin to its mode using the normal begin() call for that pin mode. Then call any configuration commands (writeInverted, writeTransformLinearMXB, etc) then call writeProcessedInputEnable(true) to enable processing.

Scaled Output Pin Modes



Servo output, PWM output, and other proportional output classes implement the Scaled Output set of services. Scaled Output provides control blocks for manipulating output based on input. Each pin's output block is separate from the others.

Scaled output system is designed to facilitate real time control of outputs based on configuration from the host without the need to issue additional commands after the initial configuration. The block also includes a timeout function which is capable of setting an output to predetermined value if the host does not reset a countdown timer within a specified number of mS. This allows a controlled shutdown if the host crashes, the data bus becomes inoperable, etc. Because the output block is serviced every 1mS, real time control can be achieved with higher performance than if control was performed over the data bus. This functionality also frees the host of the need to maintain timing sensitive communication with the Serial Wombat chip.

This block can limit output rate of change either by a limited amount of change per time, or by first-order filtering output changes. Rate limiting is useful to implement smooth motion over time (controlled within the Serial Wombat chip) such as a model railroad crossing gate attached to a servo. It also can prevent a current spike caused by requesting large changes in position at one

time. First order filtering is useful to change position rapidly at the beginning, but slow near the end to reduce impact speed.

The target output value can be provided by the host, or the Scaled Output block can be configured to get its target value from another pin or a public data source such as the Serial Wombat 18AB chip's internal temperature sensor or source voltage measurement. This capability to act on another pin's data would be useful for example if one wanted to control a 6 DOF / 6 servo robotic arm with 6 potentiometer outputs. The Serial Wombat chip could filter user inputs to provide smooth movement as well as scale the outputs so that the full range of potentiometer travel can be mapped to each joint's range of servo motion in degrees. The Arduino or other host could monitor the controls and potentially intervene if higher level logic deemed it necessary, but would be freed of the need to constantly poll the pots and update servo pulse values.

The Scaled Output block can also do simple real-time control of an output based on an input. For instance, a heater could be set to pwm at some duty cycle if an analog input dropped below a threshold, then shut off when it rose above some other higher threshold. This is hysteresis mode.

Another control method is Proportional/Integral/Derivative (PID) control. In this mode the host provides P I and D calibrations for the system, and specifies an input pin and target value. The output of the Scaled Output block is then controlled via PID to try and reach the target value. As an example, a motor's encoder output could be attached to a SerialWombatPulseInput pin configured to output the frequency of incoming pulses. The PID controller in the Scaled Output block could then vary the PWM driving a FET controlling the motor to keep the motor running at constant speed that adapts to changing motor load or source voltage. The PID controller requires that a positive output cause a positive input from the feedback system. If they are opposite then the invert function of the block can be used.

Scaling operations happen in the following sequence:

1. Read the source pin's or data source's public data (Note that the Host can also provide the input value by setting the source pin to the output pin and writing that pin's public data. In this case the output value of the pin will not be written to the pin's public data)
2. Scale the inputs from a specified Min/Max range to 0 to 65535
3. Invert if configured by subtracting the scaled value from 65535
4. Pass the input value to the specified control algorithm (PID, Hysteresis or PassThrough) to determine the output value
5. Check to see if a communication timeout has occurred if configured. If so, substitute the default output value
6. Perform output filtering if configured to smooth transitions in the output value
7. Scale the output value from 0-65535 to some other range if configured. This is useful for example if a servo is physically limited to a portion of its normal rotation.

8. Write the output data to the output pin's public data (unless the pin is configured to use its own public data as an input source)
9. Write the output data to the underlying pin mode (Servo, PWM, etc) so that the physical output is updated

Timing Resource Manager

The Serial Wombat 18AB chip is based on the PIC24FJ256GA702 microcontroller. This microcontroller has a limited number of internal resources which are useful for time related embedded systems functions such as PWM generation, pulse output, pulse input, and other similar tasks. There are 3 resources which are good for input or output, 3 which are good only for output, and 3 which are good only for input.

The Serial Wombat Firmware implements a “Timing Resource Manager”. This is firmware code that keeps track of which resources are being used, and which are free. When a pin mode (such as servo or pwm) wishes to use a hardware timing resource, a resource is requested from the Timing Resource Manager. If an appropriate resource is available, it is allocated to that pin for use. If no resource is available, the pin mode either fails to operate, or operation is degraded to using DMA based input / output, which samples at 57,600 Hz (17 uS resolution). Behavior for each pin mode is documented.

Some pin modes, such as Servo, request a resource, use it briefly, then release it. This is possible because typical servo output consists of a 500uS to 2500uS pulse which occurs about every 20mS. The precision of the pulse is important. The delay in between pulses typically is not. Therefore, the Servo pin mode can request a resource when it needs to generate a pulse, then release it when the pulse is complete. 8 pins can share the same resource if a 2500uS pulse is being generated on each.

Other pin modes, such as PWM, High Frequency Servo, and VGA output claim and hold a resource without releasing it unless told to by the host.

Users should call begin() (or attach() for servos) in an order which corresponds to the timing accuracy needed by that pin. For instance, a PWM driving a motor or generating an audible tone may require a high precision in duty cycle and/or frequency, and should be initialized first to ensure they get access to hardware timing resources. A PWM used to brighten or dim an LED as part of a user interface would have low precision requirements, and should be initialized later. SImilarly, servos in an aircraft which control flight surfaces would have high precision requirements. Servos which control accessories such as landing gear or bomb drop would have low precision requirements.

Hardware based timing typically requires less CPU time on the Serial Wombat chip than DMA based timing.

Error Handling

The Serial Wombat 18AB chip includes significant error checking on protocol requests from the host. Invalid configurations or other requests generate error codes for many scenarios. If the Serial Wombat chip determines a command is invalid it will return a packet that starts with ASCII ‘E’ followed by an error code. Many but not all of the Arduino/Python/C# interfaces will return this error code as a negative number. Defined error codes are listed at the end of this section.

The Arduino/Python/C# interfaces allow an error handler to be registered with a SerialWombatChip instance. This error handler can be used to help debug issues by dumping error codes to a debug output.

The public data SW_DATA_SOURCE_ERRORS increments each time a communication error is detected. A Serial Wombat pin can be made to pulse when a communication error occurs. This is useful when debugging.

The error codes listed below are decoded by the Serial Wombat Protocol Analyzer.

Serial Wombat Error Codes

SW_ERROR_UNNUMBERED_ERROR
(#32767)

SW_ERROR_PINS_MUST_BE_ON_SAME_PORT
(#1) Pins must be on the same microcontroller part (e.g. PORTA, PORTB, etc.). See datasheet of micro for port assignments.

SW_ERROR_ASCII_NUMBER_TOO_BIG_16
(#2) A number bigger than 65535 was provided to convert to a 16 bit value

SW_ERROR_UNKNOWN_PIN_MODE
(#3) A Pin mode was indicated that is not avaialble on this model or version of Serial Wombat chip

SW_ERROR_RESET_STRING_INCORRECT
(#4) A Packet starting with 'R' was received but didn't have the correct following bytes to cause a reset

SW_ERROR_INVALID_COMMAND
(#5) The first byte of a received packet does not correspond with a command supported by this model of Serial Wombat chip

SW_ERROR_INSUFFICIENT_SPACE

(#6) There was not sufficient space in the queue or user area to complete the command.

SW_ERROR_WUB_COUNT_GT_4
(#7) A count greater than 4 was provided as a number of bytes to write to count user buffer

SW_ERROR_WUB_INVALID_ADDRESS
(#8) An attempt to write to a user buffer address outside the user buffer was attempted.

SW_ERROR_WUB_CONTINUE_OUTOFBOUNDS
(#9) A call to Write User Buffer Continue would have written out of bounds.

SW_ERROR_RF_ODD_ADDRESS
(#10) Addresses Read From Flash must be even.

SW_ERROR_FLASH_WRITE_INVALID_ADDRESS
(#11) An attempt to write or erase flash was made to a protected or non-existant area

SW_ERROR_INVALID_PIN_COMMAND
(#12) The pin command 0xC1, 0xC2, etc is not suported by this pin mode (May vary by model)

SW_ERROR_PIN_CONFIG_WRONG_ORDER
(#13) The called pin command 0xC1, 0xC2 was called before other required prior commands (e.g. 0xC0)

SW_ERROR_WS2812_INDEX_GT_LEDS
(#14) The command references an index that is greater or equal to the number of leds

SW_ERROR_PIN_NOT_CAPABLE
(#15) The commanded pin does not have the hardware support to perform the commanded pin mode

SW_ERROR_HW_RESOURCE_IN_USE
(#16) The requested hardware or software resource in use has already been exclusively claimed by another pin

SW_ERROR_INVALID_PARAMETER_3
(#17) The pin configuration parameter in Byte 3 was invalid

SW_ERROR_INVALID_PARAMETER_4
(#18) The pin configuration parameter in Byte 4 was invalid

SW_ERROR_INVALID_PARAMETER_5
(#19) The pin configuration parameter in Byte 5 was invalid

SW_ERROR_INVALID_PARAMETER_6
(#20) The pin configuration parameter in Byte 6 was invalid

SW_ERROR_INVALID_PARAMETER_7
(#21) The pin configuration parameter in Byte 7 was invalid

SW_ERROR_PIN_NUMBER_TOO_HIGH
(#22) The pin number indicated was greater than the greatest available pin

SW_ERROR_PIN_IS_COMM_INTERFACE
(#23) The pin number indicated is currently being used for Serial Wombat protocol communications

SW_ERROR_ANALOG_CAL_WRONG_UNLOCK
(#24) The unlock value provided to write analog calibration was incorrect.

SW_ERROR_2ND_INF_WRONG_UNLOCK
(#25) The unlock value provided to enable the 2nd interface was incorrect.

SW_ERROR_2ND_INF_UNAVAILABLE
(#26) The 2nd interface hardware was not available to claim

SW_ERROR_UART_NOT_INITIALIZED
(#27) A UART operation was requested but the UART was not initialized

SW_ERROR_CMD_BYTE_1
(#28) Byte 1 of the command was invalid

SW_ERROR_CMD_BYTE_2
(#29) Byte 2 of the command was invalid

SW_ERROR_CMD_BYTE_3
(#30) Byte 3 of the command was invalid

SW_ERROR_CMD_BYTE_4
(#31) Byte 4 of the command was invalid

SW_ERROR_CMD_BYTE_5
(#32) Byte 5 of the command was invalid

SW_ERROR_CMD_BYTE_6
(#33) Byte 6 of the command was invalid

SW_ERROR_CMD_BYTE_7

(#34) Byte 7 of the command was invalid

SW_ERROR_CMD_UNSUPPORTED_BAUD_RATE
(#35) invalid baud rate enumeration

SW_ERROR_QUEUE_RESULT_INSUFFICIENT_USER_SPACE
(#36)

SW_ERROR_QUEUE_RESULT_UNALIGNED_ADDRESS
(#37)

SW_ERROR_QUEUE_RESULT_INVALID_QUEUE
(#38)

SW_ERROR_QUEUE_RESULT_FULL
(#39)

SW_ERROR_QUEUE_RESULT_EMPTY
(#40)

SW_ERROR_DATA_NOT_AVAILABLE
(#41)

SW_ERROR_TM1637_WRONG_MODE
(#42) The TM1637 pin is configured for the wrong TM1637 mode to process the command

SW_ERROR_RUB_INVALID_ADDRESS
(#43) An attempt to read user buffer address outside the user buffer was attempted.

SW_ERROR_UNKNOWN_OUTPUTSCALE_COMMAND
(#44) The command index for an output scaling command is not supported on this firmware

SW_ERROR_UNKNOWN_INPUT_PROCESS_COMMAND
(#45) The command index for an inputProcess command is not supported on this firmware

SW_ERROR_PULSE_ON_CHANGE_ENTRY_OUT_OF_RANGE
(#46) The pulse on change entry number exceeded the number of entries

SW_ERROR_PULSE_ON_CHANGE_UNKNOWN_MODE
(#47) The pulse on change Mode requested is unknown

SW_ERROR_LESS_THAN_8_BYTES_RETURNED
(#48) The Serial Wombat Chip returned less than 8 bytes (Used at host level, not firmware)

SW_ERROR_REENTRANCY_NOT_SUPPORTED
(#49) The library was used in an unsupported manner, such as calling a communication command from an interrupt when communication was in progress (Used at host level, not firmware)

Powerup Self-Configuration

The Serial Wombat 18AB chip is capable of capturing a sequence of commands and playing it back at powerup prior to any communication. This is useful for putting the Serial Wombat chip into a state with known outputs immediately after powerup or an unexpected reset. It also allows the Serial Wombat 18AB chip to be used in a stand-alone fashion for signal conversion tasks (e.g. analog signal to servo, RC receiver pulse to PWM, UART baud rate conversion, etc).

Up to 256 configuration packets can be stored. The number of packets generated from various library calls will vary. Assuming 2 packets per library call is a good estimate. Exact numbers for a given configuration can be measured using the Serial Wombat Protocol Analyzer.

Three library functions are used to store commands. startStartupCommandCapture() begins the capture process. stopStartupCommandCapture() stops the process, and writeStartupCommandCapture() initiates a write of the captured commands to flash memory. The write command may take 10s or 100s of milliseconds to complete.

Packets are stored to the Serial Wombat User Ram area during capture prior to writing. The top 3072 bytes of Serial Wombat User Ram (index 5120 and up) are used for capturing. This area should not be written to by the host or by pin mode state machines during this time. Doing so will result in a corrupt startup sequence being written, with unpredictable results at the next powerup.

It is acceptable for a program to call these three commands every time it runs. When writeStartupCommandCapture() is called the existing stored commands are examined against the captured commands. No flash write occurs if they are identical.

Warning: There may be ways that the Powerup Self-Configuration function could cause the Serial Wombat chip to be unusable if an unacceptable sequence of commands was replayed at powerup. The user should consider the results of a startup sequence before programming it. Use of a socket for the Serial Wombat chip when developing applications using Power Self-Configuration is recommended

The following video shows an example of using Powerup Self-Configuration to allow the Serial Wombat 18AB chip to use an Ammeter as a room-temperature indicator.

Simultaneous UART and I2C interfacing from 2 Hosts

The Serial Wombat 18AB chip can be controlled via UART or I2C. When controlling the Serial Wombat chip over I2C it is possible to enable the UART interface on pins 7 and 9 to process commands over both UART and I2C. A command sent to one interface will be responded to on that interface. Commands can be sent to both interfaces simultaneously, and the correct response will be sent to each.

This functionality allows easy monitoring and modification of the Serial Wombat operation from a PC using the Serial Wombat Panel application over UART while the chip is interacting with an Arduino or Micropython embedded host over I2C.

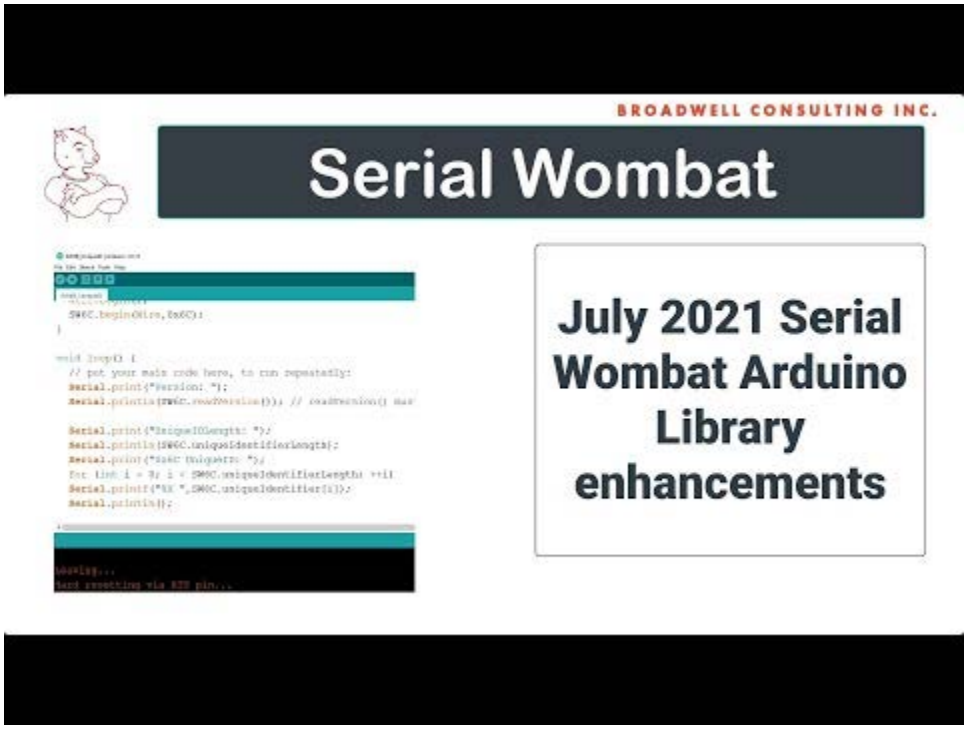
In order to enable this functionality the host communicating with the Serial Wombat chip over I2C calls the enable2ndCommandInterface method of the SerialWombatChip class

Sleep Mode

Sleep mode is not currently implemented in the Serial Wombat 18AB firmware.

Unique Identifier

Each Serial Wombat 18AB chip has a unique, unchangeable identifier programmed into the microcontroller when it is manufactured by Microchip. A demonstration of this capability is shown in this video:



https://youtu.be/IHTcKyXT_2Q

Serial Wombat 18AB Temperature Sensor

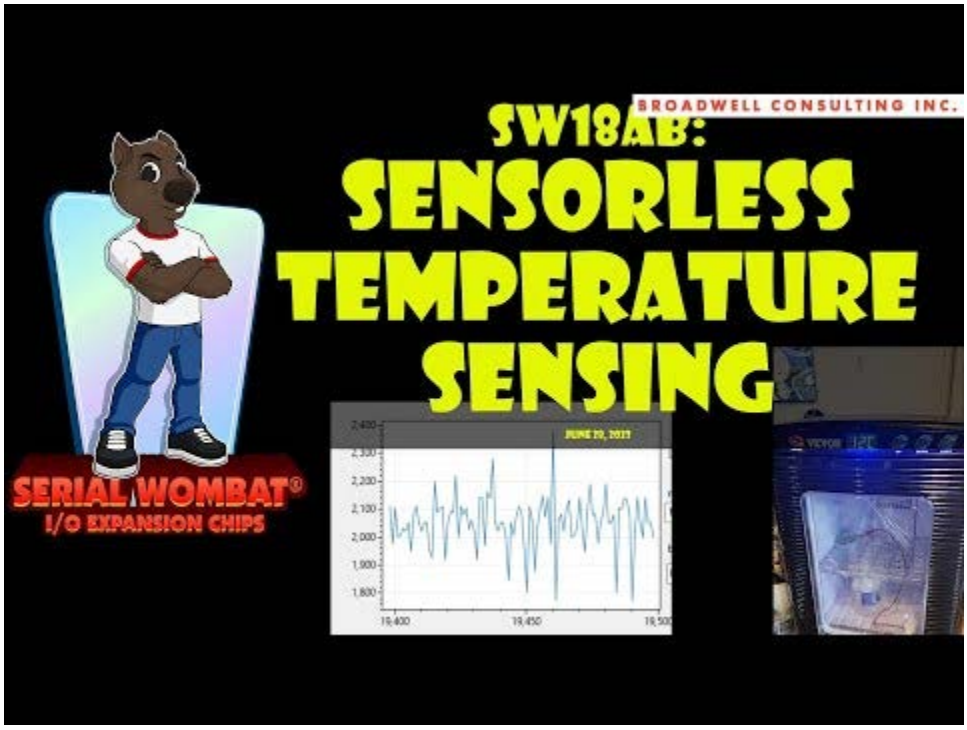
The Serial Wombat's base PIC24FJ256GA702 microcontroller includes a low accuracy temperature sensor based on 3 internal diodes. This sensor can be accessed by reading the Public Data Source associated with the temperature sensor.

The temperature sensor has good linearity over 0 to 55 degrees C or more. Therefore it is possible for the user to greatly improve the accuracy by measuring it's output at two known temperatures and creating an mX+b correction on the host side.

Serial Wombat Red Label chips are much more accurate around room temperature, as the internal voltage reference, current source and temperature are compared against high accuracy references during programming. The Serial Wombat Red Label chips use a single temperature point calibration as an offset. Users wishing to measure wide temperature ranges may still wish to do a two point calibration.

See this video for a tutorial:

https://youtu.be/Ab-H2pE9ZZk



Serial Wombat 18AB User RAM Buffer

Each pin in the Serial Wombat 18AB firmware is allocated a static set of bytes to use for its pin mode state machine. However, some pin modes require more RAM than is allocated by default. Examples include WS2812, VGA, and software UART pin modes.

The Serial Wombat 18AB firmware V2.1.0 allocates 8192 bytes of RAM to an array called the User RAM Buffer. This area is used to provide additional RAM to pin modes as needed. The User is responsible for allocating this RAM in a way that doesn't result in multiple pins using the same RAM.

This RAM can also be used as volatile storage for the host.

Serial Wombat 18AB User RAM Buffer Queues

Some pin modes that use the User Ram Buffer store data in queues. In most cases it is up to the User to initialize those queues before calling the begin() function for a pin mode that uses that queue. A Serial Wombat Queue is a class defined in the libraries. On Arduino this class inherits from Stream so it can be used with any code which expects a stream interface.

It is possible for two pins to utilize the same queue. For instance, one could set up a software UART which received data into the queue at one baud rate, then a second software UART that transmitted any data in that queue at a different baud rate.

At present two queue types are available. One is a traditional queue with moving head and tail pointers. It uses 8 bytes of RAM, plus however many bytes are allocated to the queue.

A second type of queue fills its data area with data, then shifts out the oldest data to make room for new data. In this way, the data remains stored in indexed order based on First In First Out. This can be useful for making a queue which is easily transferred internally to an LCD or other similar output.

Serial Wombat 18AB Firmware Structure

This section is background information. Knowledge of the firmware structure may be helpfu, but is not necessary for use.

The Serial Wombat 18AB firmware runs on the PIC24FJ256GA702 microcontroller. It is designed for the free version of the XC16 compiler, and the MPLAB X development environment.

A video that goes over the Serial Wombat Firmware design and how to modify it is available here:

https://youtu.be/PNPlAaIrR1o

You can compile the firmware yourself and program chips using a PICKIT4 or similar programming device, or you can buy preprogrammed kits from Broadwell Consulting Inc at https://www.SerialWombat.com .

The Serial Wombat binary image / Hex File is made up of two separate projects: A bootloader project and a Serial Wombat firmware project.

Executive Structure

The Serial Wombat firmware is a foreground / background loop system. Important hardware based events and communications Receive and Transmit to/from queues is done using interrupts.

The main loop runs a loop with a foreground subroutine that is run every 1 mS based on a flag which is set in a 1mS hardware timer. In Between runs of the foreground subroutine the communication receive queue is checked to see if a new command from the host is ready to be processed. If so, it is processed in its entirety and a response is generated and put into the transmit queue. It is possible for the start of the foreground subroutine to be delayed by some microseconds by the communication processing routine.

The main job of the foreground subroutine is to service state machines for the Serial Wombat pins. Each pin has its own state machine and memory area. Each pin's state machine is serviced every 1 mS by the executive. Actual time between servicings will vary due to execution time variation. For instance, one call may be 1100 uS after the previous, then the next call 800 uS after that. But over time it will average out to 1 mS.

The Serial Wombat 18AB firmware relies heavily on 4 DMA channels, one for reading PORTA, one for writing PORTA, one for Reading PORTB and one for writing PORTB. These DMAs are triggered by a 57600 Hz timer interrupt, and copy to or from four 128-entry, 16 bit wide circular buffers. Many 18AB pin modes read or write to these buffers every 1ms. Each 1 ms the pin mode reads new data read into the buffer since the prior 1ms call, or writes data to the outgoing circular buffer until it is full. In this way a 1mS call can generate or process wave forms that happen at 57600 Hz. It is vital that the SW18AB executive process the 1mS state machines on time to prevent overflow or underflow of the DMA channels.

The Serial Wombat 4A/4B firmwares can run in any combination of pin modes without concern for processor throughput.

The Serial Wombat 18AB chip can in some cases have pin modes assigned to it in ways that overload the processor, causing unreliable pin mode operation. This is not a concern for most users, but can be an issue when many pins are assigned to pin modes that require generation or inspection of DMA data, for example Software UART modes, or Quadrature encoder mode in high performance (DMA) mode. Multiple different diagnostics are available for monitoring processor loading.

Pin State Machines

Each pin has a limited, pre-allocated amount of memory allocated to it. This memory is used to store the current pin mode choice, 16 bits of public data, and some private data used to configure or operate the state machine.

A pin is configured to a state machine by CONFIGURE_CHANNEL_MODE command. This command includes the pin number to be configured, the mode that the pin is being commanded to, and an index indicating the meaning of bytes in the configuration packet. Many pin modes can be configured with a single CONFIGURE_CHANNEL_MODE packet. More complicated modes may require multiple packets, sent in a specific order.

For pin modes that take data from the host (Such as I2C -> UART TX on the SW4B) the CONFIGURE_CHANNEL_MODE commands are also used to load this data during operation.

For pin modes that generate data for the host (Such as the Pulse Width timer mode) the CONFIGURE_CHANNEL_MODE commands can be used to retrieve the various different data made available by that mode.

Each Pin State machine has an init function, a process function, and a structure type which defines the state machine's data organization. The init function is called whenever a CONFIGURE_CHANNEL_MODE command is sent by the host. The init function processes the command, configures the state machine or Serial Wombat hardware as required, and generates a response as required. Some init responses simply leave the echo default response unchanged.

Once a pin has been set to a mode, the process function is called every 1mS by the executive. This is where real-time processing of the pin's state machine happens.

Each pin has a fixed amount of memory allocated to it. There is an array of pin_register_t unions declared with at least as many elements as there are available state machine pins on the Serial Wombat chip.

The size of pin_register_t varies by model to allow more powerful chips to allocate more ram to each state machine. The pin_register_t.generic member is a structure that contains some number of general-purpose bytes that is consistent for all pin modes on that family of models, followed by the 16-bit public data for that statemachine, followed by an 8-bit mode byte.

On models with strong indexed addressing capability such as the PIC24FJ256GA702 based Serial Wombat 18AB chip, iteration through the pins is achieved by a single pointer, CurrentPinRegister, which is incremented prior to each process call to point to the pin currently being serviced. The variable CurrentPin is updated to be the pin number currently being serviced. Similarly, the pointer and index are updated prior to init calls.

On models with weak indexed addressing capability such as the PIC16F15214 based Serial Wombat 4 series, the array element is copied to a buffer of type pin_register_t prior to pin process execution. The pin mode then executes against the fixed addresses of the buffered values. After processing is complete, the buffer is copied back to the array. This has processing time cost to do the copies, but greatly reduces the code space required for each pin mode,

allowing much more functionality within the limited flash space of the chip. For these chips, CurrentPinRegister becomes a #define which defines CurrentPinRegister as the address of the buffer.

When a pin state machine needs to access data which is defined the same way across all state machines such as the 16-bit public data or pin mode value it accesses it using the pin_register_t definition:

switch(CurrentPinRegister->generic.mode)

When accessing the pin-mode specific area of the pin_register_t element the CurrentPinRegister is recast as a pointer to the structure type defined in the pin mode. It is important that the structure not define variables that take up more space than is allocated for pin-mode specific data.

Serial Wombat 18AB Throughput Management

The Serial Wombat 18AB chip is firmware running on a 32MHz 16-bit microcontroller. As such, it has a finite amount of processing power. Some use cases may be limited by the amount of processing power (throughput) available when running many processor-intensive pin modes.

The Serial Wombat executive runs the state machine for all 20 pins every 1mS. This is called a 1mS Frame. It is essential that each frame complete in 1mS or less. For some pin modes, such as digital I/O or Analog input, very little processing is required. Some other pin modes such as PWM depend on whether the PWM signal is being generated in hardware or in software via DMA. A hardware based PWM takes up very little processing power, but a software based PWM takes up significantly more. Eventually this guide will have an estimate of how much processing power each pin mode takes up.

The Serial Wombat chip has internal tracking metrics to allow verification that the current configuration is not overloading the chip. The public data SW_DATA_SOURCE_OVERRUN_FRAMES increments any time the processing of a frame takes more than 1mS and delays the beginning of the next frame. This value should always be 0. If this value is incrementing, then real-time deadlines for pin-mode operation may be missed, causing malfunctions.

The SW_DATA_SOURCE_SYSTEM_UTILIZATION provides a constantly updating value of proportion of the frame being used, scaled from 0 to 65535 . This value can be read by the host, or output as a PWM to be measured by a volt meter or other means.

The Frame Timer Pin Mode can be used to view the Serial Wombat 18AB throughput level externally. It goes high at the beginning of each frame, and low after all pin state machines have been serviced in that 1mS frame

The Throughput Consumer Pin Mode can be used during testing to stress the system by increasing the throughput load on the Serial Wombat chip. There is no reason to do this in production.

Firmware Updates (Bootloader)

The Serial Wombat 18AB chip is programmed with a bootloader program which allows loading of new firmware versions over I2C or UART. Bootloading of the latest firmware can be done through an Arduino sketch included in the arduino examples (a relatively high memory part such as an ESP8266 is required - an Uno doesn't have enough flash to hold the image).

Bootloading can also be done using the WombatPanel application for windows. Hex images are available here:
https://github.com/BroadwellConsultingInc/SerialWombat/tree/main/SerialWombat18A_18B/releases

A python/micropython script will be available in the future.

Video Tutorials are available for updating over UART:
https://youtu.be/7UIp910sPS4

And I2C:
https://youtu.be/q7ls-lMaL80

Serial Wombat Panel Application

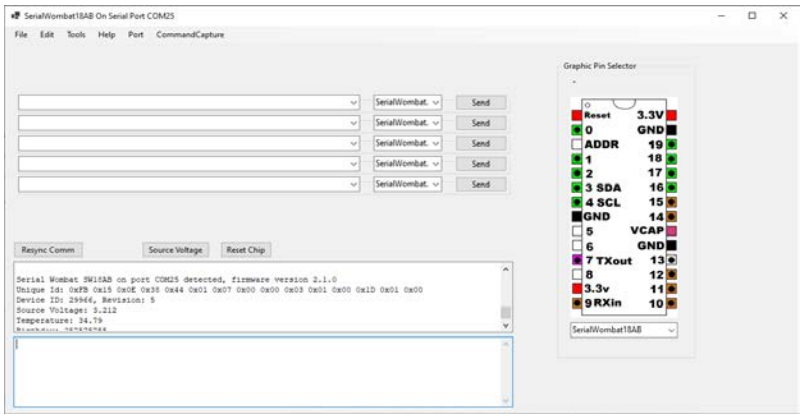
The Serial Wombat C# library includes a sample application called Serial Wombat Panel Application. This application uses .Net Windows Forms for its GUI and therefore is only compatible with Windows.

The Serial Wombat Panel Application provides an easy way to experiment with Serial Wombat 18AB features. The Serial Wombat Panel application is designed to interface to a Serial Wombat Chip over UART. It is also possible to interface to a Serial Wombat Chip over I2C if a UART to I2C bridge program is used on an Arduino or Micropython board.

The Serial Wombat Panel Application can be used to help debug Serial Wombat applications running over I2C by simultaneously connecting to the UART. See Simultaneous UART and I2C interfacing from 2 Hosts .

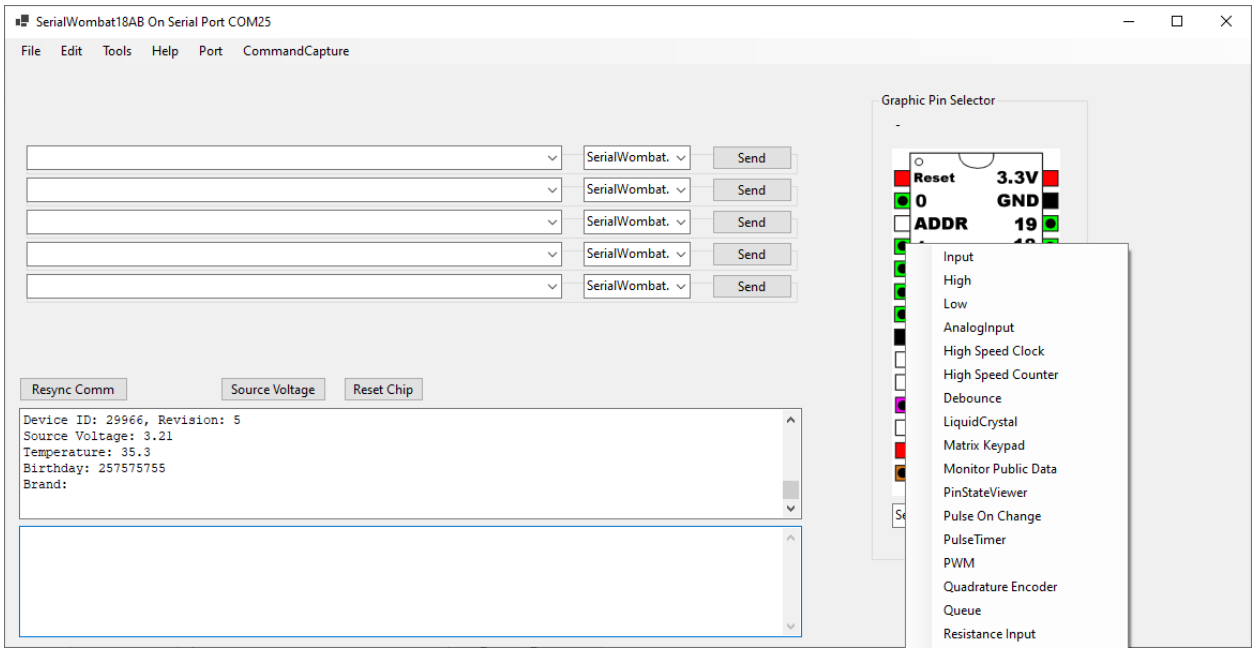
Launch the application either through Visual Studio or by double clicking the .exe file in the SerialWombatCsharpLib\WombatPanelWindowsForms\bin\Debug\net6.0-windows\WombatPanelWindowsForms.exe
Location.

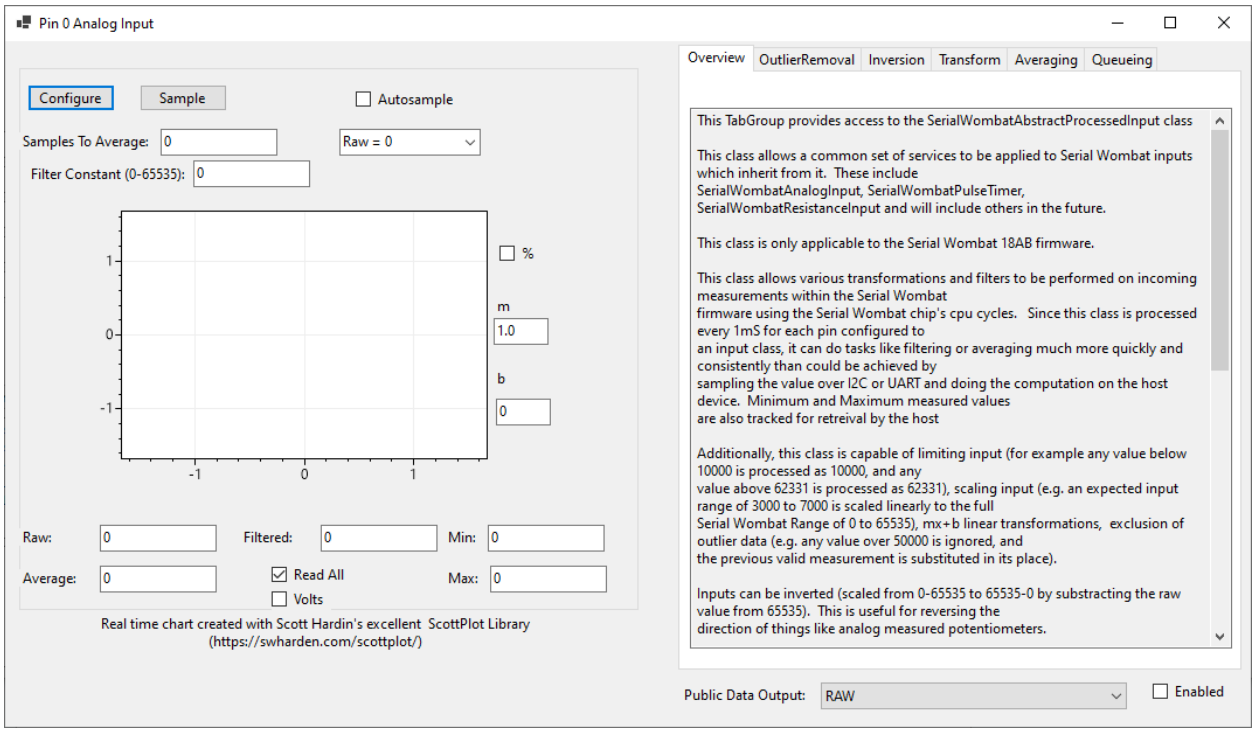
Use the Port…Open Serial menu item to connect to the Serial Wombat chip.



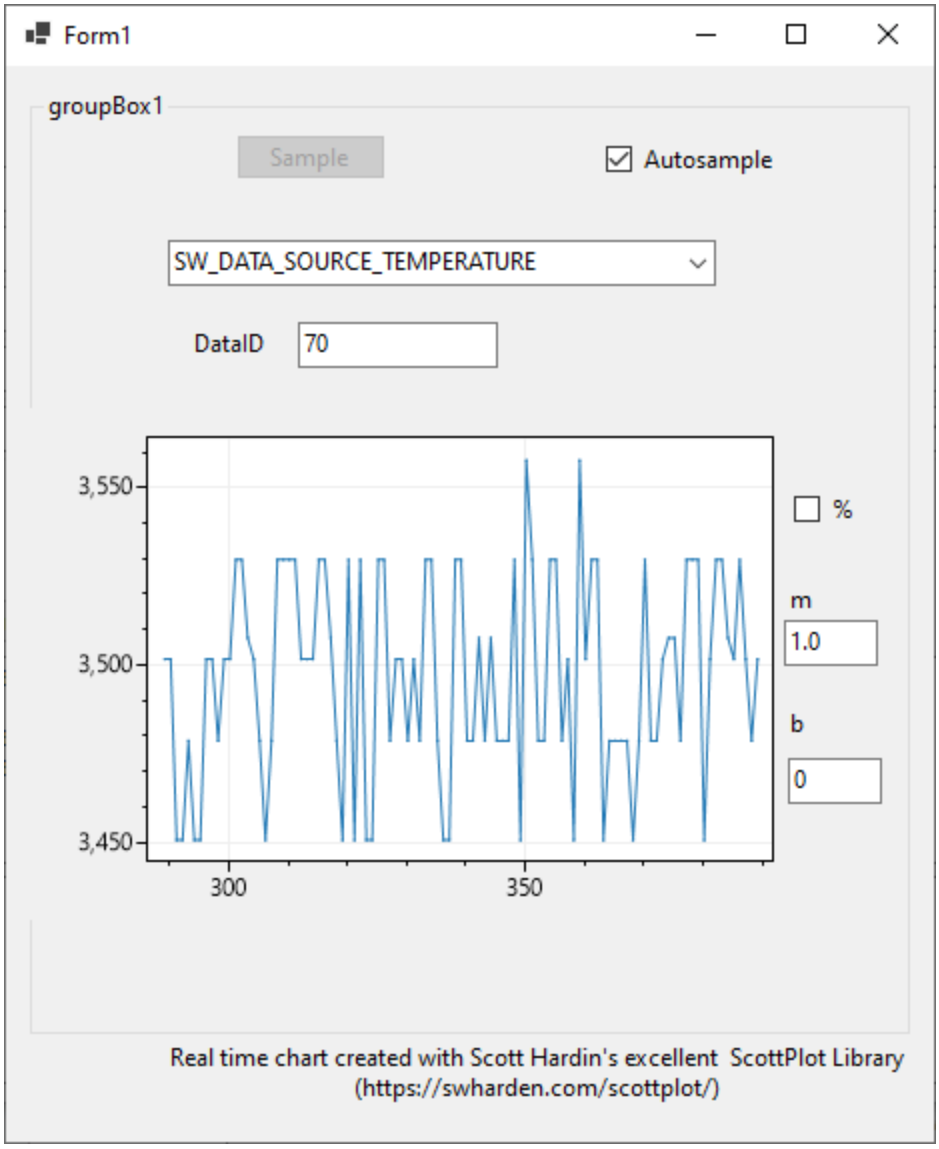
A successful connection will result in a reading of the Serial Wombat chip's firmware version and other information.

Pins can be configured by right clicking them and selecting the desired pin mode:





The public data of a pin or public data source can be monitored by right clicking a pin and selecting Monitor Public Data. Clicking the Autosample box will cause continuous requests to be sent for that piece of data.



An introduction to the Serial Wombat Panel Application is available in this video:
https://youtu.be/RgrjuJcJMmM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SERIAL WOMBAT 18AB
C#.NET CORE
LIBRARY BETA

Protocol Analyzer

A protocol analyzer is available to monitor and decode Serial Wombat commands sent over an I2C or UART bus. This analyzer runs on top of the Saleae Logic software package and is available for download through that application. This tool can be useful in debugging projects that include the Serial Wombat 18AB chip.

A video is available here:

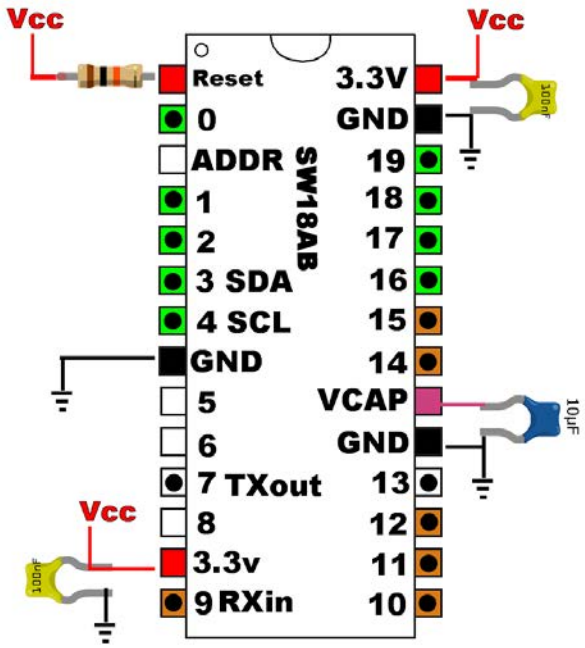
https://youtu.be/cL7kUm9qjvU

Troubleshooting

Step 1: Check the basics

General Stuff:

- Make sure your chip has a stable, in-range power supply and that the included capacitors are attached across the power and ground pins. If you can, verify power voltage using a multimeter
- Make sure your chip is connected properly. Ensure that the chip is in the proper orientation (power pins are near the notch) and that both100uF capacitors are connected across Vdd and GND.
- Make sure the 10k reset resistor is providing voltage to the reset pin (measure it with a multimeter)
- Make sure the 10uF capacitor is connecting the Vcap pin to ground.



- Disconnect any loads (such as motors, servos, or relays) from your circuit. Frequently these devices can sufficiently disrupt the power supply such that the Serial Wombat 4B chip's internal low-voltage-reset circuit triggers. It is suggested that inductive loads not be driven directly from the same supply driving logic portions of the circuit.

- If you're using a decal on the Serial Wombat chip, is it oriented in the correct direction? Make sure the black notch at one end of the decal matches up with the black dot on the chip

- Make sure you're using the latest Arduino / C# / Python library. It's possible your issue is fixed in a newer version than you have

- In Arduino, consider registering the default error handler. This provides helpful information (particularly on the 18AB) about configuration errors.

I2C related Stuff

- Make sure you're talking to the correct address. The address the Serial Wombat 18AB chip responds to depends on the configuration of the address pin (see Circuit Construction)
- If connected using I2C, make sure you have pull up resistors on SCL and SDA (don't rely on internal pull ups on your chip, they're typically out of spec for I2C).

- Make sure your SDA line from the Arduino or other host is attached to the SDA line on the Serial Wombat Chip. Same for SCL. Did you accidentally cross them?
- Make sure you have the correct pins assigned on your Arduino or MicroPython board. The begin or initialization call for I2C communications allows you to specify which pins are being used on many platforms. The examples included with the library may assume different I2C pins on the host than what you are using due to variation between boards.

- Does the Serial Wombat chip finder sketch in the Arduino Examples / Serial Wombat directory find the Serial Wombat chip? This should always work if your hardware is setup correctly

- In your sketch, do you call begin on Wire then on the Serial Wombat chip?

- Can you verify proper I2C traffic operation using a Logic analyzer? See this video for a cheap way to do this. https://youtu.be/cL7kUm9qjvU

UART Related Stuff

- Make sure you are connected to the correct UART port.
- Make sure that the ADDR pin of the Serial Wombat 18AB chip is grounded. It needs to be grounded at powerup. Grounding it after power is applied will result in the chip operating in I2C mode
- Make sure you are opening the port using 115200 / 8 / N / 1 / No Flow Control settings
- Double check that your RX and TX connections are correct. Try swapping them
- If connecting from an Arduino or MicroPython board ensure that you're connecting the proper pins from the board to the Serial Wombat Chip. Some boards require the UART pins to be declared in the initialization or begin of the UART.

Step 2: Check the YouTube video and comments

Go to the Broadwell Consulting Inc. YouTube channel and take a look at the Serial Wombat playlist. Watch the video for the task you're trying to achieve, and check the comments to see if any other users have asked a question about your issue.
If not, then leave a comment with your question on the video that best matches what you're trying to do.

Additional Resources:

YouTube

The Broadwell Consulting Inc. YouTube Channel has many helpful tutorial Videos which walk through how to use the various Serial Wombat chip pin modes and features.

Arduino Library

The Serial Wombat Arduino Library supports the Serial Wombat 4B and Serial Wombat 18AB chips.

The library documentation is available on github.io . Click on the classes tab to see documentation and interfaces for individual pin modes.

The Serial Wombat Arduino Library is available on GitHub . This is a good place to log an issue if you find a bug in the Arduino library or want to request new features. Please don't use the issue system for support requests.

Serial Wombat 18AB firmware

The Serial Wombat 18AB firmware documentation and protocol documentation are available on github.io .

The Serial Wombat 18AB firmware source code is available on GitHub.

Support and Technical Assistance

If the above troubleshooting and guides don't solve your problem, contact Broadwell Consulting at help@serialwombat.com for support. Support requests sent in over email may take a couple of days to respond. Priority is given to questions asked in public forums such as on the YouTube channel so that others can benefit from the answers. Please include the results of the troubleshooting steps above in your support request. Otherwise, the first response may be a request for the results of those steps, slowing down the process.

Revision History

Version	Changes
V2.1.0_A	Initial Version