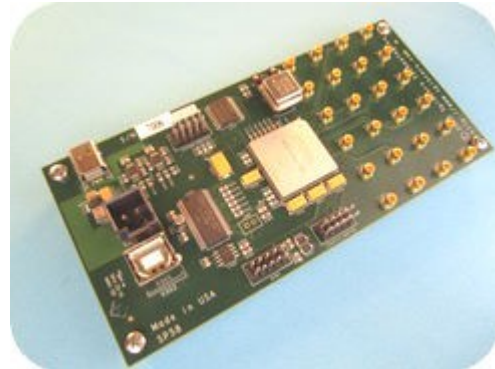
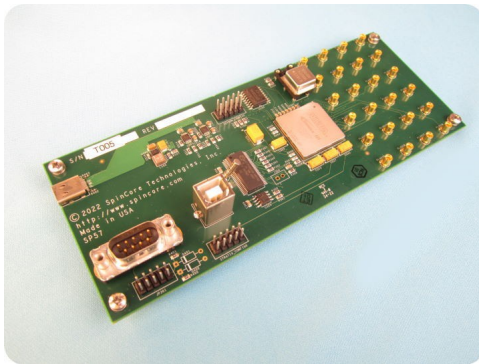




PulseBlasterESR-PRO-500-USB-MX™

(SP57, SP58)

Owner's Manual



SpinCore Technologies, Inc.
<http://www.spincore.com>

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SpinCore Technologies, Inc.**

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I. Introduction

Product Overview

The PulseBlasterESR-PRO-500-USB-MX™ is a high-speed, intelligent pulse/pattern/delay generator designed for outputting precisely timed TTL patterns. The intelligence of the PulseBlasterESR-PRO-500-USB-MX comes from an embedded microprogrammed controller core nicknamed the PulseBlaster™. The controller is able to execute instructions that allow it to control program flow much like a general purpose microcontroller.

The PulseBlasterESR-PRO-500-USB-MX's microprogrammed controller core is different from the general-purpose microcontroller in that it contains a set of highly optimized instructions developed specifically for timing and control applications. A unique and distinguishing feature of the PulseBlasterESR-PRO-500-USB-MX processor is that the execution time for instructions is user programmable. This feature makes the PulseBlasterESR-PRO-500-USB-MX processor capable of executing complex timing patterns at greatly varying update rates, ranging from nanoseconds to months, with a constant setting accuracy of just one clock period.

The PulseBlasterESR-PRO-500-USB-MX runs at 500 MHz. The SP57 measures 7.000 x 2.782 in (17.78 x 7.066 cm) and the SP58 measures 5.800 x 2.782 in (14.73 x 7.066 cm), offering unparalleled size to performance ratio. All 21 individually controlled digital output lines are routed to 50 ohm impedance matched micro-miniature coaxial (MMCX) connectors. The shortest pulse can be as short as one clock period (2 ns) and the duration per instruction can range from 12 ns to 104 days. Up to 4096 instructions can be programmed onto the board. The board offers hardware pins to externally trigger and reset the board.

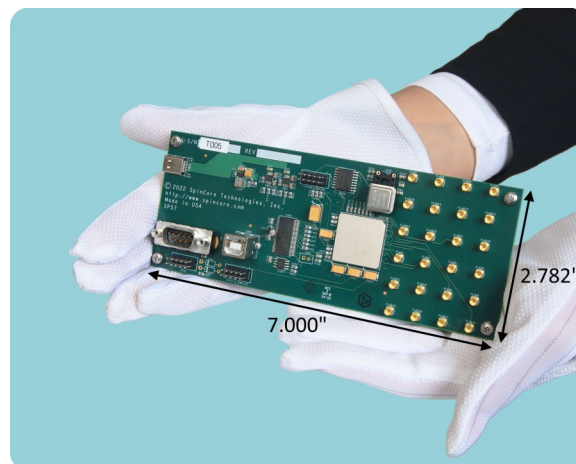


Figure 1: Image of SP57 with dimensions

Board Architecture

Block Diagram

Figure 2 presents the general architecture of the PulseBlasterESR-PRO-500-USB-MX system. The major building blocks are the static random access memory (SRAM), the PulseBlaster core, the integrated bus controller (IBC), the counter, and the output buffers. The entire logic design, including the SRAM memory and output buffers, is contained on a single silicon chip, making it a System-on-a-Chip design. User control to the system is provided through the IBC over the universal serial bus (USB).

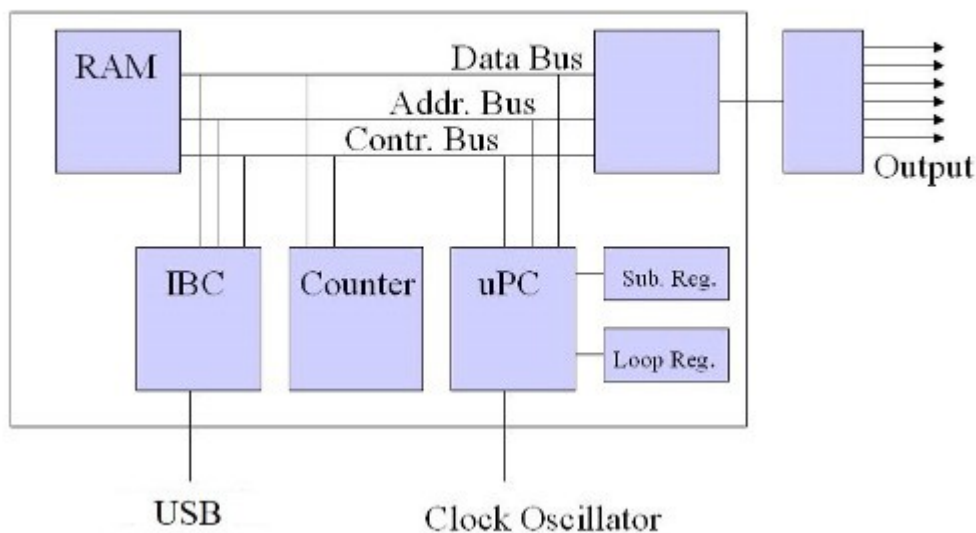


Figure 2: PulseBlasterESR-PRO-500-USB-MX Board Architecture. The clock oscillator signal is derived from an on-chip PLL circuit typically using a 50 MHz on-board reference clock.

Key Features

Output Signals

The PulseBlasterESR-PRO-500-USB-MX allows for 21 digital output signal lines, which are all routed to MMCX connectors. The output signals are impedance matched to 50 ohm.

The 21 individually controlled digital output bits comply with the 3.3V TTL-levels' standard, and are capable of delivering ± 25 mA per bit/channel. Keep in mind that this is sufficient to provide a signal to a 132 ohm load, but if more current is necessary beyond this, the individual bits/channels can be driven in parallel.

Timing Characteristics

The PulseBlaster core's timing controller accepts an external (on-board) crystal oscillator of 50 MHz. The input frequency is internally multiplied. The PulseBlasterESR-PRO-500-USB-MX is available with 500 MHz internal clock frequency. The innovative architecture of the timing controller allows the processing of either simple timing instructions (with delays of up to 2^{32} clock cycles or 8.59 s at 500 MHz), or double-length timing instructions (up to 2^{52} clock cycles long – over 100 days at 500 MHz!). Regardless of the type of timing instruction, the timing resolution remains constant for any delay – just one clock period (e.g., 2 ns at 500 MHz).

The PulseBlaster core-timing controller has a very short minimum instruction time – only six clock periods. This translates to a 12 ns machine instruction time at 500 MHz. The PulseBlasterESR-PRO-500-USB-MX is also capable of generating pulses on all outputs of lengths down to one clock cycle. For more information on this feature, please see the [Short Pulse Feature](#) section in Appendix I.

Instruction Set

The PulseBlaster core features a set of instructions for creating highly flexible pulse program flow control. The micro-programmed controller allows for programs to include branches, subroutines, and loops at up to 8 nested levels – all this to assist the user in creating dense pulse programs that cycle through repetitious events, especially useful in numerous multidimensional spectroscopy and imaging applications.

External Triggering

The PulseBlasterESR-PRO-500-USB-MX can be triggered and/or reset externally via dedicated hardware lines. These lines combine the convenience of triggering (e.g., in cardiac gating) with the safety of the "stop/reset" line (firmware-dependent).

Status Readback

The status of the pulse program can be read in hardware or software. The hardware status output signals consist of four insulation-displacement contact (IDC) connectors. The SP57 board has four DB9 connector pins for the status output in addition to the IDC connectors. The same output can be read through software using C. See Section IV (Connector Information for PulseBlasterESR-PRO-500-USB-MX, page 20) for more detail about the hardware lines and Section III (Using C Functions to Program the PulseBlasterESR-PRO-500-USB-MX, page 16) for more detail about the C function `pb_read_status()`.

Summary

The PulseBlasterESR-PRO-500-USB-MX is a versatile, high-performance pulse/pattern TTL signal generator operating at speeds of 500 MHz and capable of generating pulses ranging from 2 ns to 104 days per instruction at delays/intervals ranging from 12 ns to 8.59 s per instruction (using a 500 MHz clock signal). It is connected via USB port and can accommodate pulse programs with highly flexible control commands of up to 4096 instruction words. Its high-current output logic bits are individually controlled with an unterminated output voltage of 3.3 V.

Specifications

TTL Specifications

- 21 individually controlled digital output lines (LVTTTL levels, 3.3 V logical “one” unterminated)
- 24 MMCX connectors, 21 of which are individually controlled output channels
- Variable pulses/delays for every TTL line
- 25 mA output current per TTL line

Pulse Parameters (using 500 MHz clock frequency)

- 2 ns shortest pulse
- 12 ns shortest interval
- 104 days longest pulse/interval (using the long delay instruction)
- 2 ns pulse/interval resolution
- 4096 instructions
- External triggering and reset – 3.3V LVTTTL levels

Pulse Program Control Flow (Common)

- Loops, nested 8 levels deep
- 20 bit loop counters (max. 1,048,576 repetitions)
- Subroutines, nested 8 levels deep
- Wait for trigger – 8 clock cycle latency (16ns at 500 MHz), adjustable to 0.89 seconds in duration
- 15 MHz max. re-triggering frequency

II. Installation

Installing the PulseBlasterESR-PRO-500-USB-MX

Whenever installing or uninstalling the PulseBlasterESR-PRO-500-USB-MX, always have it disconnected from the computer initially. [Uninstall](#) any previous version of SpinAPI.

1. [Install](#) the latest version of SpinAPI found at: <http://www.spincore.com/support/spinapi/>.
 - SpinAPI is a custom Application Programming Interface developed by SpinCore Technologies, Inc. for use with the PulseBlasterESR-PRO-500-USB-MX and most of SpinCore's other products. It can be utilized using C/C++ or graphically using the options in the next section below. The API will also install the necessary drivers.
2. Shut down the computer, unplug the power cord.
3. Connect the PulseBlasterESR-PRO-500-USB-MX to the computer.
 - a) Plug a USB-B cable into the PulseBlasterESR-PRO-500-USB-MX and the other end of the USB cable into the host computer. Be sure to support the board on the opposite side of the USB-B connector to prevent bending of the board when the connection is being made.
4. Power the PulseBlasterESR-PRO-500-USB-MX board using the provided USB C power charger and provided USB C to USB C cable.
 - a) Tested with Anker model A2149 USB C power charger and Anker model A8757 USB C to USB C cable
5. Plug the PC power cord back in, turn on the computer and follow the installation prompts if prompted.
6. The simplest way to test whether the device has been installed properly and can be controlled as intended is to run a simple test program. These example files can be found in the SpinAPI package.
 - a) To open the SpinAPI package on a Windows 10 PC, simply click the Window Start icon, and scroll down to find and open the "SpinCore" folder. Example .exe files and their C source code can be found in the folder /SpinAPI/examples. From there, you may select the "PulseBlasterESR-PRO" folder and run the .exe programs to test your PulseBlaster.

III. Programming the PulseBlasterESR-PRO-500-USB-MX

SpinCore Technologies Inc. is dedicated to providing an easy and efficient method of programming your board. Various control methods available are detailed below, making PulseBlaster products flexible for any number of applications.

The PulseBlaster Interpreter

The PulseBlasterESR-PRO-500-USB-MX can be programmed using *PulseBlaster Interpreter*, which is a free programming utility provided by SpinCore for writing pulse programs. This easy-to-use editor allows you to create, edit, save, and run your pulse sequence. Figure 3, below, shows the PulseBlaster Interpreter being used with an example program.

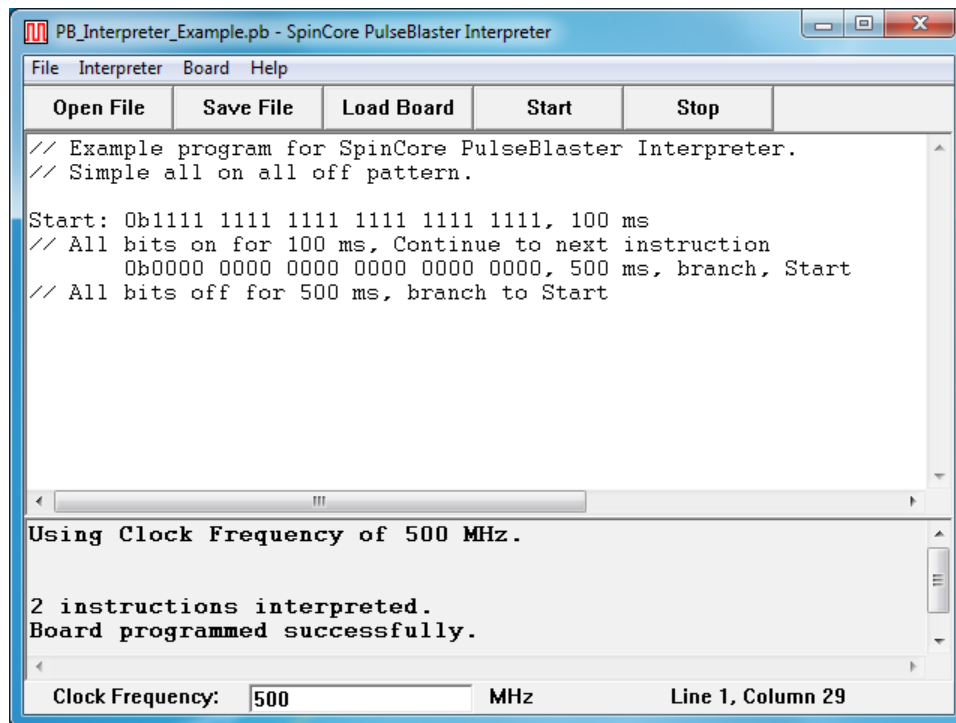


Figure 3: Graphical Interface of PulseBlaster Interpreter. The example shown creates a pulse that toggles all TTL bits on for 100 ms, then off for 500 ms, and repeats.

PBESR-PRO-500-USB-MX

The PulseBlaster Interpreter is available as part of the SpinCore driver suite, and will be automatically installed during the setup process (setup process is described in Section II. Installation). For convenience, a shortcut to the PulseBlaster Interpreter will be added to your desktop. For more information on programming using the PulseBlaster Interpreter, see the manual located at <http://www.spincore.com/support/SPBI/Doc/>.

PulseBlaster.NET

PulseBlaster.NET is a graphical interface for creating pulse programs and loading them to the PulseBlasterESR-PRO-500-USB-MX board. PulseBlaster.NET currently provides the simplest interface possible to pulse control. Figure 4 shows an example instance of the program.

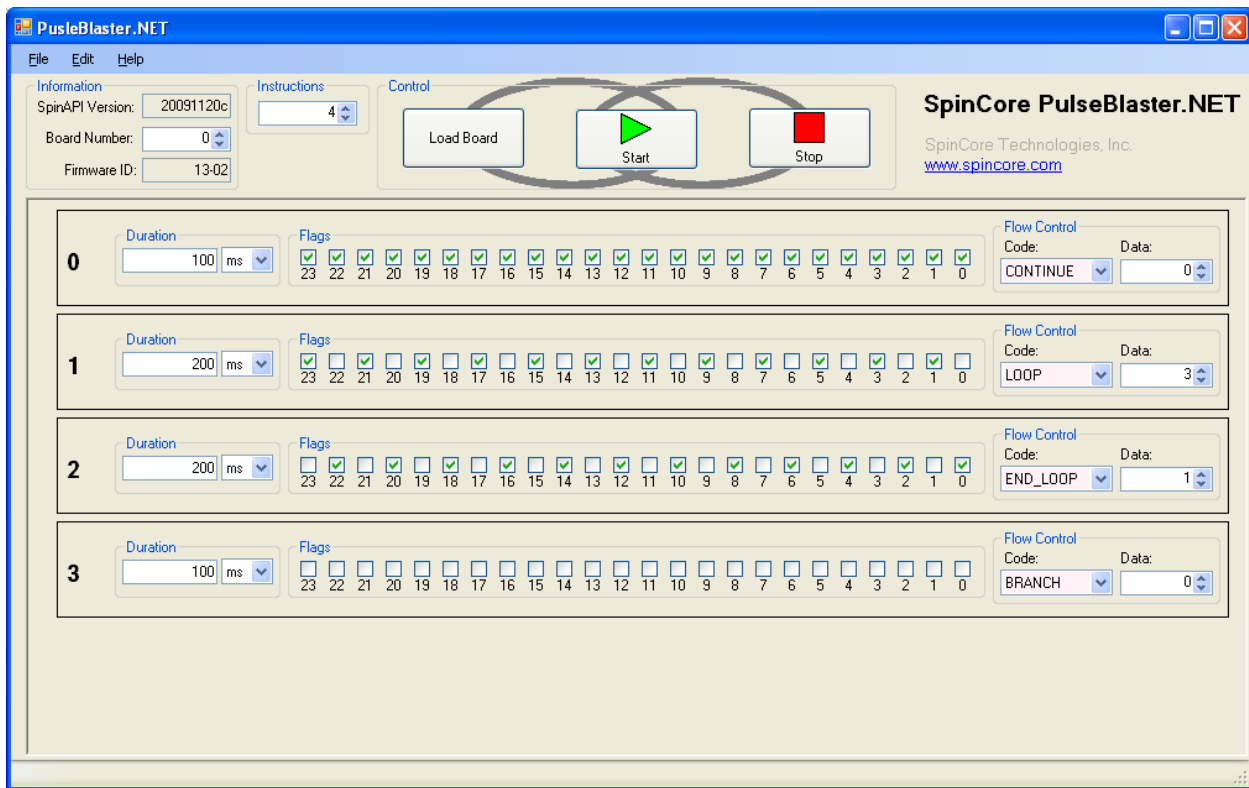


Figure 4: An example pulse program in PulseBlaster.NET. This example creates a pulse that has all TTL bits on for 100 ms, alternating bits on for 400 ms (looping three times), and then all bits off for 100 ms.

PulseBlaster.NET is available on the web from <http://www.spincore.com/support/net/>.

LabVIEW Extensions

The SpinCore PulseBlaster LabVIEW Extensions (PBLV) provide the ability to program and control the functionality of PulseBlasterESR-PRO-500-USB-MX board using the simple National Instruments (NI) LabVIEW graphical programming interface. The package contains basic subVIs that can be used to include PulseBlaster interaction from your own LabVIEW programs, as well as some complete example VIs. Additionally, all of the examples are available as stand-alone applications to control.

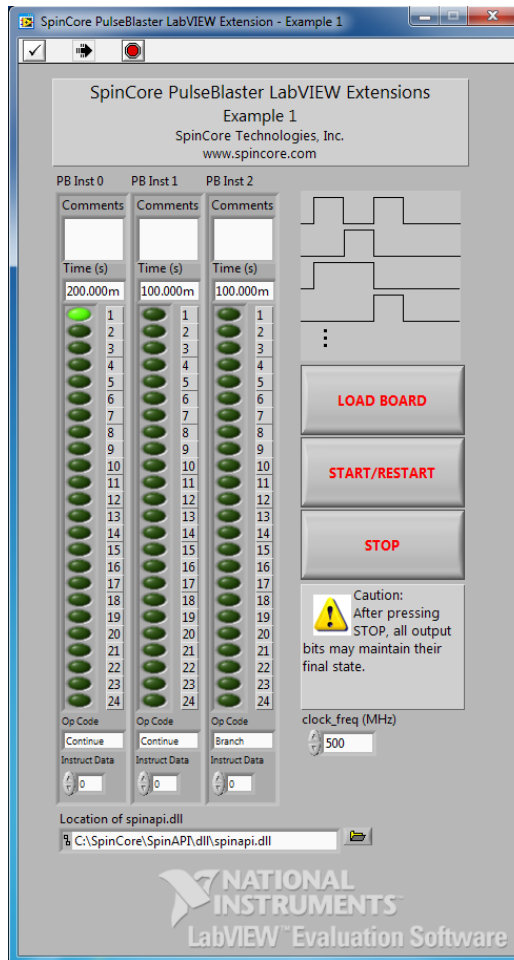


Figure 5: Example of PulseBlaster LabVIEW Extensions User Interface.

There are two versions of the LabVIEW extensions available free of charge on our website. The first is for those who do not have LabVIEW or who are not familiar with LabVIEW programming. This option is a stand-alone GUI (see Figure 5 above) that comes in executable form and utilizes the LabVIEW runtime environment. The second is for those who have LabVIEW and would like to make a custom interface for the PulseBlasterESR-PRO-500-USB-MX board. For more information and downloads please visit:

<http://www.spincore.com/support/PBLV/>

PulseBlaster MATLAB GUI

PulseBlaster MATLAB GUI is a graphical interface for creating pulse programs and loading them to the PulseBlasterESR-PRO-500-USB-MX board. PulseBlaster MATLAB GUI currently provides the simplest interface possible to pulse control. Figure 6 shows an example instance of the program.

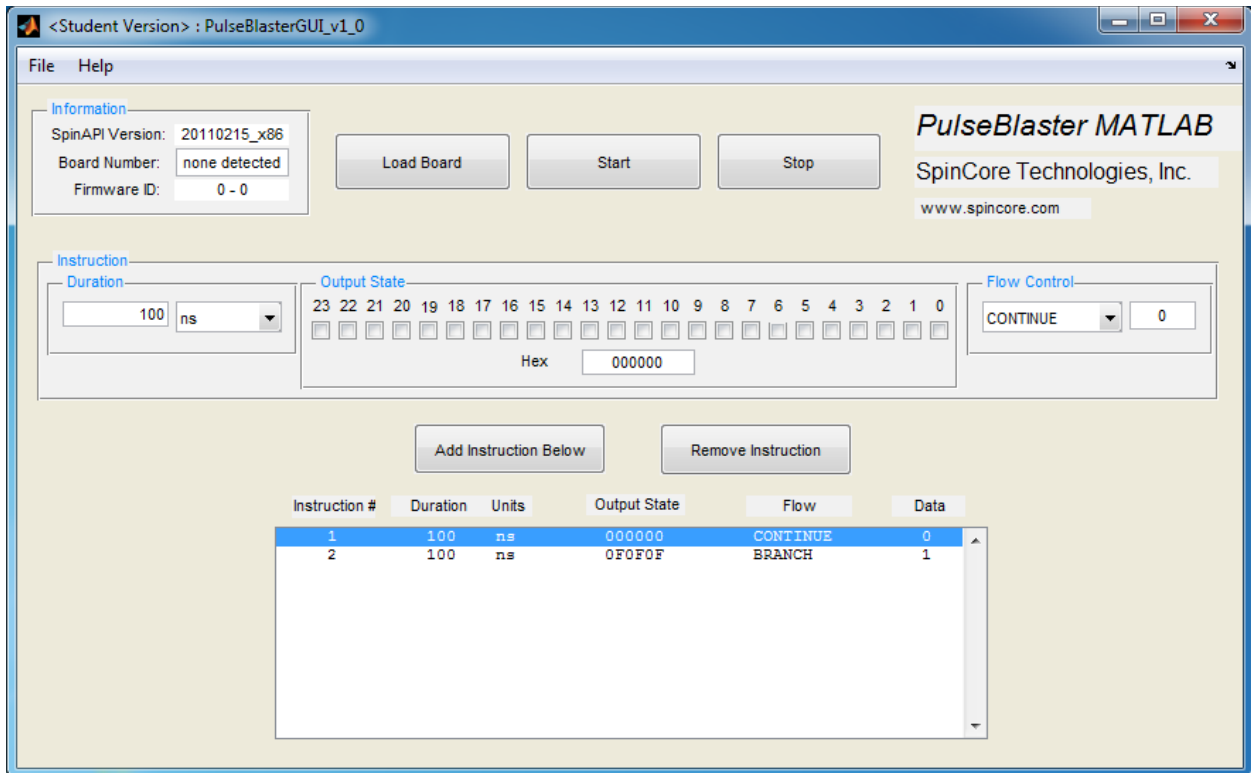


Figure 6: An example pulse program in PulseBlaster MATLAB GUI.

PulseBlaster MATLAB GUI is available at:

http://spincore.com/support/PulseBlasterMATLABGUI/pbmgui_main.shtml

C/C++ Programming

The most dynamic and flexible way to program the PulseBlasterESR-PRO-500-USB-MX board is with C/C++ using the SpinAPI package. The GUI based approaches to programming the board are designed for simplicity so they can be used by someone with no programming experience.

While GUI's are easier to use, coding in C/C++ allows you to better utilize the various features of the board and, in some cases, it may be easier to copy and paste lines of code than to make 100 instructions on a GUI. The instructions to compile on Windows can be found at http://www.spincore.com/support/spinapi/Windows_Help.shtml. After configuring the compiler, changing one of our example programs and recompiling the executable file for use with your PulseBlasterESR-PRO-500-USB-MX board is as easy as clicking "Rebuild All" (see Figure 7 below).

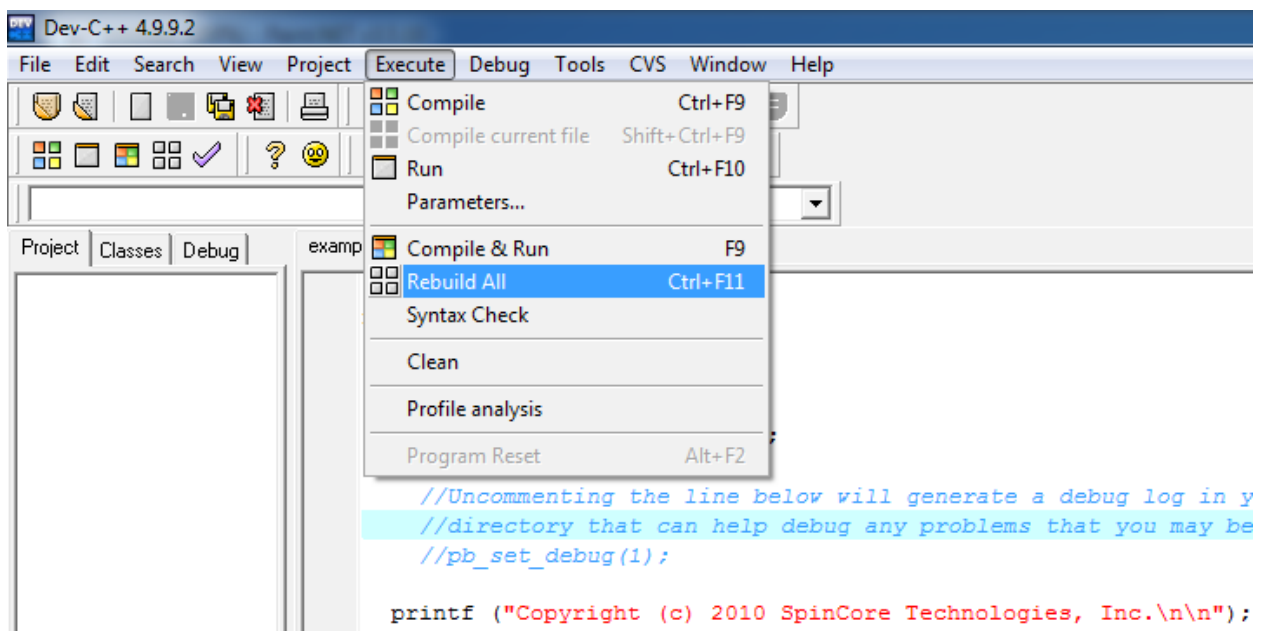


Figure 7: Compiling a C program to run the PulseBlasterESR-PRO-500-USB-MX board is easy!

PBESR-PRO-500-USB-MX

Making changes to an example program requires understanding of only a few lines of code. The following C code example generates a 50% duty cycle square wave with a 400.0 ms period.

```
1: pb_init(); /*Initialize communication with the board*/
2: pb_core_clock (CLOCK); /*Set the internal clock frequency value - this
3:   will be 500 MHz for the
4:   PBESR-PRO-500-USB-MX */
5:
6: /*Start programming the Pulse Program*/
7: pb_start_programming (PULSE_PROGRAM);
8: start=pb_inst(0x01, CONTINUE, 0, 200.0*ms); /*Bit 0 on, 200ms*/
9:   pb_inst(0x00, BRANCH, start, 200.0*ms);/*All bits off, 200ms*/
10: pb_stop_programming();
11:
12: pb_start(); /*Start the board executing*/
13: pb_close(); /*Close the communication with the board*/
```

A breakdown of the previous C code segment is as follows:

- *Line 1:* Initialize communication with the selected board. This must be called before any other functions that communicate with the board.
- *Line 2:* Set the internal block clock frequency (in MHz). This must be called to insure proper timings in the pulse program.
- *Lines 7-10:* Programs the board's pulse program memory.
 - *Line 7:* pb_start_programming (PULSE_PROGRAM) must be called before using the pb_inst(..) function.
 - *Line 8,* instruction 1: Turn on bit 0 for 200.0 ms then continue to the next instruction. The address of this instruction is stored in the “start” variable.
 - *Line 9,* instruction 2: All bits off for 200.0 ms, then branch to “start.”
 - *Line 10:* pb_stop_programming() must be called before calling any other SpinAPI functions.
- *Line 12:* Start the board executing the Pulse Program.
- *Line 13:* Close communication with the board (Pulse Program execution will continue).

Using C Functions to Program the PulseBlasterESR-PRO-500-USB-MX

A series of functions have been written to control the board and facilitate the construction of pulse program instructions. It should be noted that the `pb_inst` C function accepts any delay value greater than 10 ns. Values which are not integer multiples of the clock will be rounded to the closest integer multiple.

In order to use these functions, the DLL (`spinapi.dll`), the library file (`libspinapi.a` for MinGW, `spinapilibgcc` for Borland, and `spinapi.lib` for MSVC), and the header file (`spinapi.h`), must be in the working directory of your C compiler¹.

```
int pb_init();
```

Initializes the PulseBlasterESR-PRO-500-USB-MX board. Needs to be called before calling any functions using the device. It returns a 0 on success or a negative number on an error.

```
int pb_close();
```

Releases the PulseBlasterESR-PRO-500-USB-MX board. Needs to be called as last command in pulse program. It returns a 0 on success or a negative number on an error.

```
void pb_core_clock(double clock_freq);
```

Used to set the clock frequency of the board. The variable `clock_frequency` is specified in MHz when no units are entered. Valid units are MHz, kHz, and Hz.

```
int pb_start_programming(int device);
```

Used to initialize the system to receive programming information. It accepts a parameter referencing the target for the instructions. The only valid value for `device` is `PULSE_PROGRAM`. It returns a 0 on success or a negative number on an error.

¹ These functions and library files have been generated and tested with MinGW (www.mingw.com), Borland 5.5 (www.borland.com), MS Visual Studio 2003 (msdn.microsoft.com) compilers.

PBESR-PRO-500-USB-MX

```
int pb_inst(int flags, int inst, int inst_data, double length);
```

Used to send one instruction of the pulse program. Should only be called after `pb_start_programming(PULSE_PROGRAM)` has been called. It returns a negative number on an error, or the instruction number upon success. If the function returns `-99`, an invalid parameter was passed to the function. Instructions are numbered starting at 0.

int flags – determines state of each TTL output bit. Valid values are `0x000000` to `0xFFFFFFFF`. For example, `0x000010` would correspond to bit 4 being on, and all other bits being off.

int inst – determines which type of instruction is to be executed. Please see Table 6 for details.

int inst_data – data to be used with the previous `inst` field. Please see Table 6 for details.

double length – duration of this pulse program instruction, specified in nanoseconds (ns), microseconds (us) or milliseconds (ms).

The largest value for the delay field of the `pb_inst` is 8589 ms (using a 500 MHz clock). For longer delays, use the `LONG_DELAY` instruction (see Table 6). The maximum value for the data field of the `LONG_DELAY` is 1048576. Even longer delays can be achieved using the `LONG_DELAY` instruction inside of a loop.

```
int pb_stop_programming();
```

Used to tell that programming the board is complete. Board execution cannot start until this command is received. It returns a 0 on success or a negative number on an error.

```
int pb_start();
```

Once board has been programmed, this instruction will start execution of pulse program. It returns a 0 on success or a negative number on an error.

```
int pb_stop();
```

Stop the Pulse Program execution. TTL outputs will either remain in their last state or return to zero, depending on the firmware version of the board. It returns a 0 on success or a negative number on an error.

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```
int pb_read_status();
```

Read status from the board. Each bit of the returned integer indicates whether the board is in that state. Bit 0 is the least significant bit.

- Bit 0 – Stopped
- Bit 1 – Reset
- Bit 2 – Running
- Bit 3 – Waiting

The SpinAPI package contains C examples in the PulseBlasterESR-PRO folder which is within the examples folder. In addition, many examples in the PulseBlaster24 folder will work for this model.

Example Use of C Functions

```
#include <stdio.h>
#include <stdlib.h>

#define PBESRPRO
#include "spinapi.h"

#define CLOCK 500.0    // PulseBlaster core clock rate

int main (int argc, char **argv)
{
    int start;

    printf ("Copyright (c) 2010 SpinCore Technologies, Inc.\n\n");
    printf("Using SpinAPI library version %s\n", pb_get_version());

    if (pb_init () != 0) {
        printf ("Error initializing board: %s\n", pb_get_error());
        system("pause");
    }

    // Tell driver what clock frequency the board uses
    pb_core_clock(CLOCK);

    // Prepare the board to receive pulse program instructions
    pb_start_programming(PULSE_PROGRAM);

    // Instruction 0 - Continue to instruction 1 in 20ns. The lower 4 bits
    // (all BNC connectors) will be driving high. For PBESR-PRO boards,
    // or-ing THREE_PERIOD with the flags causes a 3 period short
    // pulse to be used.
    start = pb_inst(THREE_PERIOD | 0xF, CONTINUE, 0, 20.0 * ns);

    // Instruction 1 - Continue to instruction 2 in 40ns
    // The BNC1-3 will be driving high the entire 40ns.
    pb_inst(ON | 0xE, CONTINUE, 0, 40.0 * ns);

    // Instruction 2 - Branch to "start" (Instruction 0) in 40ns
    // Outputs are off
    pb_inst(0, BRANCH, start, 40.0 * ns);

    pb_stop_programming();    // Finished sending instructions

    pb_reset();
    pb_start();    // Trigger the pulse program

    // End communication with PulseBlasterESR-PRO-500-USB-MX board. The
    pulse program
    // will continue to run even after this is called.
    pb_close();

    return 0;
}
```

IV. Connecting to the PulseBlasterESR-PRO-500-USB-MX

The PulseBlasterESR-PRO functionality is available on the SP57 and SP58 board. The connectors for the PulseBlasterESR-PRO-500-USB-MX board are explained below in their respective sections.

Connector Information for PulseBlasterESR-PRO-500-USB-MX

The SP57 and SP58 USB-MX board both have MMCX, Trigger/Reset/Status IDC, USB type B, and USB type C connectors. In addition, the SP57 has a Trigger/Reset/Status DB9 and the SP58 has a 2-pin KK Plus 396 Molex connector. The locations of these connectors are shown in Figure 8 for the SP57 board and Figure 9 for the SP58 board, both located below.

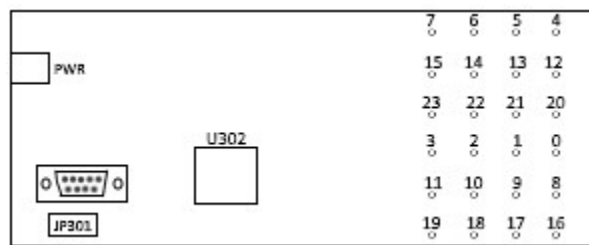


Figure 8: Top-down view of the SP57 showing connector locations. The reference numbers are printed next to the connector.

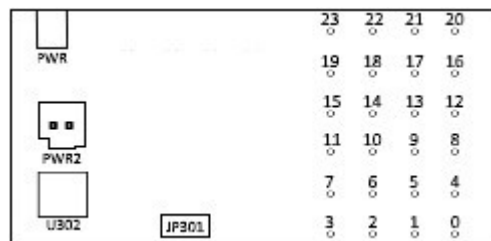


Figure 9: Top-down view of the SP58 showing connector locations. The reference numbers are printed next to the connector.

Please refer to the subsequent sections for detailed connector information.

General Connectors

MMCX Headers

There are 24 MMCX headers on the SP57 and SP58 boards which provide access to all of the digital outputs. These are labeled with Flag followed with a number which corresponds with the bit number. When mating the connectors, please be sure to support the board on the opposite side of the header to ensure that the board does not bend when connections are made.

If using a high input impedance oscilloscope to monitor the PulseBlasterESR-PRO-500-USB-MX's output, place a resistor that matches the characteristic impedance of the transmission line in parallel with the coaxial transmission line at the oscilloscope input (e.g., a 50 Ω resistor with a 50 Ω transmission line, see Figures 10 and 11, on the next page). When using an oscilloscope with an adjustable bandwidth, set the bandwidth to as large as possible. Failure to do so may yield inaccurate readouts on the oscilloscope.



Figure 10: Left: BNC T-Adapter and Right: BNC 50 Ohm resistor.



Figure 11: BNC T-Adapter on the oscilloscope with coaxial transmission line connected on the left and BNC 50 Ohm resistor connected on the right, to terminate the line.

Power Connector (PWR)

The PulseBlasterESR-PRO-500-USB-MX has a USB-C connector for supplying power and is labeled PWR. Use the provided USB C power charger (Anker part A2149) and USB C to USB C cable (Anker part A8757) with the board. Do not use the USB ports from mobile devices, or PC to power the board.

U302 Connector

The PulseBlasterESR-PRO-500-USB-MX communicates with the PC via USB. This board has a USB 2.0 type B connector that is labeled as U302 and is used for data transfer. When connecting the USB B cable, please be sure to support the board on the opposite side of the header to ensure that the board does not bend when the connection is being made.

JP301 Header

The Trig/Res/Stat IDC connector information is shown in Figure 12 and Table 1, below. The Hardware Trigger and Hardware Reset are both low-true, so each of these pins would need to be shorted to ground to cause a trigger or reset, respectively. Please refer to the Status and Hardware Pins section for additional information about each pins functionality.

CAUTION: Applying voltages to the input pins that are greater than 3.3 V or less than 0 V will damage the PulseBlasterESR-PRO-500-USB-MX.



Figure 12: HW_Trig/Reset Header Pin-Out (SP57 and SP58). Top-down view.

Pin Assignments			
Pin#		Pin#	
1	Ground	2	Hardware Trigger
3	Ground	4	Hardware Reset
5	Ground	6	WAITING
7	Ground	8	RUNNING
9	STOPPED	10	RESET

Table 1: SP57 and SP58 JP301 Pin Assignments.

SP57 Specific Connector

DB9 Header

The SP57 has an additional Trig/Res/Stat DB9 connector and its information is shown in Figure 13 and Table 2, on the next page. The Hardware Trigger and Hardware Reset are both low-true, so each of these pins would need to be shorted to ground to cause a trigger or reset, respectively. Please refer to the **Status and Hardware Pins** section for additional information about each pins functionality.

CAUTION: Applying voltages to the input pins that are greater than 3.3 V or less than 0 V will damage the PulseBlasterESR-PRO-500-USB-MX.

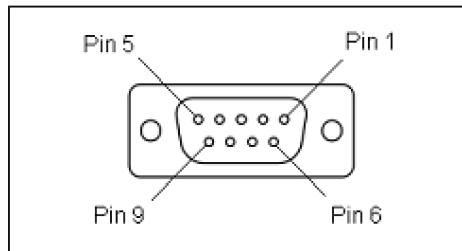


Figure 13: Trig/Res/Stat Male/Female DB9 connector drawing. This pin numbering is for both male and female DB9 connectors. When making a custom cable, starting with the mating DB9 connector may be helpful in recognizing where the pins are on the mating connector. This image is drawn with a top-down view.

Pin Number	Function
1	STOPPED
2	RESET
3	Ground
4	Hardware Reset
5	Hardware Trigger
6	Ground
7	RUNNING
8	WAITING
9	Ground

Table 2: SP57 JP301 Pin Assignments.

SP58 Specific Connector

Power Connector (PWR2)

The SP58 PulseBlasterESR-PRO-500-USB-MX has a 2-pin KK Plus 396 Molex connector (part number: 2074790002) as an alternate method for supplying power and is labeled PWR2. To use this header, connect pin 1, which can be identified by a small 1 next to the header, to a +5 V DC source and pin 2 to ground.

CAUTION: Connecting both the PWR2 and PWR connectors at the same time will damage the *PulseBlasterESR-PRO-500-USB-MX*.

Status and Hardware Pins

Status Pins Description

Stopped – Driven high when the PulseBlasterESR-PRO-500-USB-MX has encountered a STOP OpCode during program execution and has entered a stopped state.

Reset – Driven high when the PulseBlasterESR-PRO-500-USB-MX is in a RESET state.

Running – Driven high when the PulseBlasterESR-PRO-500-USB-MX is executing a program. The pin is driven low when the PulseBlasterESR-PRO-500-USB-MX enters either a reset or idle state.

Waiting – Driven high when the PulseBlasterESR-PRO-500-USB-MX has encountered a WAIT OpCode, and is waiting for the next trigger (either hardware or software) to resume operation. Note that the Running bit will also be high during a WAIT state.

Note that it is also possible to read the status bits via software by using the *pb_read_status()* function. Please see http://www.spincore.com/CD/spinapi/spinapi_reference/ for details.

Hardware Reset

The PulseBlasterESR-PRO-500-USB-MX has the HW_Reset hardware reset pin. HW_Reset is pulled to high voltage (3.3V) on the board and can be activated by a low voltage pulse (or shorting to ground). When the signal is activated during the execution of a program, the controller resets itself back to the beginning of the program. Program execution can be started from the beginning by either a software start command (*pb_start()*) or by a hardware trigger.

NOTE: The PulseBlaster requires a 3.3V input signal for HW_Reset. **Applying voltages to the input pins that are greater than 3.3V or less than 0V will damage the PulseBlasterESR-PRO-500-USB-MX.**

Hardware Trigger

The PulseBlasterESR-PRO-500-USB-MX has the HW_Trigger hardware trigger pin. HW_Trigger is pulled to high voltage (3.3V) on the board and can be triggered by a low pulse (or shorting to Ground). When the falling edge is detected, and the program is idle, code execution is triggered. If the program is idle due to a WAIT instruction, the HW_Trigger will cause the program to continue to the next instruction. If the program is idle due to a STOP instruction or a HW_Reset signal, the HW_Trigger will start execution from the beginning of the program. If the STOP instruction was used, a HW_Reset or software reset (pb_reset() or pb_stop()) needs to be applied prior to the HW_Trigger.

NOTE: The PulseBlaster requires a 3.3V input signal for HW_Trigger. **Applying voltages to the input pins that are greater than 3.3V or less than 0V will damage the PulseBlasterESR-PRO-500-USB-MX.**

Figure 14, below, shows an example of the HW_Trigger signal with a latency of 80 ns. Please refer to Instruction Set Architecture in Appendix I for more details on programming the duration of the WAIT latency. To trigger once, the trigger signal must begin at logical-high voltage (between 2V and 3.3V), then must be pulled low (to ground) and stay low for at least 10 ns before returning to logical-high voltage. The PulseBlaster will continue to trigger or reset for as long as the HW_Trigger or HW_Reset signals stay at ground. If using a long TTL cable, make sure it is terminated and a buffer is used. If necessary, use an inverter or program the triggering device to match the high-low-high HW_Trigger signal. The input impedance of the HW_Trigger pin is 10 kOhms.

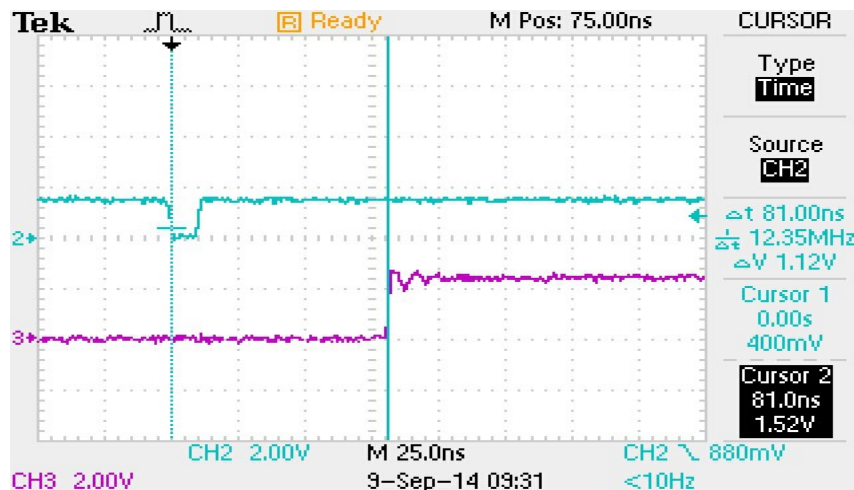


Figure 14: Demonstration of HW_Trigger high-low-high signal. The blue shows the HW_Trigger signal, the pink shows one of the output flags.
Caution: applying voltages to the input pins that are greater than 3.3V or less than 0V will damage the PulseBlasterESR-PRO-500-USB-MX.

Clock Oscillator Header

The PulseBlasterESR-PRO-500-USB-MX comes with a crystal oscillator mounted on the oscillator socket to provide a timing signal for the board. If required, it is possible to remove the oscillator that comes standard, and instead drive the PulseBlasterESR-PRO-500-USB-MX with an external clock signal. The oscillator module can be removed from the board, and an external signal can be input through the header pins. Do not attempt to drive a PulseBlasterESR-PRO-500-USB-MX board with an external clock while an oscillator module is also connected. The standard clock oscillator's orientation should be noted - if the clock oscillator is reconnected, it must be inserted in the same orientation or board damage may occur. The external clock signal must be a TTL square wave, i.e. a digital signal of no more than 3.3 V. This is the absolute maximum allowable voltage, typically a voltage of 1.5-2 V is sufficient. Be aware that the TTL signal must be a positive-only signal, any negative voltage will damage the programmable-logic chip.

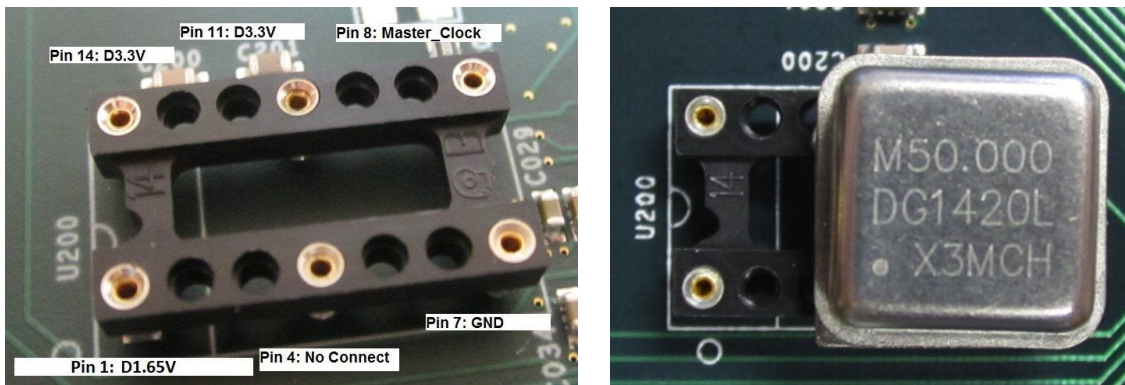


Figure 15: Both the bare header socket and the installed clock module are shown above. Please note the proper orientation of the 50 MHz clock.

Please take caution to provide a controlled signal at the correct frequency. The PulseBlasterESR-PRO-500-USB-MX requires a 50 MHz signal. A reliable option for this purpose is the [Oven Controlled Clock Oscillator](#) available for purchase. This component will provide a precision low ripple signal for all PulseBlaster boards, and ensure that appropriate signal voltages are applied to the board. Information on this product can be found in the “Related Products and Accessories” section.

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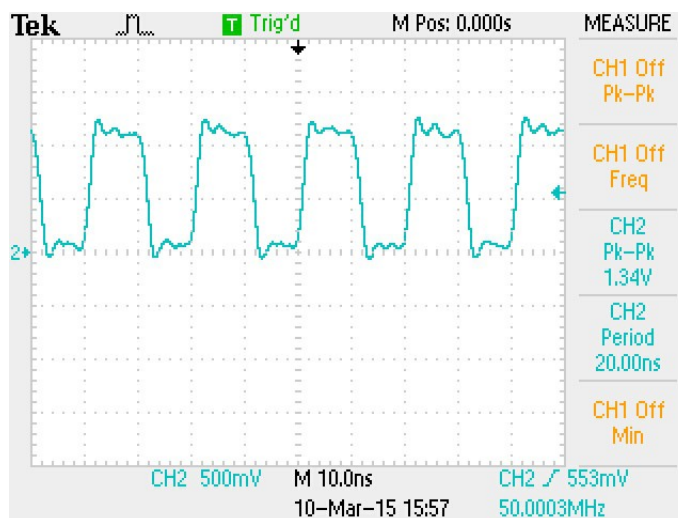


Figure 16: Example clock signal. Note that a small degree of voltage ripple is acceptable, so long as the voltage always remains above threshold for logical-high signals and below for logical-low signals.

NOTE: The PulseBlasterESR-PRO-500-USB-MX requires a 3.3V TTL input signal. A signal that is more than 3.3V or less than 0V will damage the device.

Appendix I: Controlling the PulseBlasterESR-PRO-500-USB-MX with SpinAPI

Instruction Set Architecture

Machine-Word Definition

The PulseBlasterESR-PRO-500-USB-MX pulse timing and control processor implements an 80-bit wide Very Long Instruction Word (VLIW) architecture. The VLIW is partitioned into fields dedicated to specific purposes, and every VLIW is viewed as a single instruction by the microcontroller. The maximum number of instructions that can be loaded onto the PulseBlasterESR-PRO-500-USB-MX is 4096. The execution time of instructions can be varied and is under (self) control by one of the fields of the instruction word – the shortest being six clock cycles and the longest being 2^{32} clock cycles.

Breakdown of 80-bit Instruction Word

All instructions have the same format and bit length, and all bit fields need to be filled. Table 3 shows the fields and bit definitions of the 80-bit instruction word.

Bit Definitions for the 80-bit Instruction Word (VLIW)

Output/Control Word	Data Field	OpCode	Delay Count
24 bits	20 bits	4 bits	32 bits

Table 3: Partitioning of the 80-bit Instruction Word (VLIW).

The 80-bit VLIW is broken up into 4 sections:

1. Output Pattern and Control Word: 24 bits.
2. Data Field: 20 bits.
3. OpCode: 4 bits.
4. Delay Count: 32 bits.

Output Pattern and Control Word

Table 4 shows the output pattern and control bit assignments of the 24-bit output/control word.

Bit #	Function	Bit #	Function
23	Controls Pulse Length for BNC connectors	11	Output Connector labeled Flag0..11, Pin 12
22	Controls Pulse Length for BNC connectors	10	Output Connector labeled Flag0..11, Pin 11
21	Controls Pulse Length for BNC connectors	9	Output Connector labeled Flag0..11, Pin 10
20	Output Connector labeled Flag12..23, Pin 9	8	Output Connector labeled Flag0..11, Pin 9
19	Output Connector labeled Flag12..23, Pin 8	7	Output Connector labeled Flag0..11, Pin 8
18	Output Connector labeled Flag12..23, Pin 7	6	Output Connector labeled Flag0..11, Pin 7
17	Output Connector labeled Flag12..23, Pin 6	5	Output Connector labeled Flag0..11, Pin 6
16	Output Connector labeled Flag12..23, Pin 5	4	Output Connector labeled Flag0..11, Pin 5
15	Output Connector labeled Flag12..23, Pin 4	3	Output Connector labeled Flag0..11, Pin 4
14	Output Connector labeled Flag12..23, Pin 3	2	Output Connector labeled Flag0..11, Pin 3
13	Output Connector labeled Flag12..23, Pin 2	1	Output Connector labeled Flag0..11, Pin 2
12	Output Connector labeled Flag12..23, Pin 1	0	Output Connector labeled Flag0..11, Pin 1

Table 4: Output Pattern and Control Word Bits.

When the bit corresponding to an IDC output connector is one, the voltage will be high for the duration of the instruction. If the bit is zero, the voltage will be low for the duration of the instruction.

Short Pulse Feature

The Short Pulse feature utilizes the upper three bits of the instruction flag output bits (bits 21 to 23) to control the number of clock cycles output flags are enabled. This allows for short pulses down to a single clock cycle during the instruction period. Note that **all flags** are synchronized to this instruction period. It is possible to create pulses longer than this length by setting a channel on for multiple instructions, so the Short Pulse feature does not limit the maximum length of pulses. The following table provides information on using the Short Pulse feature.

SpinAPI Define	Bits 21-23	Clock Periods	Pulse Length at 500 MHz (ns)
-	000	-	No Short Pulse
ONE_PERIOD	001	1	2
TWO_PERIOD	010	2	4
THREE_PERIOD	011	3	6
FOUR_PERIOD	100	4	8
FIVE_PERIOD	101	5	10
ON	111	-	No Short Pulse

Table 5: Short Pulse Feature Characteristics.

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When bits 21-23 are zero, the output flags remain low for the duration of the instruction. When bits 23-21 are from “000” to “101,” the programmed flag values will be outputted for the specified number of clock cycles.

Figure 17 gives an example of the Short Pulse feature. The example uses a 3 period duration. This example only shows 4 bits, but all bits will be affected.

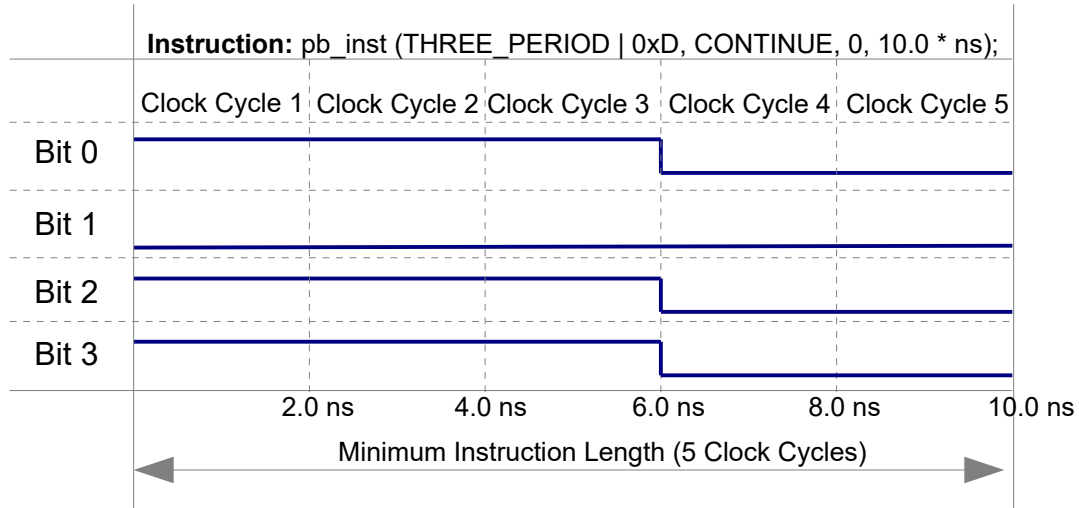


Figure 17: Example of the Short Pulse Feature. This example uses a 3 period duration. This example displays the output of 4 bits, but all bits are affected by the Short Pulse feature. Timing is done using a 500.0 MHz Clock.

NOTE: The Short Pulse functionality is firmware-dependent. Please inquire with SpinCore Technologies for upgrades or details.

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Data Field and OpCode

Please refer to the following table for information on the available instructions and their associated data field argument.

OpCode #	Inst	Inst_data	Function
0	CONTINUE	Ignored	Program execution continues to next instruction. <i>See note (1) and (2) following this table.</i>
1	STOP	Ignored	Stop execution of program. Aborts the operation of the micro-controller with no control of output states (all TTL values may remain from previous instruction). <i>See note (3).</i> Recommended that prior to the STOP OpCode a short interval (minimum seven clock cycles) be added to set the output states as desired.
2	LOOP	Number of desired loops. This value must be greater than or equal to 1.	Specify beginning of a loop. Execution continues to next instruction. Data used to specify number of loops
3	END_LOOP	Address of beginning of loop	Specify end of a loop. Execution returns to beginning of loop and decrements loop counter.
4	JSR	Address of first subroutine instruction	Program execution jumps to beginning of a subroutine. <i>See Note (2).</i>
5	RTS	Ignored	Program execution returns to instruction after JSR was called. <i>See Note (2).</i>
6	BRANCH	Address of next instruction	Program execution continues at specified instruction
7	LONG_DELAY	Desired multiplier of the delay. This value must be greater than or equal to 2.	For long interval instructions. Data field specifies a multiplier of the delay field. Execution continues to next instruction. <i>See Note (2).</i>
8	WAIT	Ignored	Program execution stops and waits for software or hardware trigger. Execution continues to next instruction after receipt of trigger. The latency is equal to the delay value entered in the WAIT instruction line plus a fixed delay of 6 clock cycles. The WAIT OpCode may not be used by the first instruction in memory. <i>See Note (2)</i>

(1) For instructions longer than 8589 ms please use a LONG_DELAY instruction.

(2) For PulseBlasterESR-PRO-500-USB-MX (design 33-1), instructions with CONTINUE, JSR, RTS, LONG_DELAY, WAIT, and STOP OpCodes, require a minimum instruction time of at least 6 clock-cycles.

(3) PulseBlasterESR-PRO-500-USB-MX (design 33-1) hold TTL values of current instruction.

Table 6: OpCode and Data Field Description.

Delay Count

The value of the Delay Count field (a 32-bit value) determines how long the current instruction should be executed. The allowed minimum value of this field is 0x00000002 and the allowed maximum is 0xFFFFFFFF. The timing controller has a fixed delay of three clock cycles and the value that one enters into the Delay Count field should account for this inherent delay. (NOTE: the pb_inst() family of functions in SpinAPI and the PulseBlaster Interpreter automatically account for this delay.)

About SpinAPI

SpinAPI is a control library which allows programs to be written that can communicate with the PulseBlasterESR-PRO-500-USB-MX board. The most straightforward way to interface with this library is with a C/C++ program, and the API definitions are described in this context. However, virtually all programming languages and software environments (including software such as LabVIEW and MATLAB) provide mechanisms for accessing the functionality of SpinAPI.

Please see the example programs for examples of how to use SpinAPI. If the programs have not been installed, then information to installing and finding them can be found in the “Installing the PulseBlasterESR-PRO-500-USB-MX” section. Reference documents for the API are available online at:

http://www.spincore.com/CD/spinapi/spinapi_reference/

<http://www.spincore.com/support/spinapi/>

Related Products and Accessories

1. Oven Controlled Clock Oscillator (sub-ppm stability) shown in Figure 18. For ordering information, please visit <http://spincore.com/products/OCXO/> or contact SpinCore at <http://www.spincore.com/contact.shtml>.



Figure 18: An Oven Controlled Clock Oscillator (or OCXO) with sub-ppm frequency stability is available for the PulseBlasterESR-PRO-500-USB-MX upon request.

2. SpinCore TTL Line Driver Figure 19 - A USB-powered device with four input channels and 8 output lines. Each output line is equipped with current driving capabilities to insure TTL voltage level over 50 Ohm loads. The SpinCore TTL Line Driver is the perfect tool to accompany any TTL device. Additional specifications, ordering information, and the manual for the TTL Line Driver are available at <http://www.spincore.com/products/SpinCoreTTLLineDriver/SpinCoreTTLLineDriver.shtml>.



Figure 19: TTL Line Driver assures TTL levels over 50 Ohm loads.

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3. Other PulseBlasterESR-PRO models can be found at <http://spincore.com/products/PulseBlasterESR-PRO/>.
4. If you require a custom design, custom interface cables, or other custom features, please inquire with SpinCore Technologies through our contact form, which is available at <http://www.spincore.com/contact.shtml>.

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Document Information

Revision history available at SpinCore.