RTBox v5/6: USTC Response Time Box

What is RTBox for?

Computer keyboard and mouse can be used to record response time (RT) to an event, such as visual or auditory stimulus. However, the accuracy depends on many factors, such as computer hardware specification, operating system, programming software, user code, and so on. Even if the user code is well written, these devices are often inaccurate, and even worse, often introduce bias. Often times, the user program can get the time when the program reads the key or mouse response, not the time when the key or mouse is pressed.

The USTC Response Time Box (RTBox) is designed to measure response time with high accuracy. The microcontroller in the device will record the event time and button identity. The user code can read them anytime when convenient. Unlike polling of keyboard or mouse response, the RTBox timing is independent of when the response is read.

Features

- Compatible to major computer systems, including Windows, MAC and Linux
- USB 1.1 and 2.0 compatible
- Measure both the button press and release time
- Built-in light port and pulse/sound port for trigger and calibration
- Built-in firmware upgrade so the device will never expire
- External buttons or button-driven TTL input for specialized keypad, such as MRI compatible keypad
- TTL output registering all input events and user event code, useful for EEG
- TTL input for TR (repetition time) trigger from MRI scanner
- Analog-to-Digital Converter function
- Many features, such as TTL input and output, are customizable

Improvements over previous version

- Larger button space and buttons are along an arc
- Either high or low active TR signal (or TTL) can be received
- Software controlled reference signal for light and sound input
- Receive 8 external button/TTL input
- Event code TTL can have 8 bits

- Hardware is more flexible, such as above TTL input and output can be assigned for different purpose

Specification

- Four buttons allowing user to label with descriptive names
- Detection time resolution: about 6 μs
- Dimensions: 5.5 x 4.5 x 1 (h) inches, 14 x 11 x 2.5 (h) cm
- Weight: ~5 oz

Parts of the Device

- Photodiode with suction and cable
- Four buttons
- USB port: connect to computer USB port with the provided cable
- Light port: receive light signal from the provided light sensor
- Sound/Pulse port: receive pulse signal from audio/stimulator device
- DA-15 input port: external switches or button-driven TTL, and TR
- DB-25 output port: output TTL for input events and 8-bit event code

How RTBox works?

When the device is connected to a USB port of a computer, it works as a serial port. The device is powered by the USB port.

For principle about how the device works, you can check the paper on *Behavior Research Methods*.

Basically, the device detects button and port events with interval about 6 μs. When it detects an event, it records the event code and time based on its own clock, and sends them to the computer serial port. Each event contains 7 bytes of data. The first byte is the event code, and the rest 6 bytes contain the timestamp.

At the computer side, the device driver reads the data from serial buffer, identifies the event type, and calculates the response time based on device clock.

Install driver for the first time

Starting from October 2017, RTBox code can use FTDI D2XX driver, which can access the RTBox directly even if the operating system does not recognize it as a serial port. It is recommended to use this driver if possible.

First, you will need to download the RTBox code for Matlab/Octave (with Psychtoolbox) or Python (with numpy, pynput and optionally pySerial), and set up the path for the folder containing the code. Then follow the details below to set up the drive for the first time.

1. Windows system

The later Windows system may include the FTDI drive with the system. If the system does not recognize the device when the RTBox is plugged in for the first time, you can install the FTDI driver from https://ftdichip.com/drivers/d2xx-drivers/ .

2. OSX

Later OSX systems include Apple's driver for FTDI VCP. RTBox code will work with this driver, but the latency timer change is almost impossible. If you don't use FTDI devices other than RTBox, the simple solution is to use D2XX driver. Download the D2xxHelper from FTDI web site, and run it to prevent the OS from locking out D2XX driver.

Then cd into the RTBox code folder, and run following bash to install ftd2xx driver:

```
sudo ./setup_ftd2xx.sh
```

3. Linux

If Psychtoolbox is configured correctly, no any issue is expected for Matlab/Octave under Linux. Users can choose to use D2XX driver by removing VCP driver. Simply cd into the RTBox code folder, and run the bash:

```
sudo ./setup_ftd2xx.sh
```

How to use RTBox?

There are two ways to use the device to measure response time. If the user code has accurate stimulus onset timestamp, we need only to get the button time based on the same clock as the onset timestamp, and then do a subtraction to get the response time. This is the recommended method. This method relies on the method we developed to synchronize the device clock with computer clock.

The second way is to provide a trigger to the device to indicate the onset of stimulus. The device will detect both trigger and button events. We get the response time by calculating the time difference between the two events. This method is only needed when the user code doesn't have accurate stimulus onset time.

If there is a TTL pulse synchronized with stimulus, you can connect it to the sound port with a cable (not provided). Some stimulus equipment, such as an electrical stimulator and audio stimulator, has built-in trigger output for this purpose.

For computer-controlled visual stimulus, it may not be easy to generate an accurate trigger. In this case, the possible timing error could be from many factors, such as the time difference between nominal onset in user code and real display onset, time difference due to the stimulus location on computer screen etc. We provide a photodiode as light trigger for visual experiments. You can mount the suction onto your screen, and program a light square which is within the same frame as the onset of your stimulus.

The second method requires additional hardware connection. Although it is the most accurate solution, it is less convenient. Also the photodiode and the trigger light may be a distractor for the subjects.

Driver code in MatLab/Octave and Python

We provided code for MatLab/Octave (RTBox.m, RTBoxClass.m) based on PsychToolbox and Python (RTBox.py). The code can detect the device automatically, and use all its functionality. If you don't use these packages, you may "translate" the code into your own language, suppose your software environment has similar functions for serial communication and timestamp.

There are also some demo codes, showing how to use RTBox in an experiment.

How to do calibration?

The timing of device is very accurate, and you normally don't need to calibrate it. However, there may be a time difference between the nominal and the real onset of the stimulus, and you can measure this difference and apply the difference to the measured response time. Ideally, this difference should be fixed for a certain setup.

The light and pulse/sound ports at the RTBox hardware can be used for calibration purpose, especially for the computer-based visual stimulus. The included light sensor is designed to detect the light onset, so we can compute the difference between nominal onset and actual onset time.

Both Matlab and Python code package have demos for the calibration.

How to test synchronization of computer and device clocks?

We synchronize the computer and device clocks by a serial trigger. When we send a trigger to the device, we record the computer time when the trigger is sent, and get the device time when the device receives the trigger. Then we get the difference between the two clocks. Later when we have device time for an event, we can calculate its computer time based on the clock difference. When possibly inaccurate clock synchronization is detected, you will see a warning message. This typically indicates your system is not accurate on timing, not only for the response box, but also for other timing related measurement.

The speed of the computer and device clocks may be slightly different. The driver code will recommend correcting clock ratio for each host computer. The code will measure and apply the correction automatically.

How to use the ADC function of RTBox?

The RTBox can be used as a simple analog-to-digital converter (ADC). For details and instruction, check the code RTBoxADCDemo.m in Matlab. For version 5+ hardware, the light signal is connected to ADC channel 8, so once the light sensor is connected to the RTBox, channel 8 will show the light signal. The ADC channels are pins 1~7 of DA-15 port.
Note that the device will stop its event report during ADC function.

Frequently asked questions and answers

1. I am warned to do run ClockRatio. What is it for, and do I have to do it?

Answer: the short answer is no. However, clock ratio correction will further improve timing accuracy. And you'd better to run it once a while, or if you have any change to your host computer, like hardware change or major system update. Another simple way is to run the 30-sec RTBoxSyncTest, and it will inform to correct ratio if needed.

2. I am asked to change latency timer to 2ms, or warned "Failed to change latency timer due to insufficient privilege" or asked sudo password to change it. What does that mean, and how do I proceed?

Answer: This indicates that you are using VCP driver under OSX or Linux. If you don't have to use VCP driver, you can follow the instruction in "Install driver for the first time" to use the D2XX driver.

If you do need VCP driver (only necessary if you have to use VCP driver for another FTDI USB serial device), you can follow the instruction below to change the latency timer to 2ms. The latency timer setting won't affect the accuracy of RTBox timing, but can make serial port reading faster. For example, on Windows and MACI systems, if the latency time is default 16 ms, 'clear' method in each trial will take about 380 ms, while with 2 ms, it takes about only 60 ms.

You can either follow the instruction in the warning to change the timer, or do it by yourself. The manual method varies with operating system. Under Linux, the driver will likely adjust the timer by itself.

Under Windows, you need to go to Device Manager (right click Computer -> Manage) -> Ports (COM & LPT) -> Right click the RTBox USB serial port -> Properties -> Port Settings -> Advanced -> Change Latency Timer (msec) to 2.

Under latest OSX, there may be no easy way to change the latency timer, except to use D2XX driver.

3. Does it make difference if I plug the RTBox to different USB port?

Answer: from our test, we didn't see time accuracy difference for different USB ports. However, we do see, on some computers, that reading speed is a little slower if the RTBox is connected to a port from a USB hub. As a rule of thumb, the USB ports at the back of a desktop computer may be better.

4. Why some of the TTL outputs are inverted, while others are not?

Answer: the diagram of RTBox with TTL outputs is shown in Appendix 2. By factory default, the output pins 1~8 are normal TTL (high active), while the output pins 17~24 of DB-25 port are inverted TTL (low active). This is compatible to the default polarity of Neuroscan EEG system. For other system, such as BrainProduct EEG, you can either set the polarity in

the EEG software, so it can receive the TTL with correct polarity, or you can change the RTBox TTL polarity to meet your system's requirement. Note that you need to change the polarity, as well as the TTL width, only once for one RTBox.

Contact us

If you have question or suggestion about the device, please contact us at:

Xiangrui Li
54 Psychology Building
The Ohio State University
1835 Neil Ave
Columbus, OH 43210

Phone: (614) 292-1847
Email: xiangrui.li at gmail.com

Appendix 1: Serial Commands

This lists all the serial commands, and the returned data, if any, by the device. All commands are a single byte data.

Uint8	Char	Returned	Function	Comments
01			Next byte will be TTL byte	5.0+
63	?	[63 state]	Ask button states	
66	B		Enter boot mode from	R to return from boot
69	E	[69 state]	Ask Enable state	1.4+
101	e	E	Wait for enable byte	4.1+
16			Send data to EEPROM	4.3+
17			Read data from EEPROM	4.3+
88	X	USTCRTBOX,921600,v5.x	Ask device identity	Also switch to advance
120	x		Switch to simple mode	1.4+
89	Y	[89 6-byte time]	Ask device time	
71	G		Go to ADC firmware	4.2+

Command uint8(1) indicates next byte will be 8-bit TTL. The device will wait for 71 ms for the next bytes. If timeout occurs, it will return 1, indicating error.

For command "?", bits 0~3 of the returned state byte are for buttons 1 to 4.

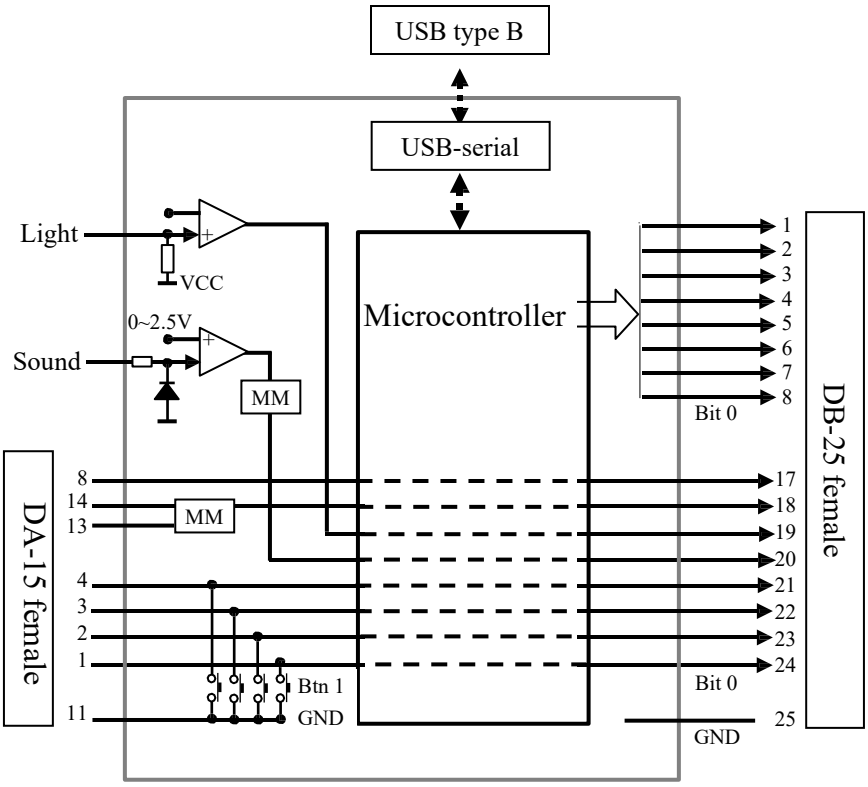
Command "B" is used for firmware update, so you should not use it.

For command "E", the 1~6th bits of the returned state byte are for button press, button release, pulse/sound, light, TR and aux respectively.

Command "T" is used by firmware developers to test the round trip speed, and is not available for normal device.

Command "X" switches device into advanced mode, and returns the device ID "USTCRTBOX", device clock frequency 921600, and version of firmware

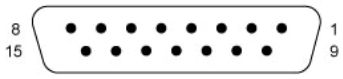
Appendix 2: Schematic of RTBox 5.x and 6.x



MM is monostable multivibrator. Both MM generate low active output.

Appendix 3: Pinout of DA-15 port

Looking at the female DA-15 port on the RTBox, the pins appear as the following picture. This port is designed to receive external button-driven TTL, or to connect external buttons (switches). There are two pins to receive MRI scanner TR trigger.

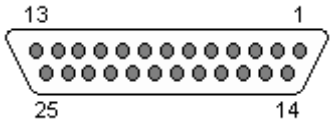


Pin	Signal	Comments
1~8	Button 1~8	5~8 may be OR'ed with other signal
9	Sound	After removing negative component
10	No connection	
11	GND	
12	No connection	
13	TR	High active pulse
14	TR	Low active pulse
15	VCC	For special purpose

If you want to connect your external buttons/switches or button-driven TTL input to RTBox, use pin 11 as ground, and connect your signal to pins 1 to 4. You could also connect switches/TTL to pins 5~8. In other words, the device can connect to up to 8 TTL/switches.

Appendix 4: Pinout of DB-25 port

Looking at the female DB-25 port on the RTBox, the pins appear as the following picture. This port is designed to output TTL signal to EEG system. For now, we know it is compatible with Neuroscan, BrainProduct and Biosemi EEG system.



Pin	Signal	Comments
1~8	TTL Bits 7~0	8-bit event code (PC 7~0)
9~14	No connection	
15	RST	For firmware flash only
16	VCC	Normally you should not use this
17	Aux	Button 8, signal from DA-15 pin 8.
18	TR	Button 7, or signal from DA-15 pin 7, 13 or 14.
19	Light	Button 6, signal from light port or DA-15 pin 6
20	Sound/Pulse	Button 5, signal from sound port or DA-15 pin 5.
21~24	Buttons 4~1	Signal from DA-15 pins 4~1.
25	GND	

A light, sound, TR and aux event will disable the later detection of itself. TR TTL output can be always on if needed. By default, the 8-bit event code is high active and 8-bit signal at pins 17~24 is low active, but the levels are configurable.