Bibliography on stimulators (in currents) of neurons (constant-current physiological stimulator)

The core component is a stimulus isolation unit (SIU) that uses DC-DC converters, rather than expensive high-voltage batteries, to generate isolated power at high voltage. The SIU has no offset when inactive and produces pulses up to 100 V with moderately fast (50 µs) rise times.

We also describe 3 methods of stimulus timing control. The first is a simplified conventional, stand-alone analog pulse generator. The second uses second uses a PC to produce a convenient user interface and a microcontroller to generate accurately timed pulses to trigger the SIU.

Method with SIU and Analog Pulse Generator:

Characteristics of the SIU :

(1) Isolation over 1 GΩand capacitative coupling under 20 pF. This keeps current leaking to the recording apparatus small compared to the biologically produced currents.

(2) Variable output of 0 to 100 V, supplying about one Watt of power (10 mA at 100 V). This is comparable to commercial units and provides enough current to stimulate most preparations. (for our project : max 20mA)

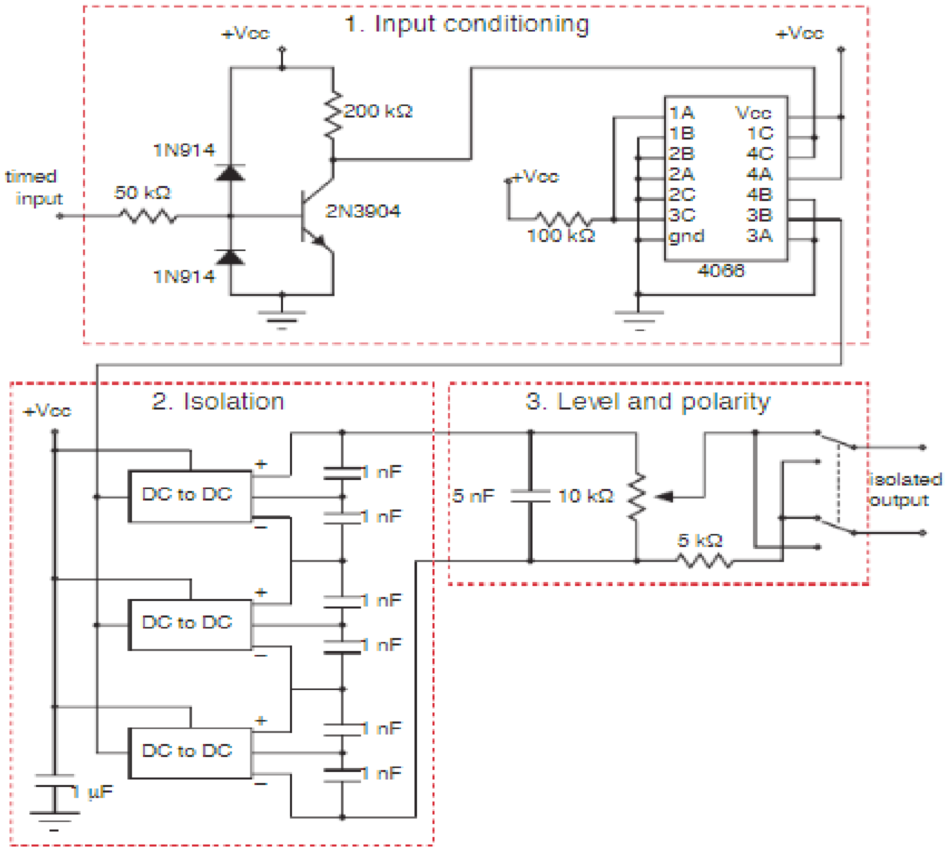
(3) Powered by line voltage instead of batteries. Many older SIUs require expensive high-voltage batteries that are now hard to find; using line voltage saves battery replacement time and cost.

4) Output controlled by a logic-level pulse with the desired timing from another analog or digital device.

The SIU circuit (Fig. 1) is based on commercially available isolated DC-to-DC converters. These can be turned on and off in about 50 µs. When on, each converter becomes a 30 V, 1 W voltage source. When off, they are passive with no offset voltage. Several DC-to-DC converters may be connected in series to produce higher voltages.

The SIU has three sections: (1) input conditioning
(2) isolation and voltage increase
(3) output level and polarity control.

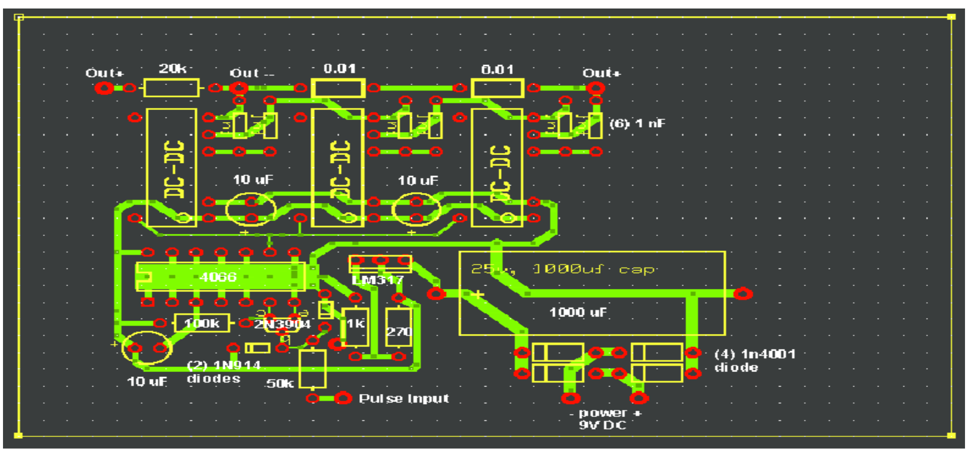
Input Conditioning (1) : The first section uses an input logic level pulse (3 to 12 V) to drive the control inputs of the DC-to-DC converters. The input transistor and diodes protect the circuit from large voltage transients. These limit, amplify, and invert the input pulse. The output of the transistor is a logic-level pulse suitable for driving a CMOS quad transmission gate (4066). A high voltage at the pulse input results in a low voltage at the output of the transistor, which turns off the CMOS transmission gate and turns on the converters in stage 2. All unused inputs to the 4066 must be grounded because CMOS gates tend to draw current if their inputs are unconnected.



<u>**Figure 1 :**</u> <u>SIU</u>

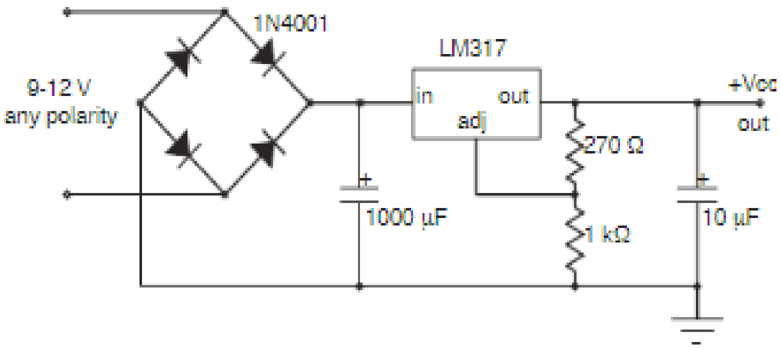
<u>Isolation and Voltage increase (2) :</u> The second stage uses one or more Burr-Brown DCP010515D DC-to-DC converters. Each converter produces 30 V output with a 6 V power supply. We used three connected in series to produce 90-100 V. Caution: The series output may cause injury if touched; use care with all high voltage sources. The 1 nF capacitors should be connected close to each converter to suppress the 400 kHz switching noise from the converters.

<u>Output level and polarity control (3) :</u> The third stage is a voltage divider to set the stimulus output level and a switch to control stimulus polarity. In addition to controlling output level, the 10 kΩ potentiometer
works with the 5 nF capacitor to form a low-pass filter that further reduces switching noise from the converters



<u>**Figure 2 :**</u> SIU layout. This printed circuit board includes the circuit shown in Figure 1 and the power conditioning shown

in Figure 3
with two additional capacitors between Vcc and ground,



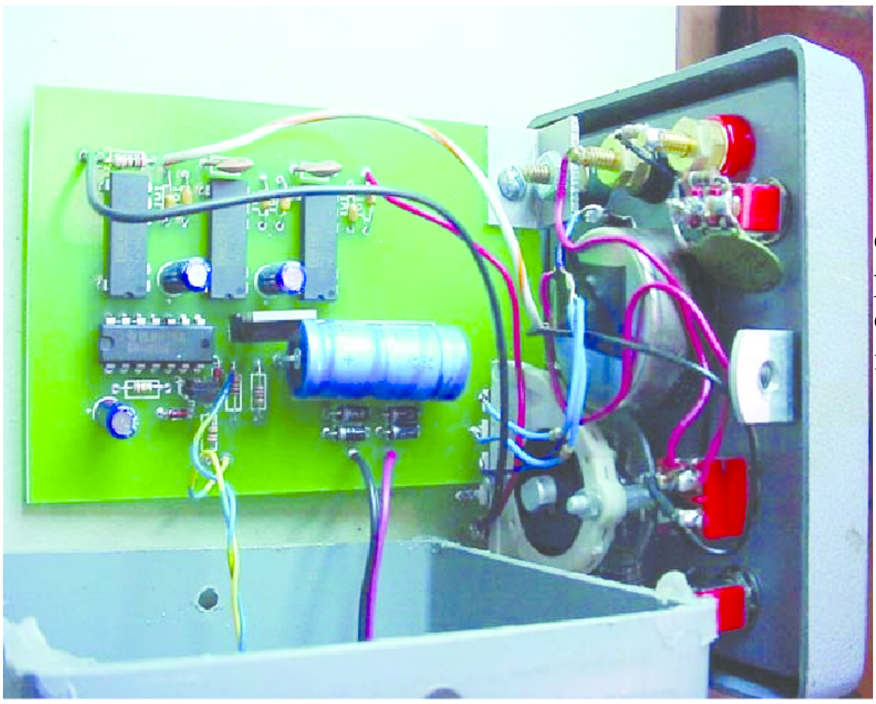
<u>Figure 3 :</u> Power conditioning. Input is any voltage from 9-12 V in either polarity; output is a regulated 6 V.

<u>Figure 2 :</u> It shows a printed circuit board layout for the SIU, including power conditioning shown in Figure 3.

The 4066 CMOS transmission gate is kept away from the onverter outputs to reduce capacitative coupling to ground. The 1 nF capacitors are as close as possible to the converter outputs. The SIU should be built in a plastic box to reduce capacitative coupling to ground.

An SIU must be controlled by a device that produces logic-level pulses with the desired timing.

<u>Characteristics of the Analog Pulse Generator :</u>



<u>Figure 4.</u> SIU construction. The circuit was placed in the housing of an obsolete WPI SIU, using its switches and jacks

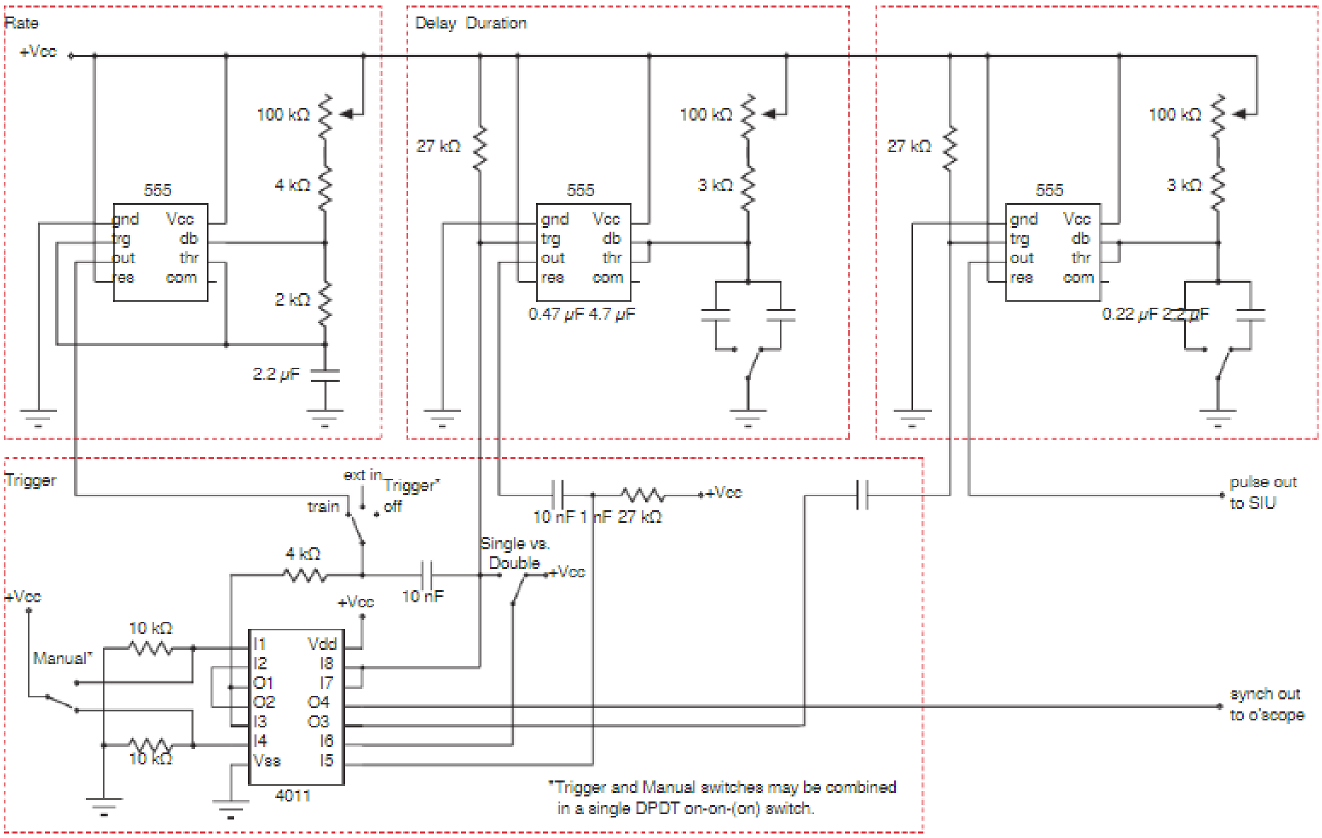


Figure 5. Analog pulse generator

The circuit shown in Figure 5 uses a 555 timer chip in each of three sections to control pulse rate, delay, and duration. Timing is determined by the capacitors and variable resistors in each section of the circuit. With the values shown in Figure 5, the pulse generator has ranges of 20-220 ms pulse period, 0-470 ms delay, and 0-220 ms duration. Increasing the size of the capacitor connected to the THR pin of the 555 timer linearly increases these times.

For example, changing the 0.47 and 4.7 µF capacitors to 1 and 10 µF would increase maximum delay to 1 s.

The first timer controls the pulse rate if the stimulator is in train mode, and is disconnected otherwise.
The second timer controls the pulse delay (time between synch out and pulse out) in single pulse mode and controls the spacing of two pulses in dual pulse mode.
The third timer controls pulse duration. A fourth section manages triggering, produces a synch output for anoscilloscope, and conditions a pushbutton for manual triggering. The 4011 quad-AND gate ensures only one pulse is produced when the manual

switch is activated.
This section also selects between single and double pulses. A train of pulses with a specific duration would have to be manually timed.

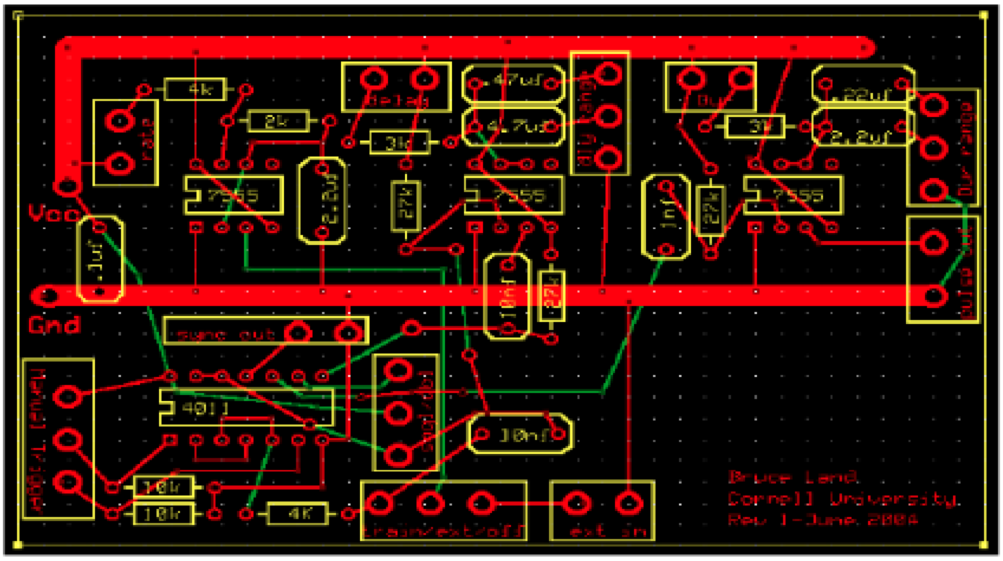


Figure 6 : Analog pulse generator layout,

Figure 6 shows the layout of the circuit on a printed circuit board.

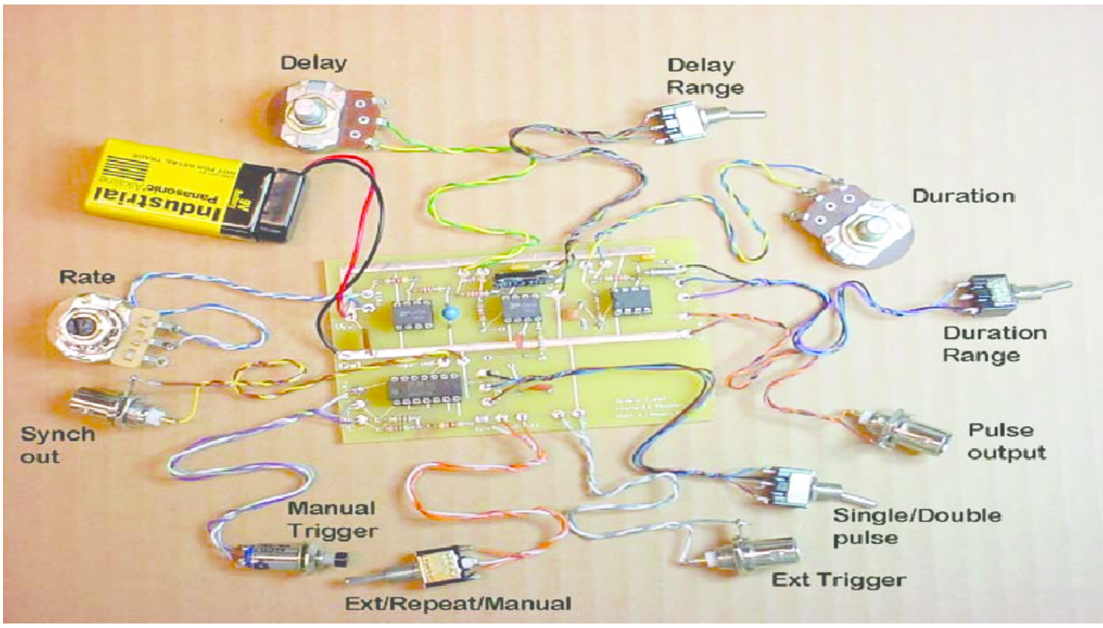


Figure 7 : Analog pulse generator construction.

A working model is shown in Figure 7. Power is from a 9 V battery, with current draw from the battery around 6 mA. A standard 9 V battery should last for around 100 hours with this use. Most of the approximately **$35** cost of parts comes from the switches and variable resistors.

Method of Microcontroller Pulse Generator

Somewhat more sophisticated stimulus timing at lower cost can be achieved by a microcontroller circuit operated by a graphic user interface (GUI) on a PC.

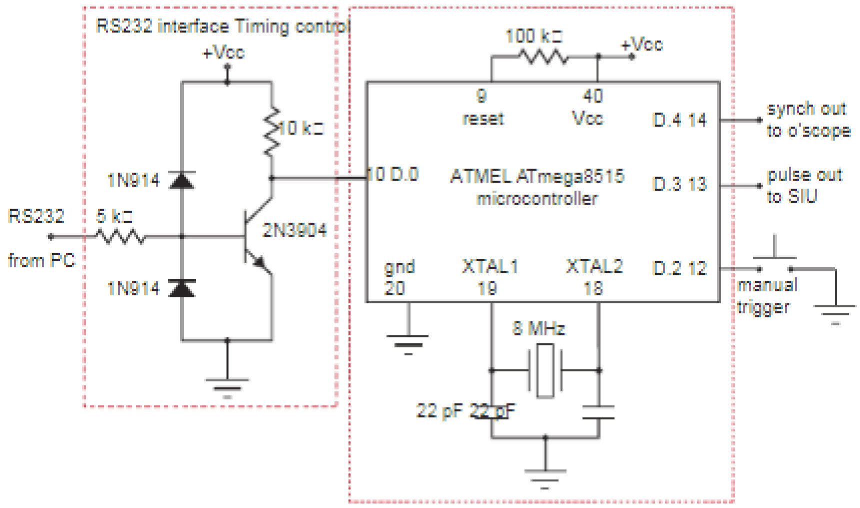
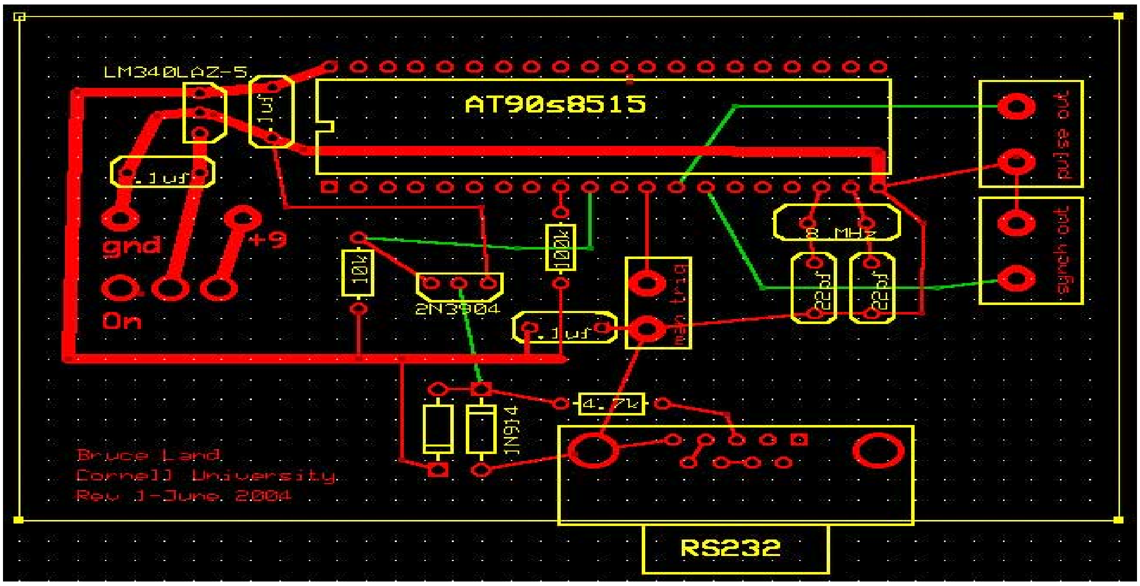


Figure 8. Microcontroller pulse generator

We designed this pulse generator to: (1) produce 1 to 255 pulses in a stimulus train, (2) repeat the train at fixed intervals up to 2 seconds, or once by pushbutton, (3) produce pulses from 0.1 ms to 2 s duration, and (4) have pulse intervals of 0.1ms to 2 s.

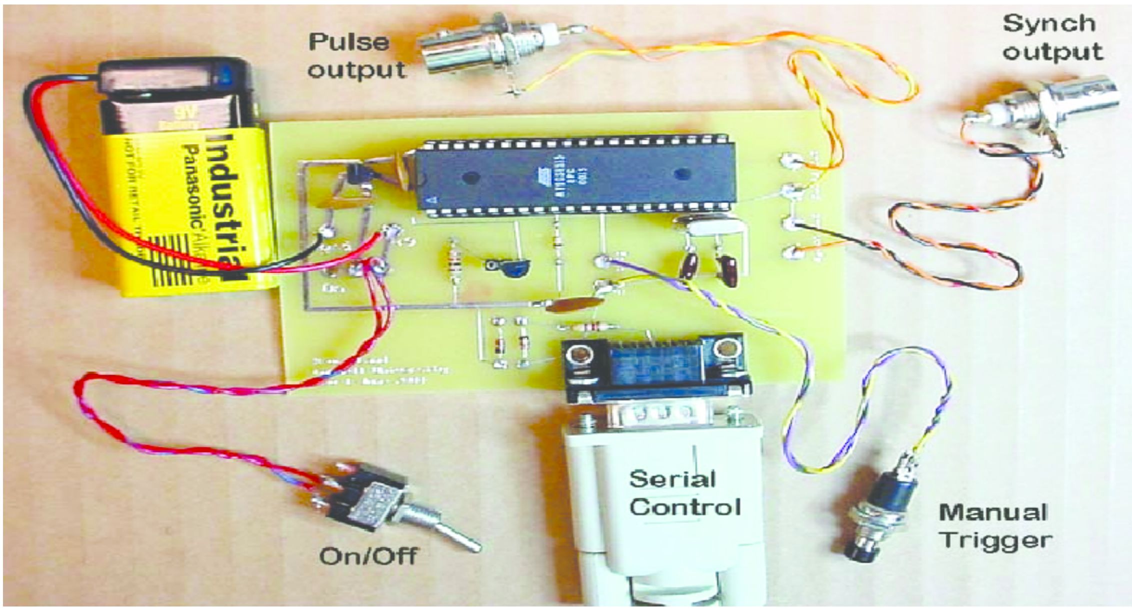
Using a microcontroller as a real-time buffer between the PC-controlled user interface and the isolator allowed us to keep timing accuracy high and cost low. The circuit is shown in Figure 8.

Software running on a PC sends simple text commands from the serial port to the microcontroller to set pulse timing. A transistor inverts the incoming RS232 signal and passes it to the microcontroller. The microcontroller is timed by an 8 MHz crystal, with the reset line tied to the supply voltage. The 8 MHz clock yields an overflow time of 32 µs for timer 0,which becomes the resolution of the pulse width. There is also a manual trigger pushbutton connected from pin D2 to ground, with an internal resister turned on by software to drive the pushbutton. Two outputs control the stimulus.
Port pin D.3 is toggled by the timer 0 interrupt service routine to control pulse timing. This pulse output is used to control the SIU. Port pin D.4 is the synch pulse output for connection to an oscilloscope or other recording device.



<u>Figure 9.</u> Microcontroller circuit board layout.

Figure 9 illustrates the layout of the microcontroller timer on a printed circuit board.



<u>Figure 10.</u> Microcontroller construction.

Figure 10 shows a working model of this timer. This circuit is powered by a 9 V battery and should run at least 60 hours on a battery, drawing around 16 mA. The cost of parts is about **20$**. Construction of the microcontroller pulse generator is simpler than the analog version because there are fewer parts.

Method of the USB and controlled isolated constant-current physiological stimulator

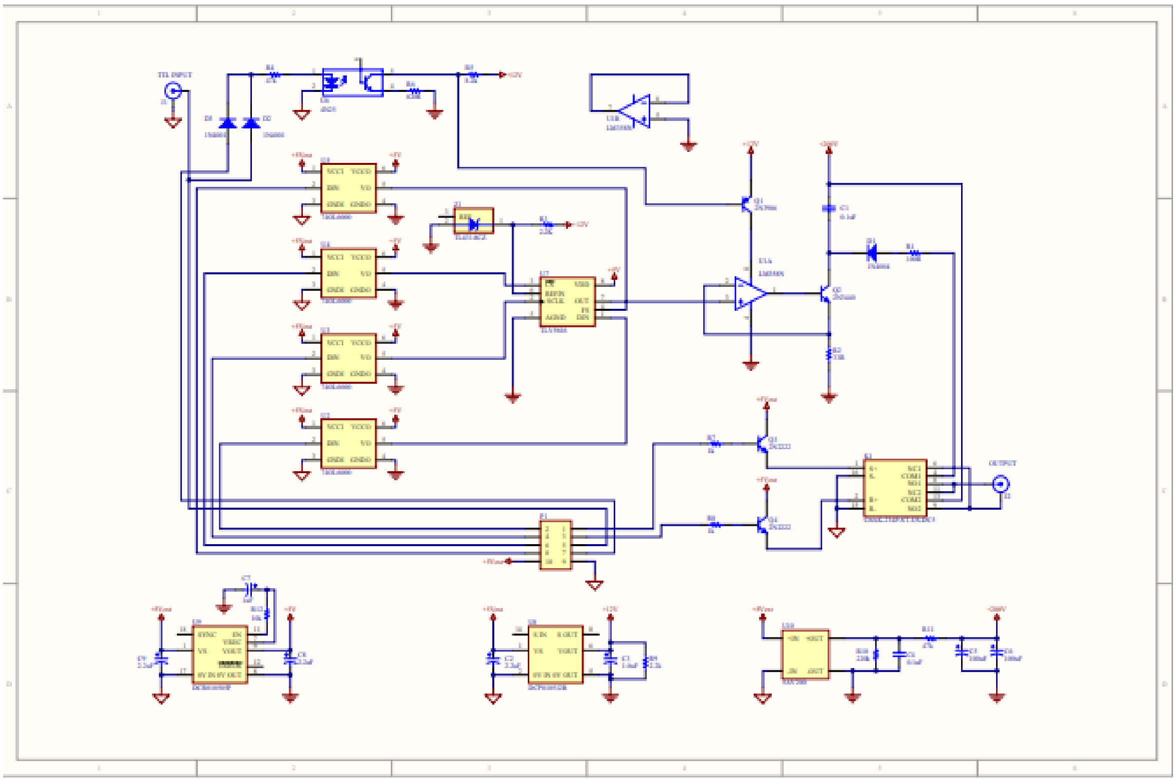


Figure 11. Color online Stimulator schematic.

The cost and features compare very favorably with commercial stimulators usually used in research and student laboratories. In addition to being USB powered, other novel aspects of our stimulator include the ability to produce large currents, up to 100 mA through a typical 1 k load, by means of a single high-voltage dc-to-dc converter; user-specified variable period, magnitude, and duration of complex monophasic or biphasic sequences; and easy integration via hardware or software into existing experimental setups.

A USB controller module MT-USB, Molex comprises a 40-pin 20 MHz programmable intelligent computer PIC 18F452 microcontroller Microchip, a 162 liquid crystal display, and a USB connector and circuitry that are used to communicate with the host personal computer PC and control the stimulator.

The MT-USB has two ten-pin headers connected to our custom printed circuit board PCB. The PIC module uses the USB connection as a virtual serial port to communicate with the host PC.

The PIC control program is written in C. The stimulator uses a classic, buffered, voltagecontrolled current source VCCS with a few modifications.

Figure 11 shows a schematic of the circuit. A constant setpoint voltage provided by a 12 bit digital to analog converter DAC U7 and a digital enable signal both described below control the set point and activation of the VCCS. In order to prevent any output from the stimulator when it is inactive, we implemented an unconventional operationalamplifier op-amp power supply. The digital enable signal is fed into the optoisolator U6. When the digital enable signal is low, the emitter and base of Q1 are at the same potential and no current flows, which effectively disconnect the power to U1A, ensuring zero output.

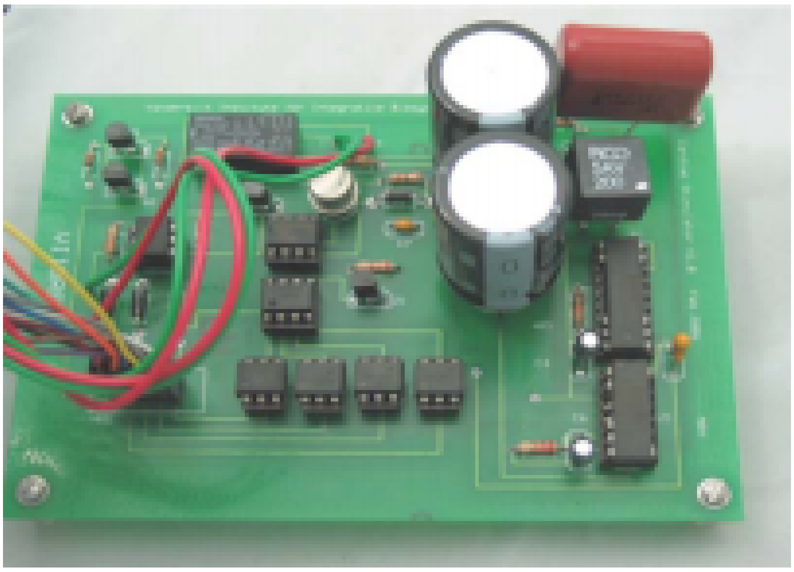


Figure 12. Custom PCB. The PIC module is mounted on the enclosure front panel not shown and connected to the PCB via the ten-pin header located in the lower left-hand corner of the picture.

We can't go any further on the subject because of the large currents, up to 100 mA through a typical of the stimulator : we must have currents of 20mA maximum.

Sources :

- https://www.researchgate.net/publication/236048257_Tools_for_Physiology_Labs_Inexpensive_Equipment_for_Physiological_Stimulation

- REVIEW OF SCIENTIFIC INSTRUMENTS 79, 126103 2008 « Universal serial bus powered and controlled isolated constant-current physiological stimulator »
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