A TDT SWITCH MODULE

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ABSTRACT
The design and construction of a switching module for use with Tucker-Davis Technologies equipment is presented. This four-pole-double-throw (4PDT) module is used, for example, to periodically switch between a recorded voltage and a reference voltage during neural recordings to mark the time of external behavioral events.

METHODS
Schematic and Design Description
The schematic for the switch module can be seen in Figure 1. The straightforward circuit has four independent single-pole double-throw switches where each switch is controlled by a logic-level voltage. Inputs and outputs are labeled in banks, signal inputs $A_i$, $B_i$, control inputs $C_i$, and outputs $D_i$, where $i$ ranges from 1 to 4. The behavior of the circuit is described by the following equation:

$$ D_i = \begin{cases} 
A_i, & \text{if } C_i = 0 \\
B_i, & \text{if } C_i = 1 
\end{cases} \quad (1) $$

The analog switch chosen, the Maxim MAX333A, is fast, robust, and has low on-resistance. If the MAX333A is not available, the older MAX333 is a good alternate, as is the MAX4533.
They are all pin-compatible. Switching times are well under 200 ns, and power consumption is well under 10 mW.

**Parts List**

A list of required parts is given in Table 1. At the time of this writing, these parts are all readily available, and reasonably inexpensive. The table below lists IC1 and IC2 as the MAX333 sourced from Digi-Key, but the MAX333A is available directly from Maxim in sample quantities.

<table>
<thead>
<tr>
<th>Item</th>
<th>Manufacturer; Part Number</th>
<th>Description</th>
<th>Source; Order Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>BB1</td>
<td>TDT BB1</td>
<td>breadboard module</td>
<td>TDT BB1</td>
</tr>
<tr>
<td>IC1–IC2</td>
<td>Maxim MAX333CPP</td>
<td>quad analog switch</td>
<td>Digi-Key MAX333CPP</td>
</tr>
<tr>
<td>Q1–Q8</td>
<td>Chicaco Miniature CMC01G</td>
<td>T1 green LED</td>
<td>Digi-Key CMC01G</td>
</tr>
<tr>
<td>R1–R4</td>
<td>Yaego MFR-25FBF 402R</td>
<td>400Ω resistor</td>
<td>Digi-Key 402XBM</td>
</tr>
<tr>
<td>J1–J16</td>
<td>Amphenol 31-10-RFX</td>
<td>isolated BNC connector</td>
<td>Digi-Key ARFX1063</td>
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<tr>
<td>C1–C4</td>
<td>Panasonic ECU-S1H104KBB</td>
<td>0.1µF 50V X7R</td>
<td>Digi-Key P4923</td>
</tr>
<tr>
<td>Misc</td>
<td>Vector ???</td>
<td>press-in pins</td>
<td>??? ???</td>
</tr>
</tbody>
</table>

**Table 1: Parts List**

A list of parts for constructing one switch.

**Construction**

Most of the assembly time for the switch will be in wiring the circuitry, but a fair fraction will also be taken by drilling the necessary holes (some 24 in the front panel, and 16 in the circuit board). A drawing is provided in figure 2 to assist in this, as well as photographs of the finished product in figure 3. Be sure to tighten the BNC connectors with sufficient torque to insure that they do not loosen over time, as tightening them after the module has been assembled is difficult. Care should be taken to route wires cleanly. Although the schematic as presented does not include power supply decoupling capacitors for the two integrated circuits, they should be included, one per voltage rail, adjacent to the packages. Additionally, there should be a larger set of capacitors at the module power entry point.

**Operation**

Operation is numbingly simple. Inputs are connected to $A_i$ and $B_i$, control voltages to $C_i$, and outputs taken from $D_i$. The lights next to each $A_i$ and $B_i$ input are illuminated when the corresponding input is being routed to the output. Signals $A_i$ and $B_i$ can range from −10 to 10 V, and controls $C_i$ should be TTL/CMOS logic levels between 0 and 5 V.

**Results**

The results are nearly as simple as the operation. The switch is quiet, quick, and reliable. In use, we typically route signals from a multi-channel neural recording to the $A_i$ inputs, put a grounding cap over the $B_i$ inputs, and have a computer-driven logic level feeding all four $C_i$ inputs in parallel. This is used to periodically impress a fixed voltage (0 V for
Figure 1: 4PDT Switch Schematic
Figure 2: Front Panel Drawing

A layout of the holes to be drilled in the front panel. The four medium-sized holes are pre-drilled in the BB1 front panel for mounting screws. The eight small holes (0.125 inch) are for rear-mounted T1-size LED lamps; when assembling the board leave just enough lead length so that the LEDs are pressed up slightly against the front panel. The 16 larger holes (0.375 inch) are for the BNC connectors, and, if possible, should be punched as D-shaped cutouts.

100 ms) on the recording by the behavioral control computer as can be seen in figure 4; these marks can be used to later synchronize the neural signal to other records. Although not presented here, these values have been readily and repeatedly recovered by an inverse threshold (signal must be in magnitude below a certain value determined by the inherent noise in the A/D subsystem). Precise characterisation of the switch is beyond the scope of this brief paper.

SUMMARY AND CONCLUSIONS

In brief form, we have covered a simple module that was constructed to allow remote electronic selection between two banks of signals. The parts are readily available, construction is straightforward, and the results have been excellent.

_— SOUL COUGHING (Is Chicago, is not Chicago, Ruby Vroom, 1994)_
Figure 3: Four Views of Assembled Module

A, front view. Going left to right the four columns are the connections for $A_1$, $B_1$, $C_1$, and $D_1$, respectively. The indicator LEDs can be seen above and to the left of each $A_i$ and $B_i$ input. B, rear view, showing wiring. Notice the holes made in the circuit board to allow access to the BNC connector soldering leads. C, left side view. The LED legs for the $A_i$ inputs can be seen from this side. D, right side view. The MAX333 chips can be seen just behind the column of output BNC connectors.
Figure 4: Sample Switching
An example recording switching between four channels of neural signal on $A_i$ and ground on $B_i$. The vertical scale is signal strength in volts for each of the four outputs from the switch; the horizontal axis is time in milliseconds. $D_i$ was switched from $A_i$ to $B_i$ at 20 ms, and back 10 ms later. (cmem3310s.au)