Frequency and Volume Measurement Transducer
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Introduction:
For the final project in ME240 the team consisting of Jeff Blettner, Brian Decker, and Kevin Armendariz decided to measure the frequency and volume of sound waves. This was done by hooking a standard microphone up to the USB6009 National Instruments DAQ board which was used in conjunction with a LabView program, Tuner Idea1.vi that the team created. This program took the inputs and displayed the Decibel reading, the closest musical note value, and how far out of tune the source note was. The transducer setup can be seen in Figure 1.

Figure 1: Transducer Set Up

Transducer:
The added difficulty in this project came from the fact that acoustics were never covered in class and a lot of outside research was needed. The microphone was a Philips swa2080w/17 uni-directional with a 600 ohm impedance and a frequency response between 80-12000hz. This worked great for the scope looked at in this project because it was designed for use with a human voice; which produces the volume levels and frequencies similar to those which this system was meant to measure. In fact all of the data was taken in the 100-500 hz range, which is well within the bounds of the operating range. The outputs were computed by taking the inputs from the transducer manipulating them in Labview. Calibrations were done through the Labview program rather than through physical changes such as those done in the TC assignment.

LabVIEW VI:
Although there was no need to calibrate the frequency, it had to be manipulated to achieve the required output in musical note form. A table was created in Excel showing the note, an incremental integer value assigned to each note, the frequency of the note, and the wavelength. These values were found at http://www.phy.mtu.edu/~suits/notefreqs.html. A portion of this chart can be seen in Figure A1. The

integer value assigned to each note was plotted against the frequency of the note which was used to find an equation relating music notes to frequency. The inverse of this equation was used in the round frequency sub vi to convert a frequency to the numerical value for a note, which was then rounded to a integer and sent to the case structure in Tuner Idea1.vi and also converted back to a frequency which was then output to the Tuner Idea1.vi to determine the frequency to tune to. The case structure used the rounded numerical note values to light up an LED corresponding to an alphabetical note value if the notes are in the 4th octave, which is the common octave for human voices and musical instruments. The output frequency value was also used to determine whether the note was sharp, flat, or natural. Due to the fact that standard instrument tuners give a +/- range of 9 cents for correct tuning. Cents is a ratio that relates two frequencies by equation 1, this program also gives that range. This can be seen in Figure A3 which is a section of the Tuner Idea1.vi program. The value of .00521214 is the frequency ratio associated with 9 cents. The vi documentation is shown in figures A8,A9.1, and A9.2. The sub vi documentation is shown in figure A10.

$$C = 1200 * \log_2(\frac{f_2}{f_1}) \qquad \text{Equation 1}$$

Calibration:
Since the microphone out puts a voltage sine wave that is the same frequency as the sound it detects no calibration was needed for frequency, but calibration was needed for the decibel readings of volume. This calibration was done using the sound tube and RION NA-27 sound level meter in the lab on the third floor of Toomey Hall. A sound generator was hooked up to the sound tube and a frequency was generated. The RION NA-27 was then set to measure the Db value at that frequency. The microphone from the transducer was set at the end of the sound tube to measure the amplitude of the microphone's output. The amplitude from the microphone and the Db reading from the RION NA-27 were recorded at various loudness levels and at 3 different frequency values. The data from each of the 3 frequencies produced a similar curve on the microphone detected amplitude vs RION NA-27 detected amplitude graph, so the data from all 3 frequencies were put into one graph and a logarithmic best fit line was created. The data can be seen in Figure A4 and the graph can be seen in Figure A5. The equation from the graph was then put into to Tuner Idea1.vi to calibrate the voltage amplitude that were input from the microphone to a Db reading. This can be seen in Figure A6.

Data Collection:
Since the purpose of this transducer is to measure the note value of a sound and its volume, digital data collection is not necessary. The most common application for this transducer and program would be as an instrument tuner. Data was recorded manually for the purpose of showing the outputs of this system and can be seen in Figure A7. Figure A8 shows a screen shot of the program operating.
The error in the data collection could be do to several things. By design, the tuner can only read data at the microphone. If there is a sufficient distance between the transducer element of the microphone and the source of sound, there could be error due to ambient noise. As seen in Figure A7, the amount of error present during the reading is insignificant compared to amount needed to change numerical value of the note. Other possible causes of error could be due to the wiring of the connections used. The connections were soldered to insulated wires and connected to the DAQ board. The insulation prevents grounding but does little to prevent electronic noise induced from other sources. These sources of interference could include the wires themselves or other electronics in the area, e.g. the DAQ board.

Conclusion:

In conclusion, the purpose of the project was to create a LabView VI that could be used as a pitch tuner. The concepts demonstrated in class and labs were utilized to accomplish this task. LabView VI's were created to interpret an input frequency, truncating it to the nearest note. The frequencies were collected with the use of a microphone and DAQ board, which were calibrated to output the decibel value of the input signal at the given frequency. The tuner works according to its intended use, giving the user a functional interface for tuning an instrument.

Appendix:

Note	Numerical Value	Frequency (Hz)	Wavelength (cm)
C4	48	261.6	132.0
C#4/Db4	49	277.2	124.0
D4	50	293.7	117.0
D#4/Eb4	51	311.1	111.0
E4	52	329.6	105.0
F4	53	349.2	98.8
F#4/Gb4	54	370.0	93.2
G4	55	392.0	88.0
G#4/Ab4	56	415.3	83.1
A4	57	440.0	78.4
A#4/Bb4	58	466.2	74.0
B4	59	493.9	69.9

Figure A1: Note Frequencies

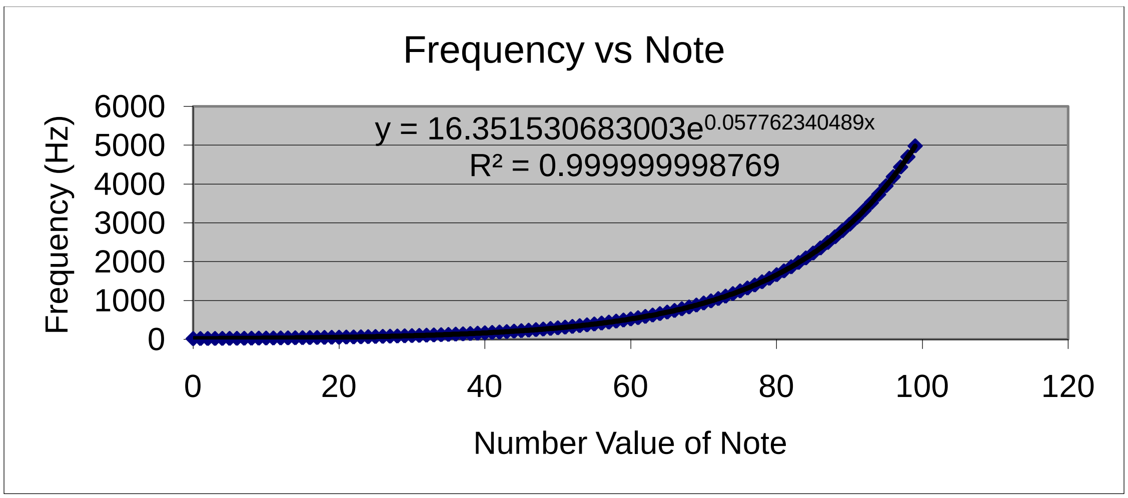


Figure A2: Frequency vs Note

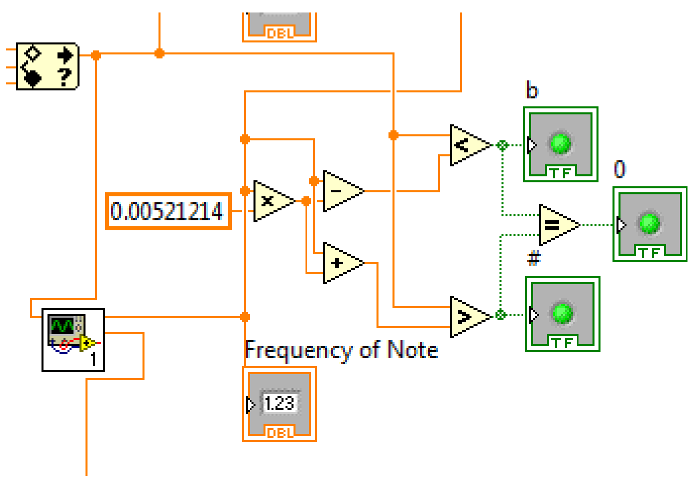


Figure A3: Flat, Sharp, Natural Equation

Frequency (hz)	Mic Amp	RION NA-27 Amp
125	5.1	110.0
	11.2	117.0
	24.4	123.2
	2.5	103.6
	4.1	108.0
	7.5	113.3
	10.5	116.2
	15.1	119.8
	26.1	123.7
	15.2	119.8
	23.3	123.5
	13.1	118.5
	20.5	122.3
	26.2	124.5
	18.7	121.4
	26.7	124.6
250	3.7	107.3
	4.4	108.8
	6.2	112.0
	8.1	114.5
	10.4	116.3
	12.1	117.6
	14.1	118.9
	17.2	120.7
	19.1	121.5
	21.2	122.4
	23.8	123.4
	28.7	125.1
	2.1	99.0
400	4.0	104.7
	6.1	108.7
	7.4	110.3
	8.5	111.5
	9.9	112.7
	11.1	113.8
	15.1	116.4
	18.1	118.0
	20.1	119.0
	22.6	120.0
	25.1	121.0
	30.0	122.4

Figure A4: Calibration Data

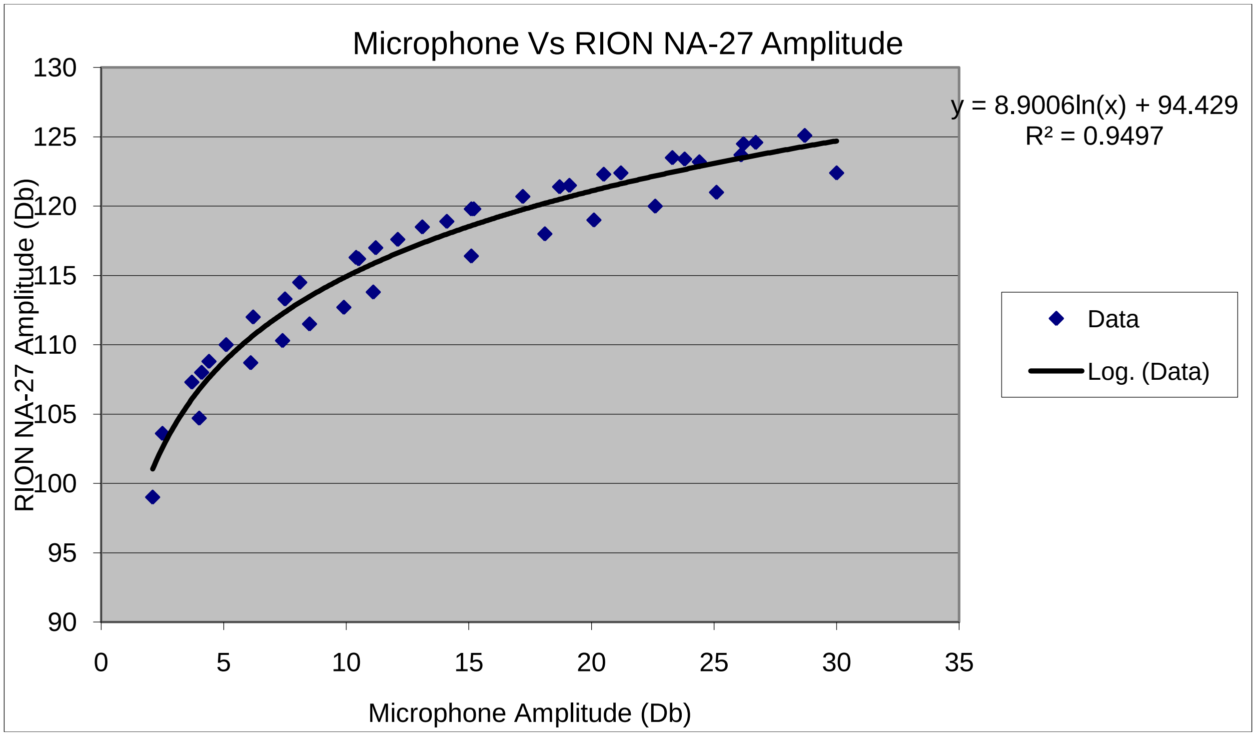


Figure A5: Calibration Graph

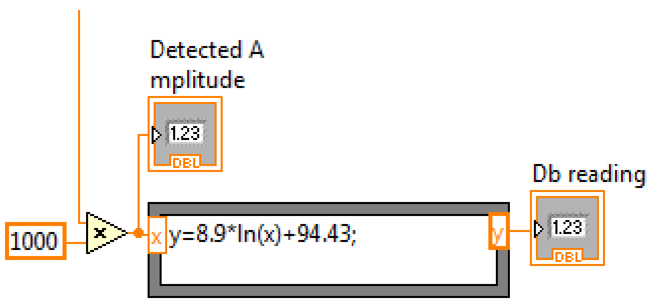


Figure A6: Amplitude Calibration in Labview

Tone Played (Hz)	Frequency Detected (Hz) (RION NA-27)	Frequency Detected (hz) (Microphone)	Nearest note	Tune to	Tunning LED	%Error (Tone Played and Microphone)
438	437.8	437.9	A	440hz	natural	0.02283
439	439.1	439.1	A		natural	-0.02277
440	440.1	440.1	A		natural	-0.02272
441	440.9	441.1	A		natural	-0.02267
442	442.1	442.1	A		natural	-0.02262
443	442.9	442.9	A		Sharp	0.02257
444	444.1	444.1	A		Sharp	-0.02252
445	444.9	444.9	A		Sharp	0.02247

Figure A7: Collected Data

Figure A8: Tuner Idea1.vi Running

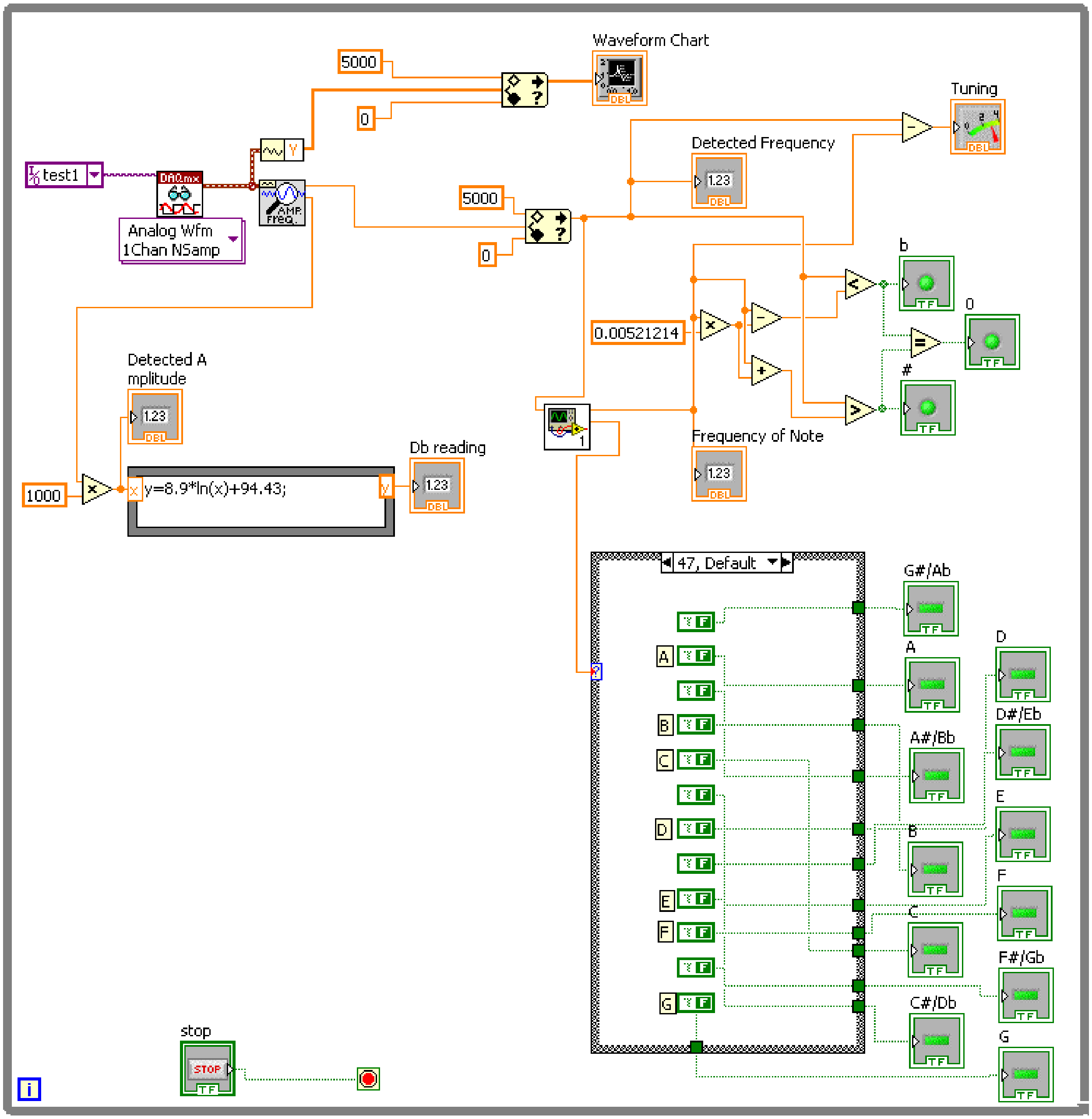
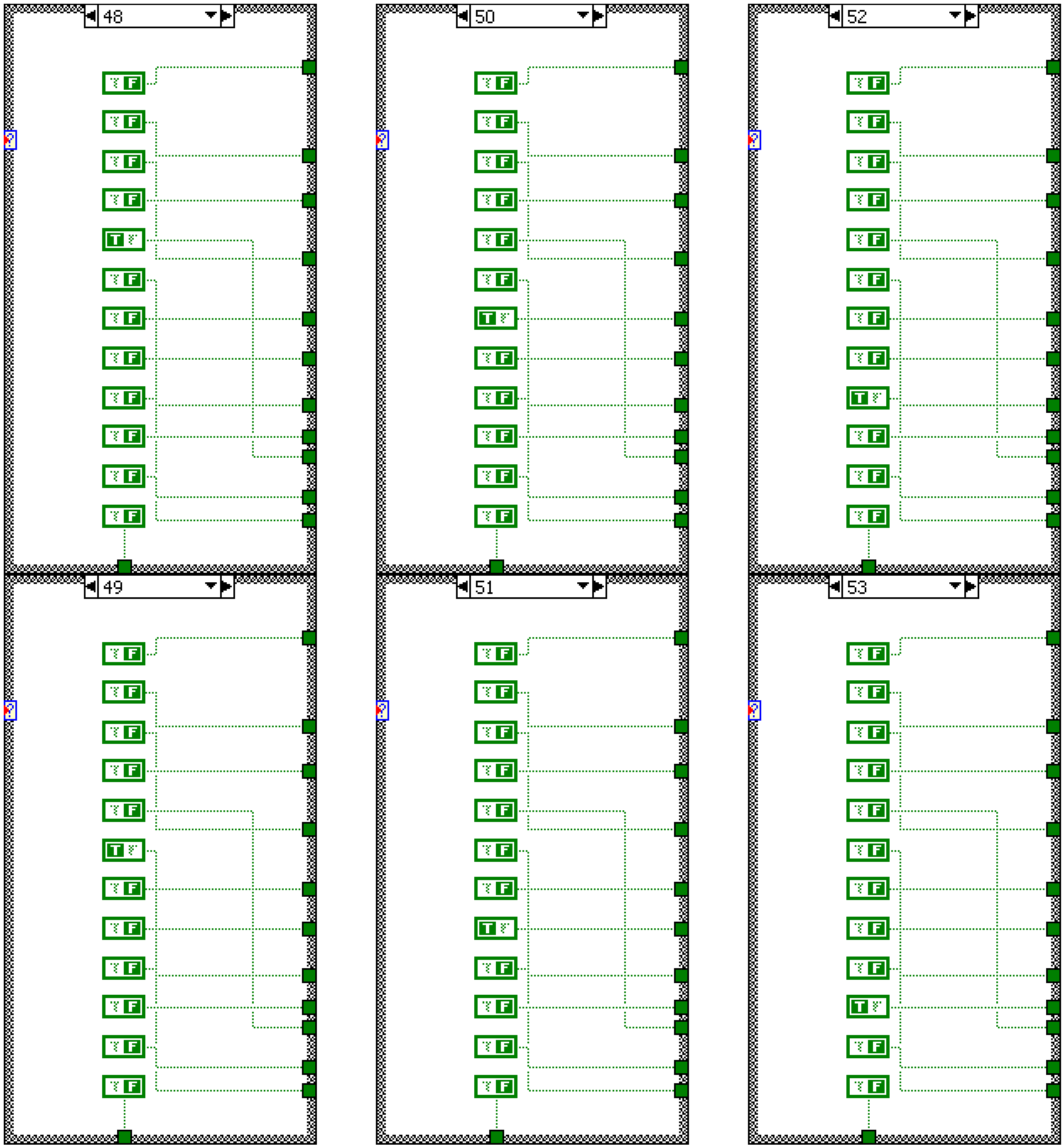


Figure A9.1: Tuner Idea 1.Vi Block Diagram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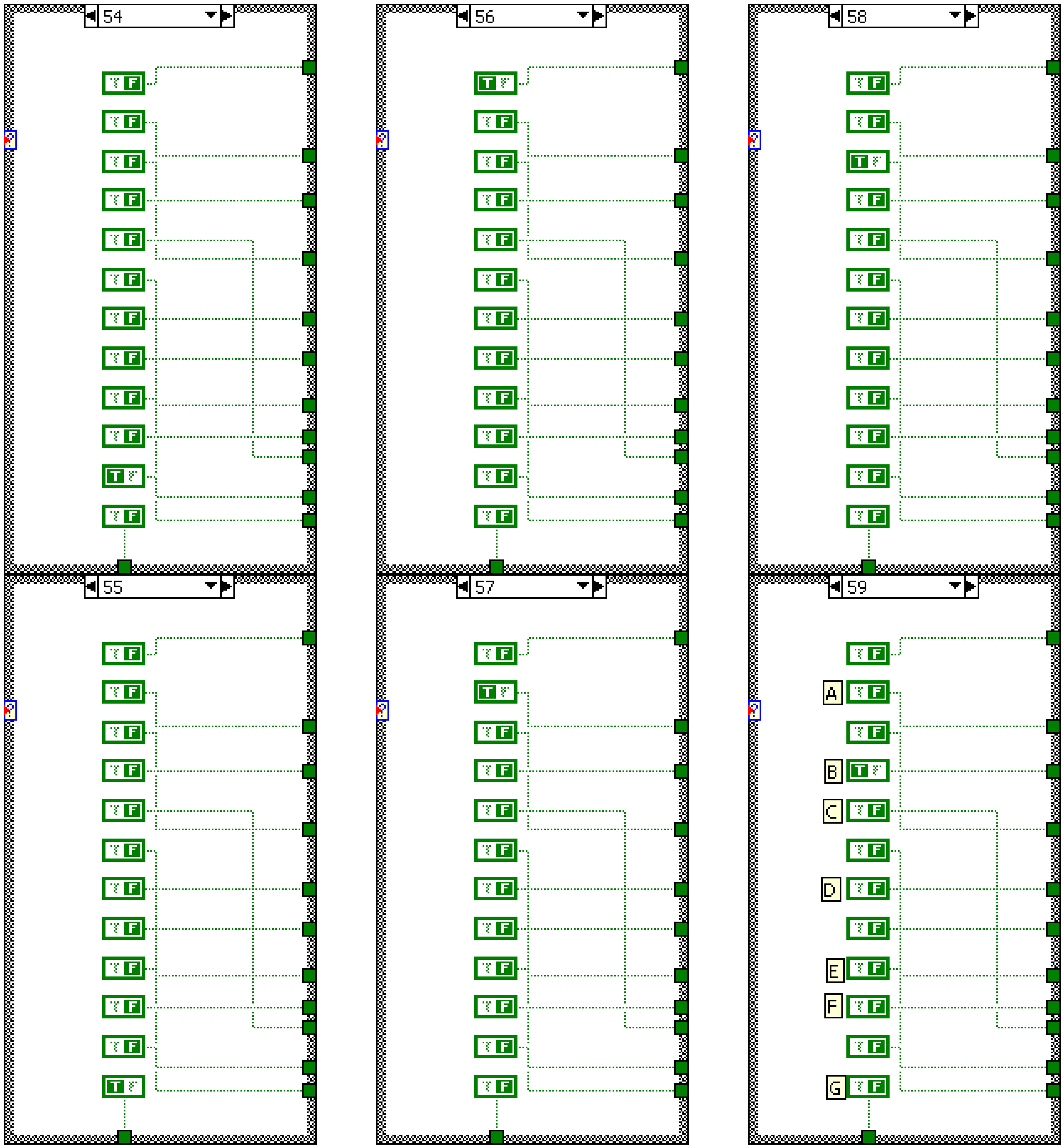

Figure A9.2: Case Structure Hidden States

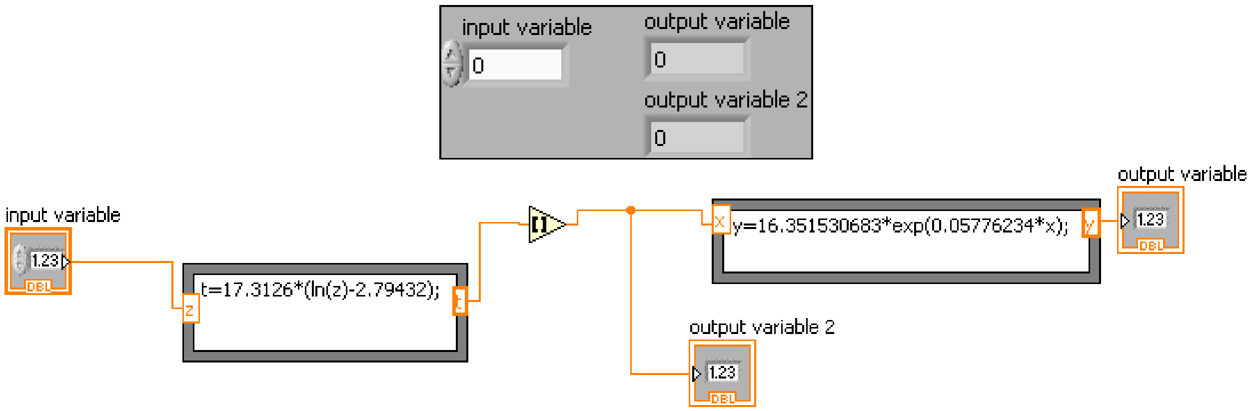

Figure A10: Round Frequency sub VI documentation