USAF ACADEMY
DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING
LESSON 13 LAB - DTMF
Lab Packet
Spring 2027

Name: _____ **Section:** _____ **Date:** _____

Learning Objective 6.2: I can decode DTMF tones from a captured audio signal.

This packet is the L13 Lab, in three parts, and you turn it in once, complete, before Lesson 14. Do **Part 1** on your own before the lab period: run the receiver and the link, and work out the block settings you will use at the bench. **Part 2** is your own measurements, recorded in class on your own laptop. Do **Part 3** on your own after the lab: explain what you saw, and answer the analysis questions.

Grading. One submission, graded against Objective 6.2 on the course's 1 / 0 scale, with revision allowed under course policy. Paste screenshots where a question asks for one.

Transmitting. Nothing in this lab transmits. Question 7 uses your phone's speaker and your laptop's microphone.

The flowgraphs are on the L13 lesson page, `L13-dtmf-rx.grc`, `L13-dtmf-link.grc`, and `L13-dtmf-keypad.grc`, and on the L13 Lab page, `L13-dtmf-mic.grc`, with the captures `L13-capture.wav` and `L13-lab-capture.wav`. Both captures are synthetic: `L13-dtmf-capture.grc` dialed them and added noise. Every number below assumes the flowgraphs' settings: $f_s = 8$ kHz, Goertzel blocks of $N = 205$ samples unless a question changes N, and the decoder's rules from the lesson: the best row and column bins hold 35% of a block's energy, each beats its group by 6 dB, the twist is within -10 to $+6$ dB, and three blocks in a row agree.

	1209 Hz	1336 Hz	1477 Hz	1633 Hz
697 Hz	1	2	3	A
770 Hz	4	5	6	B
852 Hz	7	8	9	C
941 Hz	*	0	#	D

Part 1: Pre-Lab (individual, before the lab period)

1. **Run the receiver.** Put every L13 file in one folder. Open `L13-dtmf-rx.grc` in GRC and run it on `L13-capture.wav`, the default.

   (a) After about 10 s, record the Digits and Numbers labels.

   (b) Paste a screenshot of the running flowgraph's window.

2. Settings and a first look at noise.

(a) Choose a number of at least seven digits that ends in #, such as a voicemail code. Write each key's row and column frequency from the grid.

(b) The bench changes the Goertzel Length N. Find the block time N/f_s and the bin spacing f_s/N, which is also the distance to the first null, for $N = 102$ and $N = 410$. For each, say whether a 50 ms tone can fill a whole block.

102:

410:

(c) Open and run `L13-dtmf-link.grc`. Set the Twist slider to -6 dB, so the column tone arrives weaker. Then lower the SNR slider from 20 dB, 1 dB at a time, waiting about 15 s at each step. Record the SNR at which the Numbers label first shows a number missed or wrong, and describe what the spectrum looks like there.

SNR

Part 2: Measurements (in class)

3. **Build the keypad and its bins.** Start GRC with an empty canvas. Do not open `L13-dtmf-keypad.grc`: build the keypad yourself as the lab page lists, then add the receiver's eight Goertzel bins.

   (a) Paste a screenshot of your flowgraph on the GRC canvas and of its spectrum with one key held. Every connection must be black, not red.

   (b) For three keys, read both spectrum peaks and compare them with the grid.

Key			
Row peak (Hz)			
Column peak (Hz)			

   (c) Add the eight Goertzel bins and the DTMF Decoder to your keypad, as the lab page lists. Hold one key and paste a screenshot of both time sinks. Which traces rise, and how high?

   (d) Press each key of your Question 2(a) number. Record the keys the decoder reports, and say whether they match.

4. Decode the lab capture. Run `L13-dtmf-rx.grc` on `L13-lab-capture.wav`, as the lab page lists.

(a) Record the number and paste a screenshot.

(b) Read the row and column peak heights. Which group arrives weaker, and about what fraction of the other group's height does it reach?

row

column

weaker

(c) Find the time from one dialing to the next and estimate the time per key, tone plus gap.

period

per key

5. The decoder's limits. Run `L13-dtmf-link.grc` as the lab page lists. At each setting, wait about 30 s and record the Numbers label as correct of decoded. A count of 0 of 0 means that no number decoded.

(a) Twist, with all 16 keys as the number:

Twist (dB)	-11	-10	-9	-8	$+4$	$+5$	$+6$	$+7$
Correct								

(b) Tone length, with 60 ms gaps:

Tone (ms)	25	28	30	33	35	40
Correct						

(c) Gap length, with 60 ms tones:

Gap (ms)	10	15	20	25	30	40
Correct						

6. **Block length.** Change the Variable `N` in `L13-dtmf-link.grc` as the lab page lists, and record the Numbers label.

N	Setting	Correct
102	22 ms tones, 60 ms gaps	
102	25 ms tones, 60 ms gaps	
102	30 ms tones, 60 ms gaps	
102	50 ms tones, $+1.5\%$ error	
102	50 ms tones, $+2.5\%$ error	
102	50 ms tones, $+3.5\%$ error	
410	50 ms tones and gaps	
410	100 ms tones, $+0.5\%$ error	
410	100 ms tones, $+1.0\%$ error	

7. A real phone. Run `L13-dtmf-mic.grc` as the lab page lists.

(a) Record the number you pressed and the Digits label, and paste a screenshot of the window while you press one key.

(b) Press keys as fast as you can. What does the decoder miss?

(c) Talk, whistle, or play music near the microphone. Record any false digits.

Part 3: Writeup (individual, after the lab)

8. Analysis.

(a) Lesson 13 says DTMF tones last 40 ms or longer and gaps 20 ms or longer, and the decoder's twist test allows -10 to $+6$ dB. Compare each with what you saw in Question 5. Where does the decoder start to miss digits, and why there?

(b) Use Question 6 to explain what a shorter and a longer Goertzel block gain and lose, and why $N = 205$ is the usual choice at 8 kHz.

(c) Compare the phone with the synthetic captures, and propose one change to the decoder for a noisy room.

Documentation: _____