USAF ACADEMY
DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING
LESSON 10 LAB - PAM LINK
Lab Packet
Spring 2027

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

Learning Objective 4.4: I can implement a PAM link that transmits and receives ASCII text end-to-end.

This packet is the L10 Lab, in three parts, and you turn it in once, complete, before Lesson 11. Do **Part 1** on your own before the lab period: run the link flowgraph and work out the packet you will see at the bench. **Part 2** is your own measurements, recorded in class: Questions 3 to 6 on your own laptop, and Question 7 at a PlutoSDR station with your team. Do **Part 3** on your own after the lab: explain, in words, what you saw.

Grading. One submission, graded against Objective 4.4 on the course's 1 / 0 scale, with revision allowed under course policy. Paste screenshots where a question asks for one.

Transmitting. In class we transmit only into a cable, into a shielded enclosure, or at very low power in an ISM band, and only when the lesson says to. Questions 1 to 6 run on your laptop and transmit nothing. Question 7 transmits from a PlutoSDR's TX port, through a cable with an inline 30 dB SMA attenuator, to the same Pluto's RX port, at 915 MHz. Connect the cable and attenuator before you run the flowgraph, and never connect an antenna in this lab. Never set TX attenuation below 30 dB or change the slider's range; the RX input is rated to only a few dBm.

The flowgraphs are on the L10 lesson page, `L10-pam-tx.grc` and `L10-pam-link.grc`, and on the L10 Lab page, `L10-pam-raw.grc` and `L10-pam-pluto.grc`. Every number below assumes their settings: `samp_rate` = 32 kHz, `sps` = 8, so 4 kbaud, $\alpha = 0.35$, and the default line `USAFA ECE 448: ASCII over PAM.`, 30 characters and a newline, 31 bytes.

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

1. **Run the link.** Open `L10-pam-link.grc` in GRC and run it with the sliders at their defaults, a noise amplitude of 0.3 and a clock error of 500 ppm.

   (a) After about 20 s, record the Lines label.

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

2. The packet. You will see each of these at the bench.

(a) Each line is a packet: a 64-bit access code, a 32-bit header, and the 31 bytes of the line. Find the bits per packet, the time per packet, and the number of packets in 30 s.

bits =

time =

in 30 s =

(b) Choose a line of text of your own, such as your class year and name. Write it below, count its bytes with the newline, and write the 16-bit length field the header will carry and the 8 bits of its first character.

Part 2: Measurements (in class)

3. **Bytes without packets.** Follow the lab page's steps for `L10-pam-raw.grc`, the link with no access code and no header. Each run, the receiver starts listening at a random bit.

   (a) For three runs, record the bit offset at which the Received bytes label reads as text.

Run	1	2	3
Offset that reads			

   (b) Stop and start `L10-pam-link.grc` three times. Record how long the first line takes to appear, and explain in words how the receiver finds the byte boundary that you had to find by hand in part (a).

4. **Build the transmitter.** Start GRC with an empty canvas. Do not open `L10-pam-tx.grc`: build the packet transmitter yourself as the lab page lists, with your line of text from Question 2(b) in `msg`.

   (a) Paste a screenshot of your flowgraph on the GRC canvas. Every connection must be black, not red.

   (b) Paste a screenshot of the time sink. Mark where the access code ends, where the header ends, and the bits of your first character, and check the length field against Question 2(b).

   (c) Read the edges of the shaped signal's spectrum from the frequency sink.

5. Noise. Run `L10-pam-link.grc` with the clock error at its default, 500 ppm, and the matched filter on. Start the noise amplitude at 0.5 and raise it by 0.1 at a time, waiting about 20 s at each step and watching the Lines label, the eye, and the Symbol Sync output, which is the 2-PAM constellation drawn against time. Note the displays at the default 0.3 first. The count restarts each time a slider moves.

(a) Record the noise amplitude at which lines start to break, where the correct count first falls behind the received count on the Lines label, and the setting at which no line arrives intact in 20 s.

break at

stop at

(b) Describe the eye and the Symbol Sync output at 0.3, at your break setting, and at your stop setting.

Noise	0.3	break	stop
Eye			
Symbol Sync output			

(c) Near 1.1, wait for a line with a wrong character in the Received label and paste a screenshot. Find the character, write its correct and received bytes in binary, and count the bits that differ.

(d) Set the noise to 0.5. Switch the matched filter off, wait 20 s, and record the Lines label and how the eye looks. Then switch it back on and do the same.

Matched filter	off	on
Lines label		
Eye		

6. Clock error. Set the noise amplitude back to 0.3. Set the clock error to 0, then raise it through the next four values below, in order, without stopping the flowgraph. At each, wait about 20 s, record the Lines label, and note how the eye sink looks. Then stop the flowgraph, run it again so the loop locks at the default 500 ppm, type 40,000 into the clock-error box in one jump, and record the Lines label after 20 s in the last column.

(a) Fill in the table.

ppm	0	$10{,}000$	$20{,}000$	$30{,}000$	$40{,}000$	jump to $40{,}000$
Lines correct						
Eye sink						

(b) Paste a screenshot at 10,000 ppm, and explain how the eye can look smeared while the Symbol Sync output stays at ± 1.

7. **The link on a PlutoSDR.** At a PlutoSDR station, with your team, follow the lab page's steps: connect the Pluto's TX port to its RX port through the 30 dB attenuator, check the Pluto with `iio_info -s`, and run `L10-pam-pluto.grc`. The transmitter and receiver share the Pluto's clock, so there is almost no clock or frequency error between them; the noise and the carrier phase come from the hardware.

   (a) If no line arrives within 5 s, switch Polarity. If neither setting works, raise the TX attenuation by 10 dB and try both again. Once lines arrive, paste a screenshot that shows the constellation, the received line, and the Lines label.

   (b) Stop and start the flowgraph three times. Each time, record which polarity setting delivers lines.

Run	1	2	3
Polarity that works			

   (c) Stop the flowgraph, put your line from Question 2(b) in `msg`, run it again, and paste a screenshot of your line arriving.

Part 3: Writeup (individual, after the lab)

8. Analysis. Answer in words; no formulas are needed.

(a) Your link went from every line intact to none over a fairly small change in the noise amplitude. Explain why, using what a line needs in order to count as correct, and say what that means for a link on a real radio.

(b) Explain why switching the matched filter off broke the text at a noise level the link handled easily with it on.

(c) Your link held nearly every line to at least 10,000 ppm. Compare that with two radios whose crystals are accurate to 20 ppm each, and say what would happen to the link if you replaced Symbol Sync with Keep 1 in N, which samples at a fixed point.

(d) Explain why the working polarity changed between runs on the Pluto, and propose a change to the receiver that would make the polarity switch unnecessary.

Documentation: _____