Amplitude Modulation Systems Theoretical Modeling and Hardware Validation Questions and Answers

Part 2.1

Question 1

The theoretical phase shift between a sinewave and a cosine wave is 90°. If your measurement isn't exactly 90°, what could explain the difference?

- A: *Real world components introduce parasitic capacitance and inductance that cause unintended phase lag. Additionally, the Master Signals module uses electronic circuitry to derive the cosine from the sine; any slight mismatch in the component tolerances of the phase-shifting network will result in a deviation from the ideal* $90°$

Question 2

Calculate the Buffer module's gain (on its present gain setting).

- A: **values are from Part 2.1 Table 3*

$$A_v = \frac{V_{out}}{V_{in}} = \frac{4.11V}{3.92V} = 1.05$$

Question 3

Calculate the Buffer module's new gain.

- A: **values are from Part 2.1 Table 4*

$$A_v = \frac{V_{out}}{V_{in}} = \frac{360mV}{3.92V} = 0.09$$

Question 4

In terms of the gain figure, what's the difference between gain and attenuation?

- A: *A gain figure greater than 1 ($A_v > 1$) indicates amplification, where the output signal is larger than the input. A gain figure between 0 and 1($0 < A_v < 1$) indicates attenuation, where the signal is reduced in size. A negative gain figure simply indicates a $180°$ phase inversion.*

Question 5

What do you think the output signal would look like if the buffer's gain was sufficiently large?

- A: *The signal would undergo "clipping" or saturation. Since the ETT 101 modules are powered by fixed voltage rails, the output cannot exceed these limits. A sine wave with excessive gain would be flattened at the peaks, eventually resembling a square wave.*

Question 6

Why is the Master Signals module's 100kHz SINE output inaudible?

- A: *The human auditory system is biologically limited to a frequency range of approximately 20kHz to 20kHz. A 100kHz signal is ultrasonic, meaning its frequency is too high to vibrate the mechanisms of the human ear.*

Part 2.2

Question 1

What aspect of the Adder module's performance does the G control vary?

- **A:** *It varies the "weighting" or scaling factor of the A input. It acts as a dedicated volume control for that specific channel before it is summed with input B.*

Question 2

What is the range of gains for the A input?

- **A:** *On the ETT-101, the G and g controls typically provide a range from 0 (fully attenuated) to approximately 2 (doubling the signal voltage).*

Question 3

Compare the results in Tables 1 and 2. What can you say about the Adder module's two inputs in terms of their gain?

- **A:** *The inputs are functionally identical and independent. The gains G and g are matched in performance, allowing for symmetrical summation of two signals.*

Question 4

What is the relationship between the amplitude of the signals on the Adder module's inputs and output?

- **A:** *It follows the linear summation law:* $V_{out} = (G \cdot V_a) + (g \cdot V_b)$ *The output amplitude is the sum of the scaled versions of the individual inputs.*

Question 5

This module's output signal can be phase shifted by different amounts

☑ but it always leads the input signal.
☐ but it always lags the input signal.
☐ and can either lead or lag the input signal.

Question 6

Is the Phase Shifter module capable of shifting a signal by 360°? Tip: If you're not sure, repeat steps 31 to 33.

- **A:** *No. Most analog phase shifters are limited to a range of* $180°$*. To achieve a* $360°$ *shift (which is effectively returning to* $0°$*), multiple phase-shifter modules would need to be cascaded in series.*

Part 2.3

Question 1

What happens to the Variable DCV module's VDC output when you turn the VDC control clockwise?

- **A:** _Turning the control clockwise increases the positive DC voltage output of the Variable DCV module._

Question 2

What happens to the frequency of the VCO module's output when you turn the VDC control clockwise?

- **A:** _With relation to the answer to question 1, When this is fed into the Voltage Controlled Oscillator (VCO), the increased control voltage causes the output frequency of the VCO to increase proportionally._

Question 3

What happens to the Variable DCV module's VDC output when you turn the VDC control anti-clockwise?

- **A:** _Turning the control anti-clockwise decreases the DC voltage (moving toward 0V or negative)._

Question 4

What happens to the frequency of the VCO module's output when you turn the VDC control anti-clockwise?

- **A:** _With relation to the answer to question 3, This causes the VCO frequency to decrease, as the oscillator's timing circuit slows down in response to the lower control voltage._

Part 3

Question 1

Is the Adder module's measured output voltage exactly 8Vp-p as theoretically predicted?

- **A:** _No, it is rarely exact._

Question 2

What are two reasons for this?

- **A:** _This is due to component tolerances within the Adder circuitry and loading effects where the oscilloscope's input impedance slightly draws current from the module, causing a small voltage drop._

Question 3

What are two reasons for the output not being 0V as theoretically predicted?

- **A:** _For perfect cancellation, the two signals must be exactly $180°$ out of phase and have identical amplitudes. In hardware, slight phase errors in the phase shifter and minor differences in the G/g gain settings prevent a perfect "null" output._

Question 5

What can be said about the phase shift between the signals on the Adder module's two inputs now?

- **A:** *For maximum output, the phase shift between inputs is now $0°$(in phase).*

Question 6

What can be said about the gain of the Adder module's two inputs now?

- **A:** *The gains G and g are both set to their maximum (approximately 2) to achieve the largest possible summed amplitude.*

Part 4

Question 1

In what way is the Adder module's output now different to the signal out of the Master Signals module's 2k/2 SINE output?

- **A:** *The Adder output contains a DC Offset. While the original signal was centered at $0V$, the Adder output is shifted upward, making the entire sine wave sit in the positive voltage region.*

Question 2

What feature of the Multiplier module's output suggests that it's an AM signal? Tip: If you're not sure about the answer to the questions, see the preliminary discussion.

- **A:** *The appearance of the Symmetrical Envelope. The high-frequency carrier's peaks now trace the shape of the low-frequency message signal, indicating that the carrier's amplitude is being successfully modulated.*

Question 3

The AM signal is a complex waveform consisting of more than one signal. Is one of the signals a 2kHz sinewave? Explain your answer.

- **A:** *Yes, the 2kHz is the modulating signal or message used to create an AM signal. When the 100kHz carrier signal and the 2kHz modulating signal combines at the mixer, the lower frequency signal modulates the higher frequency signal.*

Question 4

For the given inputs to the Multiplier module, how many sinewaves does the AM signal consist of, and what are their frequencies?

- **A:** *The AM signal consists of 2 sine waves, A 2khz Modulating signal and a 100kHz Carrier signal.*

Question 5

Why is there still a signal out of the Multiplier module even when you're not talking, whistling etc.

- **A:** _There is still an input from the speech module because it is sensitive and have internal noise, and the carrier is still providing input and is being modulated by this input from the modulating signal therefore there is still an output._

Question 6

What is the relationship between the message's amplitude and the amount of the carrier's modulation?

- **A:** _They are directly proportional. As the message amplitude increases, the "swing" of the carrier's amplitude increases, leading to a higher Modulation Index (m)._
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Question 7

What is the problem with the AM signal when it is over-modulated?

- **A:** _In over-modulation ($m > 1$), the envelope crosses the zero axis and the carrier undergoes a $180°$ phase reversal. This makes it impossible for a simple envelope detector to recover the message, resulting in severe audio distortion._

Question 8

What do you think is a carrier's maximum modulation index without over-modulation?

- ☐ **A minus number**
- ☐ **0**
- ☑ **1**
- ☐ **Greater than 1**