Multiple Choice

1. You need to drive a high-current DC motor with the capability to operate forwards and in reverse. Which component is best suited for this task?
    a. A single NPN transistor
    b. A single PNP transistor
    c. A voltage regulator with adjustable output
    d. An H-bridge motor driver
    e. A potentiometer with a high resistance

    Justification: (d) an H-bridge is specifically designed to control the direction and speed of DC motors by enabling current flow in both directions. The other options lack this bidirectional capability.

2. You are designing a circuit with a push-button switch, connected to a microcontroller input pin. What is the purpose of using a pull-down resistor with the switch?
    a. To limit the current flowing through the switch when pressed
    b. To ensure a defined voltage level on the input pin when the switch is open
    c. To prevent electrical noise from affecting the input signal
    d. To increase the switching speed of the button
    e. All of the above

    Justification: (b) a pull-down resistor provides a default low logic level when the switch is open, preventing a floating input state that can lead to unpredictable behavior.

3. What are the key differences between a potentiometer and a rheostat?
    a. A potentiometer has three terminals, while a rheostat has two
    b. A potentiometer is typically used for voltage division, while a rheostat is used for variable resistance
    c. A potentiometer provides a linear output when used as a voltage divider, while a rheostat's output depends on the circuit configuration
    d. A and C
    e. A, B, C

    Justification: (e) accurately encompasses the difference in the number of terminals and typical applications of potentiometers and rheostats, including the linear output characteristic of potentiometers in voltage divider configuration.

4. Many computer components include bypass capacitors near the integrated circuit (IC). What is the purpose of placing capacitors in close proximity to the IC?
    a. To store energy and provide a stable voltage supply during high-frequency switching
    b. To filter out low-frequency noise from the power supply
    c. To increase the current carrying capacity of the power supply
    d. To protect the circuit from electromagnetic interference
    e. All of the above

    Justification: (a) bypass capacitors act as local energy reservoirs to counteract rapid voltage drops caused by sudden current demands during high frequency switching of digital circuits.

5. What is the primary difference between classification and regression tasks in machine learning?

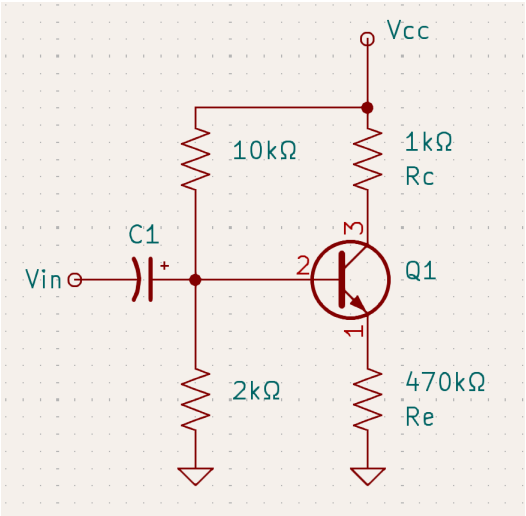
a. Classification used labeled data, while regression uses unlabeled data
b. Classification is used for prediction, while regression is used for data analysis
c. **Classification predicts discrete categories, while regression predicts continuous values**
d. Classification models are simpler than regression models
e. Classification models are used for organized data, while regression models are used for random data

Justification: (c) accurately distinguishes the fundamental difference between classification and machine learning tasks based on the output they predict.

Long answer

Problem 1

Transistors are essential semiconductor devices that control current flow. In this circuit, we are using a bipolar junction transistor (BJT) with three terminals: 1) emitter, 2) base, and 3) collector. The voltage divider bias circuit sets the BJT's operating point using resistors to control the base current, which in turn affects the larger current flow between the collector and emitter. This bias voltage determines whether the transistor operates in its active region (for amplification) or its saturation/cutoff regions (for switching).



a. Calculate Vbase.

$Vbase = Vcc * R2 / (R1 + R2)$

Vbase = 12V * 2kΩ / (10kΩ + 2kΩ) = <u>2V</u>

b. Calculate the base current (Ib) and the collector current (Ic). Assume the transistor has a β (beta) value of 100 and a base-emitter voltage drop (Vbe) of 0.7V.

$Ib = (Vbase - Vbe)/(RE + (\beta + 1) * RE)$

$Ic = \beta * Ib$

Ib = (2V - 0.7V) / (470Ω + (100 + 1) * 470Ω) = 2.71*10^-5 A ≈ <u>2.67 µA</u>

c. Determine the voltage at the collector node (Vc) using the equation:

$Vc = Vcc - Ic * RC$

Ic = 100 * 2.67 µA ≈ <u>267 µA</u>

d. Explain the purpose of the capacitor (C1) in the circuit and how it affects the circuit's operation.

C1 is a coupling capacitor. It blocks the DC component of the input signal while allowing the AC component to pass through to the transistor. This prevents DC bias of the previous stage from affecting the biasing of the transistor.

Problem 2

You're tasked with developing a smart energy monitoring system for homes. The goal is to identify individual appliances (e.g. refrigerator, washing machine, toaster) based on their unique electrical power consumption signatures using machine learning. This information can then be used to provide insights into energy usage patterns and potentially automate energy-saving actions.

a. Identify and describe at least 3 potential features from power consumption data that can effectively differentiate between appliances. *For example, the maximum power consumption for a blender will be significantly higher than a radio.*
    - **Peak power consumption: appliances like blenders and hair dryers exhibit high peak power usage compared to low power devices, like radios or lamps**
    - **Duty cycle: applications with cyclical on-off patterns, such as refrigerators or air conditioners, can be identified by analyzing the ratio of on-time to total cycle time**
    - **Frequency of power cycles: washing machines and dishwashers have distinct operating cycles with characteristic frequencies of power fluctuations**

Answers are not limited to these three and can include: avg power consumption, duration of power cycles, characteristic shapes of power consumption curves (e.g. spikes, plateaus)...

b. Describe how cross validation can be used to evaluate the performance of the trained model and estimate its ability to generalize to unseen data, such as a new appliance added to the home.

Cross-validation involves splitting the labeled power usage dataset into k folds, training the model on k-1 folds, and testing on the remaining fold. This process is repeated k times, with each fold used for testing once. The performance metrics (e.g., accuracy, precision, recall) are calculated for each fold, and the average performance across all folds provides a more reliable estimate of the model's generalizability to new appliances or unseen power usage patterns.

c. Discuss the advantages and limitations of k-fold cross-validation compared to other model evaluation techniques (e.g. cross validation vs training error).

Advantages:

- **Provides a more comprehensive estimate of the model's performance compared to using a single training/testing split or just the training error, as it reduces the variance in the performance estimate and helps assess the model's ability to generalize to unseen data**

Limitations:

- **Can be computationally expensive, especially for large datasets or complex models**
- **Choosing the optimal value of k involves a trade-off between bias and variance in the performance estimate**