PULSE WIDTH MODULATION

Objective:

To design and simulate a circuit that demonstrates Pulse Width Modulation (PWM).

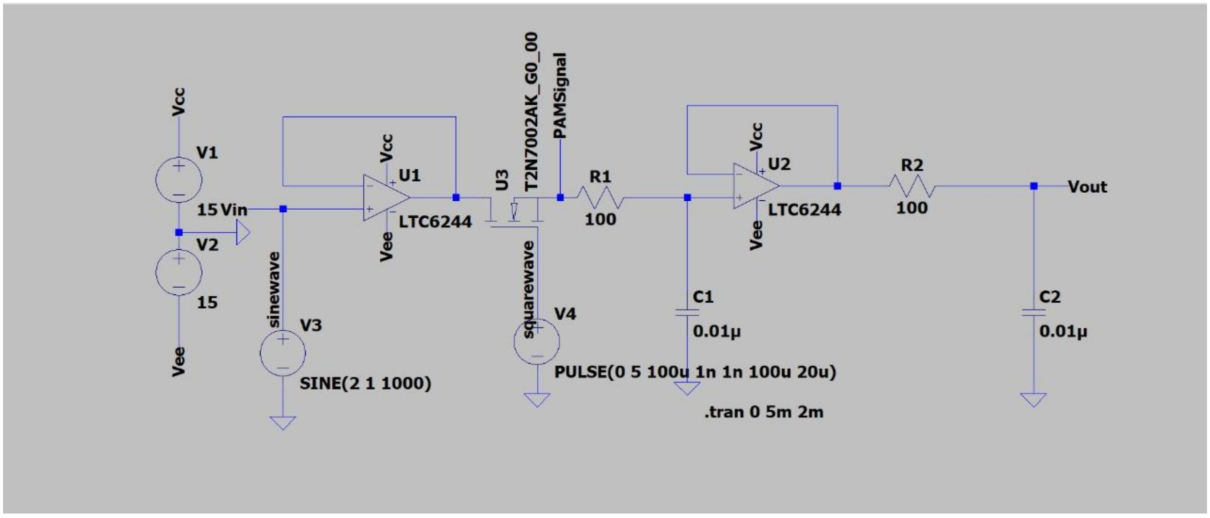
Understand how analog signals (sine wave) can be modulated with a digital control signal.

Introduction to PWM:

PWM, or Pulse Width Modulation, is a technique used to control the power delivered to a device by varying the width of pulses in a signal.

Applications include motor speed control, audio signal modulation, power control, and communication systems.

Circuit Overview:



Components Used:

- LTC6244 Op-Amps (U1, U2)
- 2N7002 N-MOSFET
- Passive components: Resistors (R1, R2), Capacitors (C1, C2)

- Voltage sources: Sine wave input, Pulse input

Function: Op-amps buffer signals, transistor acts as a comparator switch

Working Principle:

- Sine wave and pulse signal are applied to the circuit.
- When the sine wave voltage is greater than the pulse voltage, the transistor conducts.
- This results in a modulated PWM output that varies with the sine wave amplitude.

Simulation Setup:

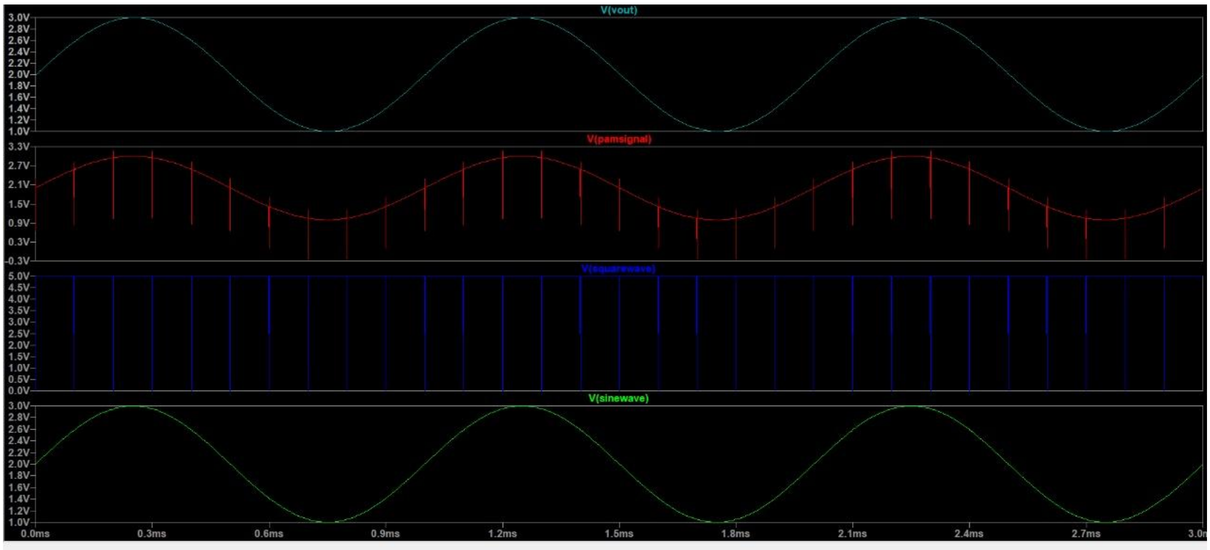
Software Used: LTspice

Input Signals:

- SINE(2 1 1000): 2V offset, 1V amplitude, 1kHz frequency
- PULSE(0 5 100u 1n 1 n 100u 20u): 0-5V pulse with defined timing

Simulation Command: .tran 0 5m 2m

Simulation Results:



- V(sinewave): Analog sine input
- V(pwm signal): Pulse waveform
- V(pamsignal): Modulated signal at gate of transistor
- V(out): Final PWM output

Output Analysis:

- PWM output width increases with rising sine amplitude.
- Width decreases as the sine wave amplitude drops.
- This shows the analog signal is effectively converted to PWM.

Applications:

🔁 1. Motor Speed Control (DC & Servo Motors)

Where: In fans, electric vehicles, robots, drones.

Why: By adjusting the PWM duty cycle, the average voltage sent to the motor changes—controlling its speed **without wasting energy** as heat.

💡 2. LED Dimming

Where: Smart lighting, TV backlights, LED displays.

Why: PWM can switch LEDs on and off very quickly. By changing how long it's ON vs OFF (duty cycle), you **control brightness**.

🔊 3. Audio Signal Generation / Amplification

Where: Audio systems, music synthesizers, class-D amplifiers.

Why: PWM can be used to create audio waveforms or drive speakers efficiently with less heat loss compared to analog amplifiers.

🔌 4. Power Delivery / Voltage Regulation

Where: Power supplies, battery chargers, solar inverters.

Why: PWM helps regulate output voltage using high-frequency switching, improving efficiency over analog regulators.

🖥️ 5. Communication Protocols

Where: Infrared remotes, RC (remote control) systems, some types of wireless communication.

Why: PWM can encode data using the width of pulses, making it useful for simple communication systems.

🤖 6. Robotics & Automation

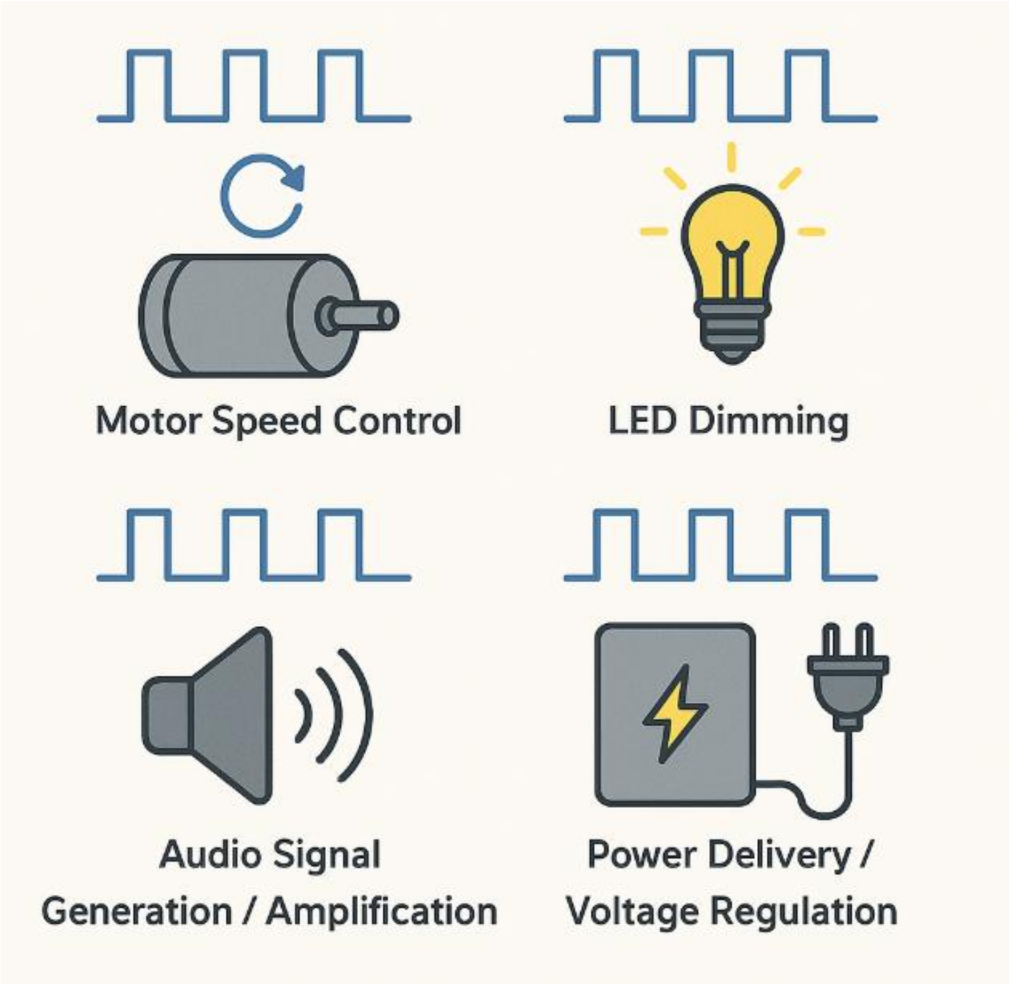
Where: Arduino/embedded systems, robotic arms, hobby drones.

Why: PWM is used to control motor speed, servo position, or even modulate signals for sensors and actuators.

🚘 7. Automotive Systems

Where: Electric window motors, throttle control, lighting, climate control.

Why: PWM provides **efficient control** without needing heavy analog circuits—crucial for automotive electronics.



Conclusion

- PWM successfully generated based on sine wave input.
- Circuit and simulation demonstrate expected modulation.
- PWM technique is essential in many real-world electronic applications.

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