Converting Motor RPM into a 0-to-360-degree ramp signal

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1.0 Abstract

This article presents a method to convert motor rotational speed (RPM) into a continuous ramp signal spanning 0 to 360 degrees, utilizing LTspice for simulation and implementation. The approach starts with foundational mathematical equations that translate mechanical RPM into electrical angular position, incorporating key conversions such as half the electrical speed in radians per second and the rotor's angular displacement in degrees.

The LTspice implementation leverages behavioral voltage sources and integrators to generate a dynamic ramp signal that accurately reflects rotor position, adapting to both positive and negative RPMs. A key insight includes the necessity of halving the electrical speed to align with trigonometric function behaviors, particularly due to the doubling frequency of the tangent function compared to sine and cosine. Simulation results validate the technique with varying RPMs and rotor pole counts, showcasing bidirectional ramp generation suitable for applications in motor control and position tracking systems.

2.0 Introduction

Understanding rotor position is a fundamental requirement in electric motor control systems, especially for applications such as field-oriented control (FOC), sensorless control, and real-time monitoring. One key technique is converting a motor's rotational speed (RPM) into a continuous ramp signal that spans from 0 to 360 degrees—representing the angular position of the rotor within a single electrical revolution. This article outlines the mathematical approach and LTspice implementation to generate such a ramp, complete with practical examples and simulation results.

3.0 Foundational Mathematical Equations

First, let us look at math. Equations numbered 1 through 6 below illustrate the steps.

$$n = RPM \quad \text{... Motor RPM (1)}$$

Motor RPM (n): This is the input mechanical speed of the motor in revolutions per minute (RPM).

$$p = number\ of\ rotor\ poles \quad \text{... (2)}$$

Where *p* is the number of poles. The electrical speed is proportional to mechanical speed and number of pole pairs.

$$W_{e\frac{1}{2}} = \frac{\pi.n.p}{120} \quad \text{... Half Electrical Speed in rad/s (3)}$$

This adjustment plays a critical role, as explained later, due to trigonometric frequency behavior.

$$\theta_i = \int W_{e\frac{1}{2}} dt$$ ... Intermediate rotor angle in Electrical rad/s (4)

The integration of half the electrical speed gives a linearly increasing (or decreasing) signal over time, essentially a “forever ramp.”

$$\theta_r = \tan^{-1}\left(\frac{Sin(\theta_i)}{Cos(\theta_i)}\right) + \frac{\pi}{2}$$ ... Rotor position in Electrical radians (5)

$$\theta_{360} = 360.\frac{\tan^{-1}\left(\frac{Sin(\theta_i)}{Cos(\theta_i)}\right)+\frac{\pi}{2}}{\pi}$$ ... Rotor Position in Electrical degrees (6)

This ensures the ramp wraps around at 360 degrees, producing a clean cycle from 0 to 360 and back.

4.0 LTspice Implementation

The above equations are implemented in LTspice using B-sources—behavioral voltage sources capable of defining voltage or current based on mathematical expressions.

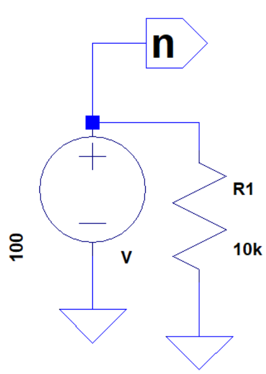

Figure 1: The motor speed n is modeled as a voltage source that varies with time. For example, a sinusoidal input mimics acceleration and deceleration.

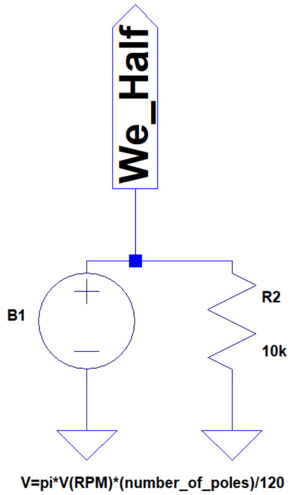

Figure 2: Implementation of We Half, Half of Electrical Speed in rad/s. A behavioral voltage source calculates half of the electrical speed in rad/s using the motor RPM and number of poles.

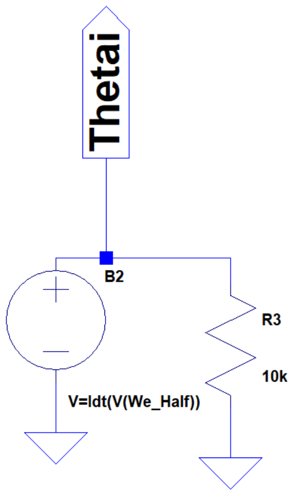

Figure 3: Implementation of the Integral Function to obtain θ_i, which is essentially a forever ramp. LTspice integrators accumulate the electrical speed over time, forming a ramp signal representing rotor angle in electrical radians.

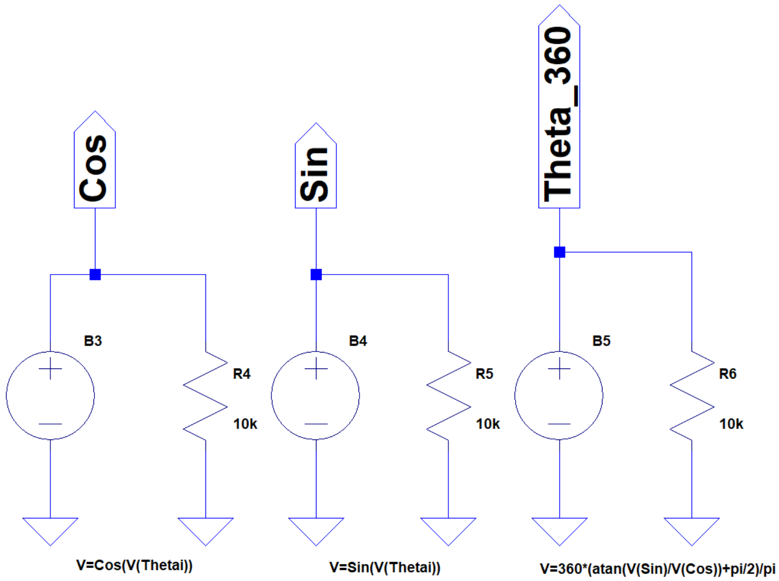

Figure 4: Implementation of θ_{360} ramp that increments positively from 0 to 360 for positive rpm and decrements 360 to 0 for -ve rpm. The final behavioral block uses the Tanfunction to constrain the ramp between 0 and 360 degrees. The direction of the ramp reflects the sign of the motor RPM—positive for forward rotation and negative for reverse.

5.0 Why do we calculate We half – Half electrical speed?

A common question arises: Why calculate half of the electrical speed? The answer lies in the behavior of trigonometric functions. To answer this, we need to look at the Sine, Cosine and Tangent functions.

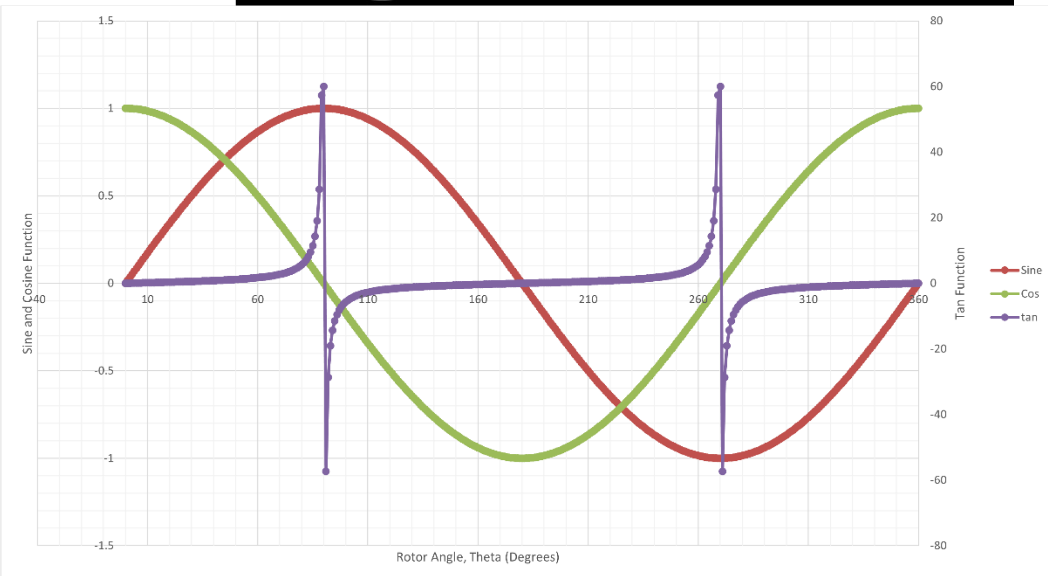

Figure 5: A plot of sine, cosine, and tangent functions reveals that the tangent function completes two cycles in the same period where sine and cosine complete one. This doubling in frequency can lead to distorted position signals when interpreting ramp outputs using tangent-based decoding with We half adjustment. By halving the electrical speed before integration, the resulting ramp frequency matches the expected sine/cosine-based waveforms used in most motor control algorithms.

6.0 Simulation Results

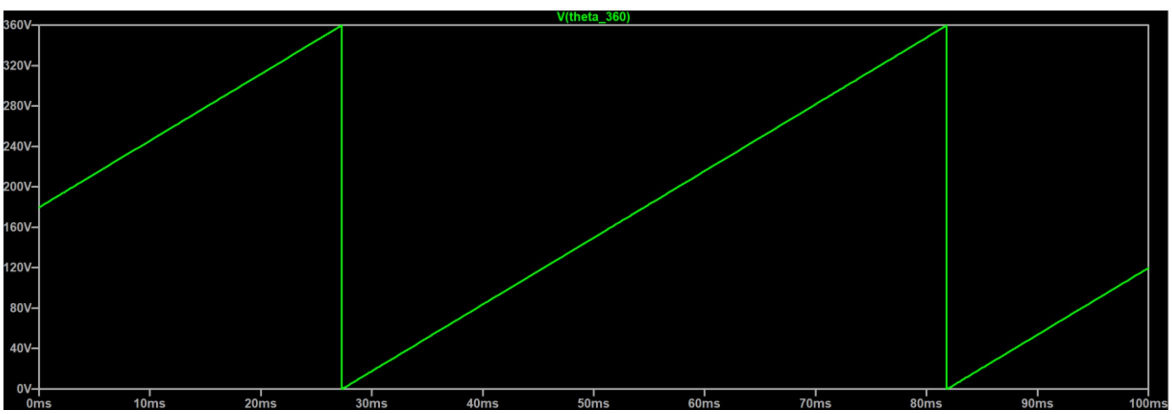

Figure 6: Zero-to-360-degree Ramp for Motor Speed of 100 RPM with 22 number of rotor poles

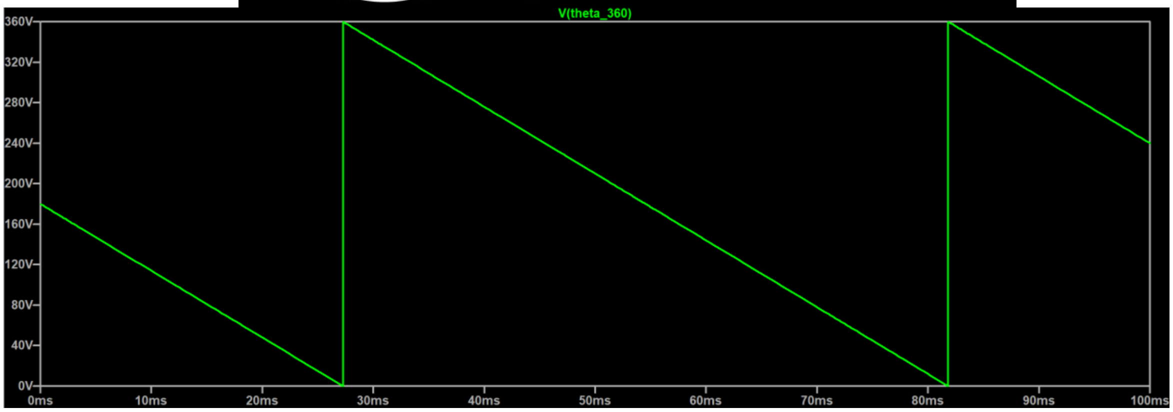

Figure 7: 360-to-Zero-degree ramp with -100 rpm Motor Speed.

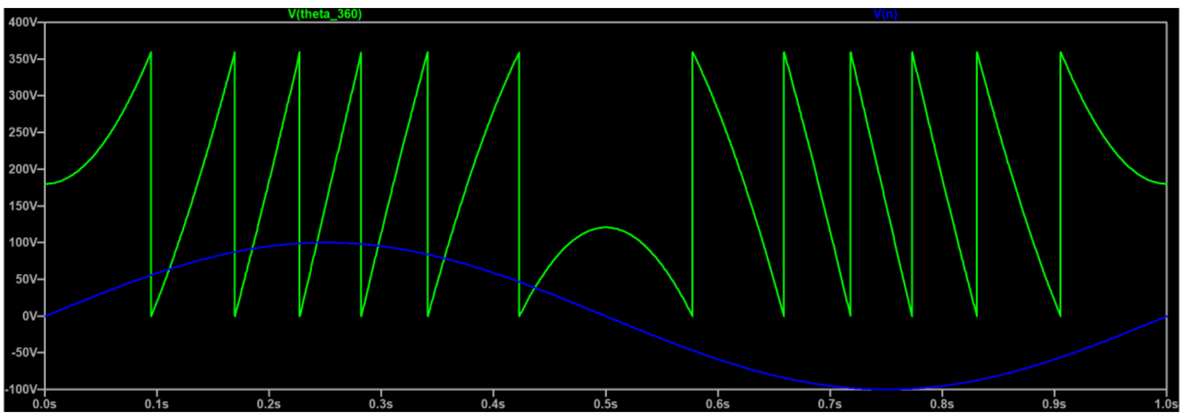

Figure 8: Up and Down rotor position ramp with the Motor Speed varying as a Sine with 100 rpm as max speed.

7.0 Applications and Significance

This approach is highly valuable in simulation environments for validating control algorithms, sensorless estimation techniques, and hardware-in-the-loop testing. Engineers can use the 0-to-360-degree ramp as a reference input or internal signal in motor control strategies. Additionally, the modularity of the LTspice implementation allows easy adaptation to different pole counts and motor types.

8.0 Conclusion

The conversion of motor RPM into a 0-to-360-degree rotor position ramp using LTspice provides a robust and insightful method for modeling motor behavior. By leveraging a sound mathematical foundation and behavioral modeling, the approach supports accurate and dynamic simulation of electrical angle tracking. This forms a crucial building block in the development and validation of modern electric motor control systems.