Signal Processing with PWM Power Supplies

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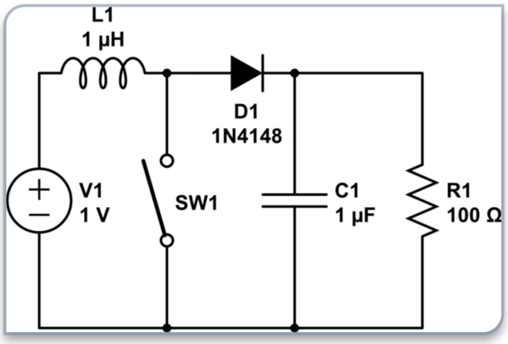
***Abstract*—Switching mode power supplies appear in many consumer and commercial electronic devices. Their efficient and cost-effective nature allows companies to design their products with lower costs. This paper focuses on how microcontrollers, paired with simple switching hardware can create a relatively stable output supply from varying input.**

I. Introduction

In basic terms, switching power supplies take an input supply and use pulse-width modulation(PWM) to create an output supply. While more efficient than its linear regulator counterpart, the switching power supply needs more hardware to function correctly. The PWM frequency must be constantly monitored in order to maintain the desired output voltage, if the load varies, the output voltage will swing; this problem is accounted for with a microcontroller or integrated circuit to monitor the output voltage; an algorithm is employed to correct the PWM frequency need be. A sample boost circuit is shown below.



II. Collecting Voltage Data

Collecting voltage data can occur in a few ways depending on desired accuracy. One method consists of using the microcontroller's built in analog to digital converter; which gives a reasonable amount of accuracy and has a simple implementation, additionally if more accuracy is needed a I2C connected daughter board equipped with a higher resolution ADC can be used. Both methods give varying signals that need appropriate filtering; by using polynomial interpolation we can take discrete varied sample data and transform it into continuous less varied data, this allows for smoother PWM frequency adjustments. Additionally, continuous functions allow operations like differentiation and integration to be carried out more easily.

III. Polynomial Interpolation

In basic terms, interpolation is the computation of points or values between ones that are known or tabulated using the surrounding points or values (Interpolation -- from Wolfram MathWorld, 2019). This idea leads to the notion of an "interpolant", which is a function that agrees with a particular set of data points. In this case, we use the monomial basis to construct the interpolant; linear algebra is employed to construct a system of equations. Note, for a given set of points, there is a unique polynomial that flows through them. The Vandermonde matrix is specifically used when constructing an interpolant from the monomial basis(Shown Below).

$$\begin{bmatrix} 1 & x_1 & x_1^2 & \dots & x_1^{n-1} \\ 1 & x_2 & x_2^2 & \dots & x_2^{n-1} \\ 1 & x_3 & x_3^2 & \dots & x_3^{n-1} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ 1 & x_n & x_n^2 & \dots & x_n^{n-1} \end{bmatrix}$$

The Vandermonde matrix is filled with corresponding x-values and the following linear system is constructed:

$$V\boldsymbol{x} = \boldsymbol{y}$$

Where the x and y vectors are the coefficients to the interpolant polynomial, and data point function values respectively. Row reduced echelon form yields the x vector, which can be formed to create the cubic polynomial:

$$P_3(x) = a_2x^2 + a_1x + a_0$$

IV. Fundamentals of Power Conversion

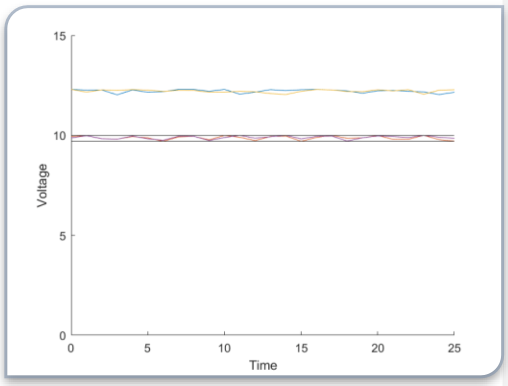
One of the most simple and fundamental ways to transform electrical power is with the resistor; many circuits can be created in order to translate between various voltage levels and current demands. Unfortunately, this method has significant drawbacks in terms of efficiency(heat). As technology progressed, engineers quickly realized heat wasted is energy lost from a system, and consequently looked for clever ways to reduce the amount of energy lost due to potential conversions.

Engineers developed the linear voltage regulator which provides a fixed output current and voltage regardless of its input; while an improvement compared to a primitive voltage divider, linear regulators still dissipate their power drop as heat. However, they shine in terms of simplicity, reliability and practical usage. Linear voltage regulators generally require much less components to build than their switching supply counterparts and can actually help reduce the amount of voltage ripple. Overall, linear regulators do not lend themselves very well to high-efficiency converters but have their place in designs (Basso, 2014, p. 18).

With the invention of the transistor, clever engineers suggested the notion of using switches(transistors or MOSFETS) in power supply designs. These silicon devices would allow for a much more efficient conversion of electrical power due to their higher efficiency switching states. By sending varying square waves(duty cycle) to the switching devices, output voltage regulation is achieved. Overall, switching power supplies provide higher efficiency, less overhead cost, and more compact designs; making them the ideal choice for many applications.

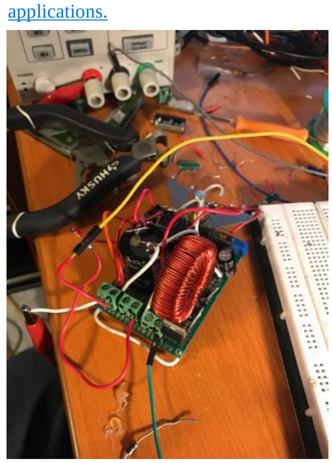
Algorithm Implementation

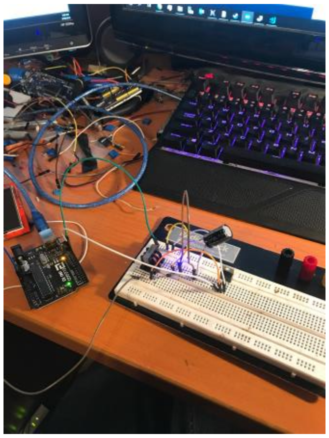
Voltage data is collected by an ARM microcontroller, to reduce noise 10 samples are taken and averaged; this is repeatedly done to yield 10 total datapoints. The resulting data is interpolated using a preformed Vandermonde matrix; the row reduced echelon form is hard coded in order to allow for a performance boost. At this point we "query" the interpolant function; if no PWM frequency change is required, at least 90 percent of the queried interpolant points should fall within the voltage threshold. This is demonstrated below, the voltage samples at the top represent unmodified values; the PWM frequency is adjusted to force the output voltage into the acceptable threshold range.



VI. Conclusion

Constructing switching power supplies is no easy task, after many attempts; acceptable parameters were achieved. Pictured below is the final construction of a switching power supply driven by the feedback algorithm previously mentioned and an AVR microcontroller. At an input voltage of 12 volts, and a boost voltage of around 14.4 volts; a load of 200 milliamps results in a current draw of about 500 milliamps from the 12-volt source. This investigation has shown that switching power supplies are efficient, and worthy of varying engineering applications.





VIII. Works Cited

Basso, C. P. (2014). *Switch-Mode Power Supplies.*

Burden, R. L., & Faries, J. D. (2011). *Numerical Analysis* (9th ed.). Boston: Cengage.

Interpolation -- from Wolfram MathWorld. (2019). Retrieved from Wolfram MathWorld: http://mathworld.wolfram.com/Interpolation.html