# Frequency Dither Circuit for Electronic Ballast EMI Reduction

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## Abstract

Electronic ballasts include switched-mode circuits that can generate a high amount of electro-magnetic interference (EMI). This EMI can conduct through various paths within the electronic ballast circuit and eventually reach the AC mains voltage as conducted noise. To block this noise, an L-C filter is typically placed at the input of the circuit. These filters can be difficult to design due to their second-order nature, and, can be a significant overall cost increase due to the size and the multi-winding requirements of the filter inductor. This paper describes a novel frequency dithering circuit used to spread and reduce the amount of EMI and therefore reduce the size and cost of the EMI filter. This paper introduces the designer to the main circuit blocks of an electronic ballast, presents the new frequency dither EMI reduction circuit, and provides the complete electronic ballast circuit driving a single 26W compact fluorescent lamp with experimental results.


## 1. OVERVIEW

The functions performed by present day electronic ballasts include electromagnetic interference (EMI) filtering to block ballast generated noise, rectification, and a half-bridge resonant output stage for high-frequency AC control of the lamp (Figure 1). This is presently one of the most popular approaches to powering fluorescent lamps with power levels below 26W. Controlling fluorescent lamps also requires additional circuitry necessary for preheating the lamp filaments, constant ignition voltage control, and end-of-life (EOL) protection. The focus of this paper is on the oscillator circuit used to control the operating frequency of the half-bridge resonant output circuit and the new frequency dithering feature to reduce EMI.

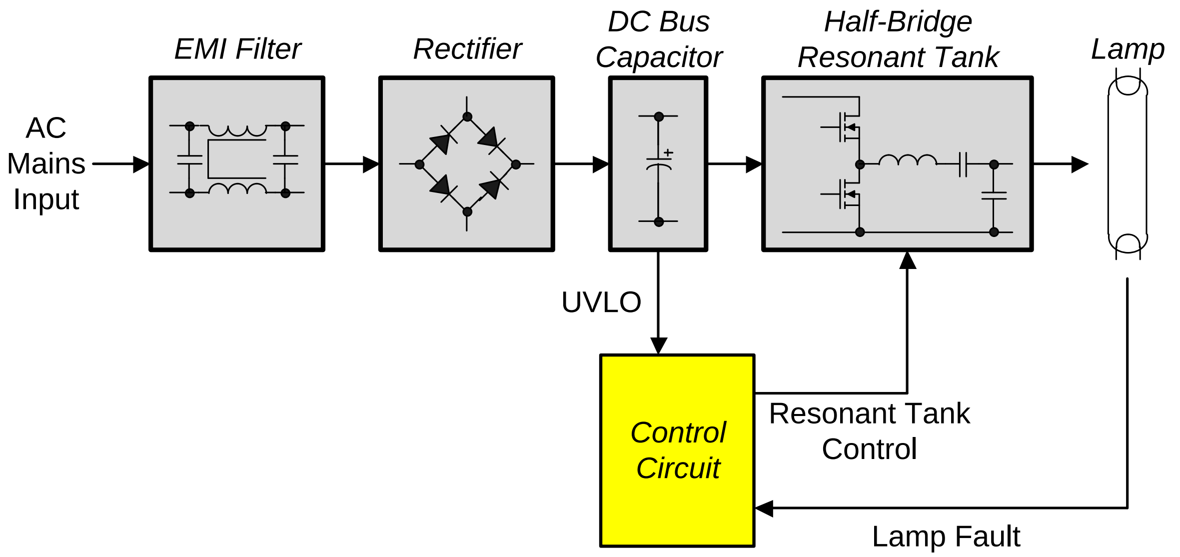


**Fig. 1.** Electronic ballast block diagram.

## 2. Control Circuit

The resonant output stage is controlled with a voltage-controlled oscillator (VCO) input and a high- and low-side half-bridge driver output (Figure 2). The half-bridge driver operates at a given frequency with a 50% duty cycle and a fixed non-overlapping dead-time. This produces a high-voltage square-wave that feeds the resonant tank and lamp. The frequency of the square-wave first starts at a higher frequency to preheat the lamp filaments, and is then decreased through resonance to ignite the lamp to a final lower frequency for running. The frequency is controlled by the VCO input, which starts at a higher voltage during preheat and is then decreased smoothly to a lower voltage for ignition and running.

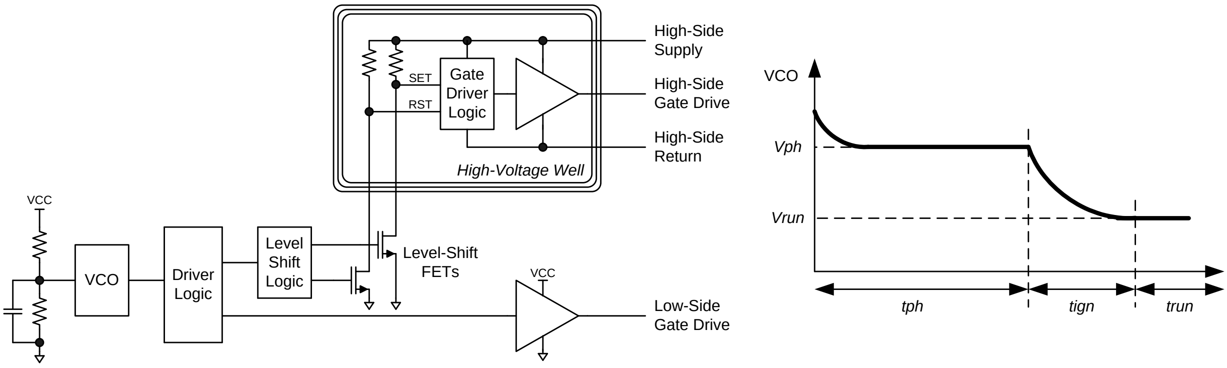


**Fig. 2.** Voltage-controlled oscillator (VCO) and half-bridge driver circuit.

The VCO circuit includes an additional frequency dithering function that varies the frequency linearly above and below a nominal frequency level continuously at a given dithering rate. The frequency dither circuit (Figure 3) includes a current source and current sink for charging and discharging the VCO voltage above and below the nominal level. The source and sink currents are turned on and off from a second oscillator (dither oscillator) running at 50% duty-cycle and at a given frequency. The frequency of the dither oscillator directly sets both the desired rate and amount of dithering necessary for spreading the operating frequency to reduce EMI.

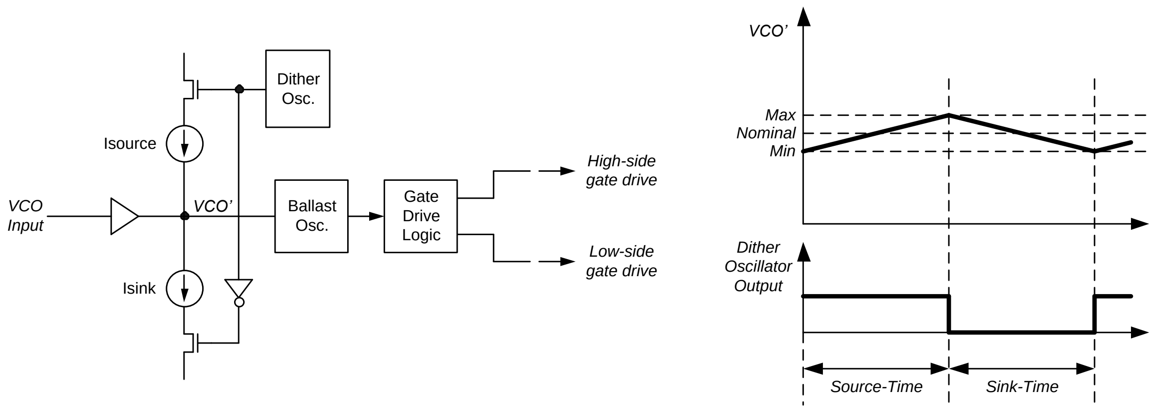


**Fig. 3.** Frequency dither circuit

# 3. Ballast Design

A fully functional 26W ballast is designed around the IRS2526DS “Mini8” Ballast Control IC. The circuit includes (Figure 4) the complete control for the half-bridge resonant output stage and the lamp. The ‘VCO’ pin sets the frequency of the half-bridge gate driver outputs, ‘HO’ and ‘LO’ pins. A resistor voltage divider at the ‘VCO’ pin programs the desired VCO voltage levels. These voltage levels control the frequency of the internal voltage-controlled oscillator (Figure 3). The internal oscillator signal then feeds into the high- and low-side gate driver logic circuitry to generate the correct preheat, ignition, and running frequencies for the half-bridge and resonant output stage. The EMI inductor now consists of a single-winding differential-mode inductor (LF) instead of the multi-winding common-mode inductor that is typically required to adequately filter out ballast generated noise.

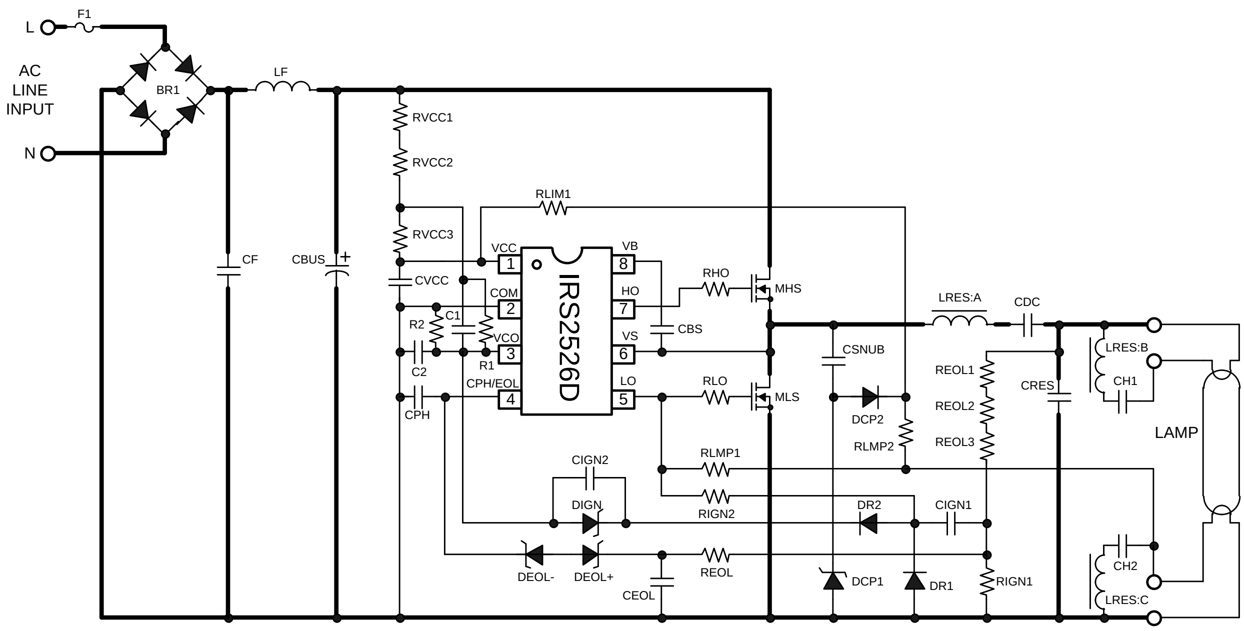


**Fig. 4.** 26W electronic ballast circuit schematic

# 4. Experimental Results

The evaluation results from the functional ballast show that the half-bridge resonant stage and lamp are both working properly. The waveforms include (Figure 5) the half-bridge switching voltage, the AC lamp voltage and AC lamp current during running at maximum (left waveforms) and minimum (right waveforms) dithering frequencies. The conducted EMI measurements are also shown (Figure 6) for a wide range of measured frequencies (9kHz to 300MHz). The circuit demonstrates proper fluorescent lamp control with conducted EMI below the allowed limits using only a single-winding filter inductor.

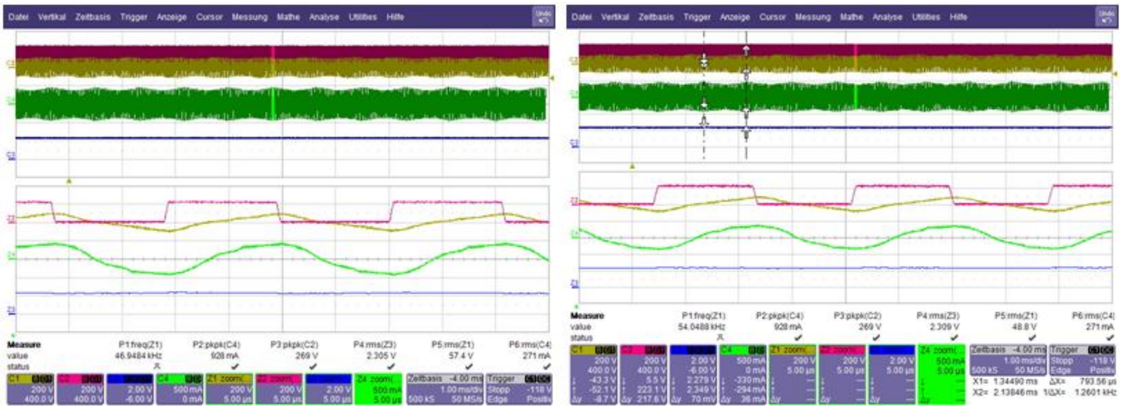

**Fig. 5.** Half-bridge voltage (red trace), lamp current (green trace) and lamp voltage (yellow trace) during running with maximum dithering (left waveforms) and minimum dithering (right waveforms)

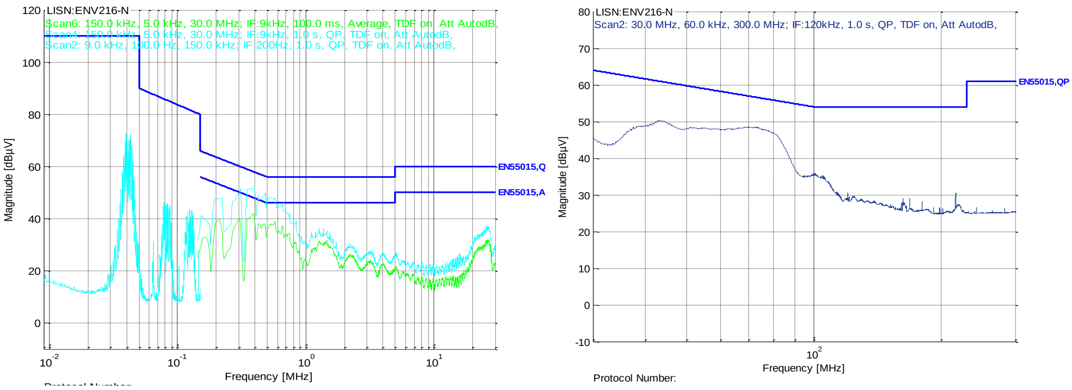


**Fig. 6.** Conducted EMI measurement results for 9kHz to 30MHz (left graph) and for 30MHz to 300MHz (right graph).

# 5. Literature


[1] E.E. Hammer and T.K McGowan, "Characterization of F40 Fluorescent Systems at 60Hz and High Frequency," IEEE Trans Ind. Appl., vol. IA-21, no. 1, pp. 11-16, Jan/Feb. 1985.

[2] T. Ribarich, J. Ribarich, "A New Model for High-Frequency Ballast Design," IEEE-IAS Conf. Rec., 1997, pp. 2334-2339.

[3] International Rectifier, IRS2526DS Mini8 Ballast Control IC Datasheet, www.irf.com, 2011.

[4] International Rectifier, IRPLLMB7E 26W Reference Design Kit, www.irf.com, 2011.