

### RF Power Capabilities of the IXRFD615X2 MOSFET Gate Driver in a Resonant Full-Bridge Configuration

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#### Abstract

The IXRFD615X2 dual 15 A MOSFET driver is evaluated in a resonant full-bridge circuit to compare operation against an older application note operating the previous-generation DEIC420 MOSFET gate driver in a resonant half-bridge circuit. Simulations for both full-bridge and half-bridge configurations are presented to complement and verify circuit operation. This circuit can also be used as a medium-power RF source for applications where a compact RF source is required.

#### Introduction

The IXRFD615X2 is a dual 15 A peak high-speed MOSFET gate driver and is simply an IXRFD630 single 30 A gate driver split into two independent drivers. It is compact and self-contained requiring only a voltage supply, a +5 V input signal, and a suitable heatsink. Built on the same substrate means that the two drivers share a common ground and therefore cannot operate isolated from each other with respect to ground. The driver output stage is configured as a half-bridge with a ground-referenced low side 'switch' and a floating high side 'switch' which lends itself for use in a half-bridge circuit for the single driver and full-bridge for the dual driver. The internal logic of the driver provides for the complementary high and low side drive signals by way of a single +5 V input signal. With the addition of a simple LC resonant tank and an impedance matching network, a sine wave output is produced which is then applied to a 50  $\Omega$  load. For the dual driver, a resonant full-bridge circuit can be constructed and will produce roughly double the output power over a resonant half-bridge circuit. It must be noted, however, that splitting the driver in two reduces the current capability of each output stage by one half.

The basis for this note is a IXYSRF application note using the previous generation DEIC420 gate driver titled "Stand Alone" RF Power Capabilities Of The DEIC420 MOSFET Driver IC at 3.6, 7, 10, 14 MHz'. It focuses on using the DEIC420 as a miniature half-bridge to generate amateur radio frequencies at values noted in the title. The goal of this note is not to verify operation at all of the amateur radio frequencies tested, but to select one frequency, model the original half-bridge circuit using LTSPICE at the one frequency, synch up the simulation model to previously tested values, then double the half-bridge to simulate a resonant full-bridge to identify potential output power values, and finally to construct and test the full-bridge circuit.

#### Theory of Operation

As previously indicated in the application note titled "Stand Alone" RF Power Capabilities Of The DEIC420 MOSFET Driver IC at 3.6, 7, 10, 14 MHz', the single totem-pole output stage of the driver is used in a series resonant half-bridge, while in this application note the IXRFD615X2 is used in a series resonant full bridge. The primary difference is that a full-bridge has the ability to apply twice the supply voltage across the load and it can be visualized as two half bridges driving each end of the resonant tank. Another difference is that the 50  $\Omega$  load is transformer coupled between the bridge outputs as opposed to auto-former coupled in the older application note using a half bridge. Since the resonant tank is floating across the outputs of the two half bridges, the 50  $\Omega$  load cannot be directly tied to the tank and ground referenced and must be transformer isolated so that the resonant current can drive the transformer primary while reflecting the 50  $\Omega$  load as the tank impedance.

The output matching transformer used is wound on a Fair-Rite #286100202 balun core with 1 turn primary and 5 turns secondary of AWG 22 enameled solid magnet wire twisted tightly together. This ensures tight coupling between the windings.

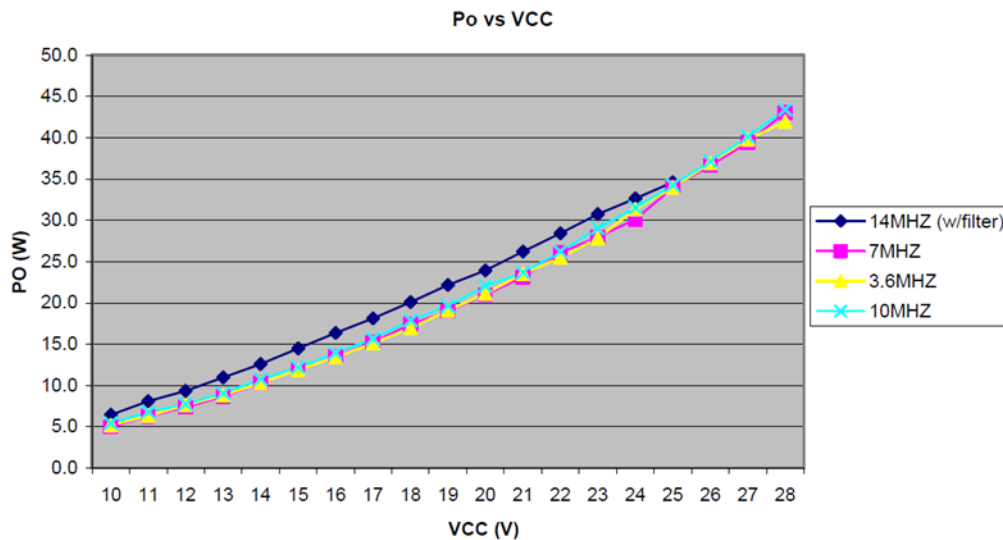
For testing purposes the simulations and circuit construction use the resonant component values readily available on hand at the 7 MHz test frequency only, C1 at 1.2 nF and L1 at 430 nH. The following table outlines the resonant tank component values for each of the four frequencies used for the DEIC420 application note.

Table of resonant component values from previous DEIC420 application note

Frequency (MHz)	C (pF)	L (nH)	Q	RL tank load ( $\Omega$ )	T1 Z ratio
3.6	2700	723	8	~2	1:25
7	1200	430	5	~2	1:25
10	1000	258	8	~2	1:25
14.1	780	164	10	~1.4	1:36

## Simulation

The following chart represents data collected in the DEIC420 application note for RF output power versus the supply voltage. It can be seen that the power ranges from a little over 5 W to greater than 40 W in the series resonant half-bridge circuit with respect to the 10 to 28 V supply values.



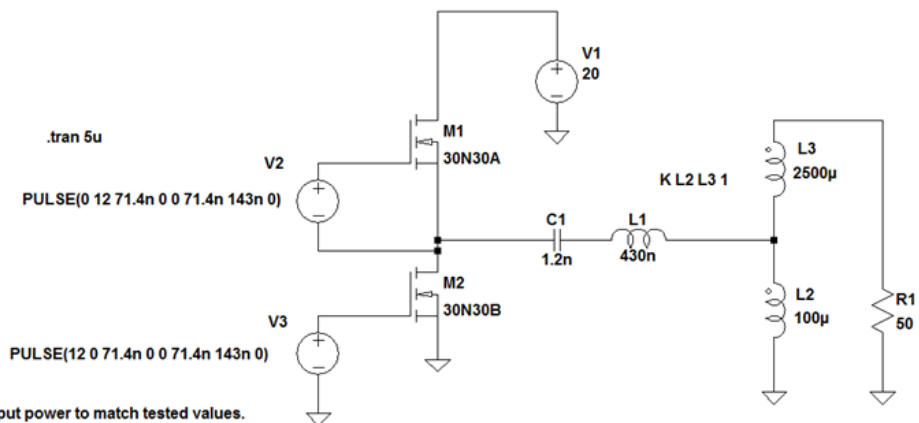
The first circuit for simulation is the half-bridge configuration and is as described below.

```

*SYM=POWMOSN
.SUBCKT 30N30A 10 20 30
* TERMINALS: D G S
* 30 Volt 30 Amp High Side Driver MOSFET
M1 1 20 3 3 DMOS L=1U W=1U
RD 4 1 0.25
LS 3 30 1N
LD 10 4 1N
.MODEL DMOS NMOS (LEVEL=3 VTO=3.5 KP=0.5)
.ENDS 30N30A

.tran 5u

*SYM=POWMOSN
.SUBCKT 30N30B 10 20 30
* TERMINALS: D G S
* 30 Volt 30 Amp Low Side Driver MOSFET
M2 1 20 3 3 DMOS L=1U W=1U
RD 4 1 0.17
LS 3 30 1N
LD 10 4 1N
.MODEL DMOS NMOS (LEVEL=3 VTO=3.5 KP=0.5)
.ENDS 30N30B
    
```



0.48 Ohms series resistance added to L2 to reduce output power to match tested values. The correct way is to reduce the K constant, away from the ideal value of 1, in the mutual coupling directive, but that induces leakage inductance and throws off the resonant frequency which requires adjustment of all the PULSE statments.

V1 is applied to the Vcc pins and is simulated at 10 to 28 V.

M1, M2 represent the drivers output stage.

The components for the half-bridge circuit are as follows:

Two sub-circuit statements are for MOSFETs M1 and M2 which represent the upper and lower switches in the output stage of the MOSFET driver. Two statements are used to account for the slight differences in the drain to sources resistance and they are also used to include the parasitic inductance of the drain and source bond wires.

V1 is the power supply voltage from 10 to 28 V.

V2 and V3 are the pulsed input signal which, when combined, form the input section of the driver. Two pulse statements have been added to provide the inverted signals required to drive the output stage.

C1 and L1 components for the series resonant tank. The values shown are for 7 MHz.

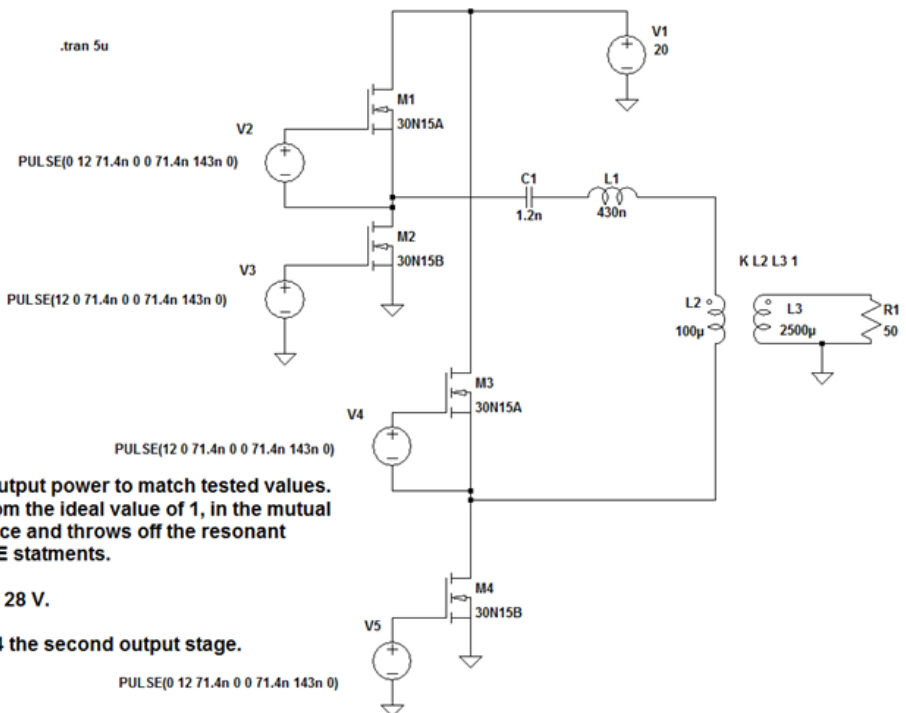
L2 and L3 represent the autoformer with the “K” constant or coupling variable defined with ideal coupling value of 1, this negates the leakage inductance term from the simulation. The inductance values are large enough as to not influence the resonant frequency, while the ratio represents the impedance ratio 1 to 25, not the turns ratio of 1 to 5.

R1 is the output load and is equal to 50 Ω.

The second simulation circuit is for the full-bridge configuration and is as described below.

```
*SYM-POWMOSN
.SUBCKT 30N15A 10 20 30
* TERMINALS: D G S
* 30 Volt 15 Amp High Side Driver MOSFET
M1 1 20 3 3 DMOS L=1U W=1U
RD 4 1.5
LS 3 30 1N
LD 10 4 1N
.MODEL DMOS NMOS (LEVEL=3 VTO=3.5 KP=0.5)
.ENDS 30N15A
```

```
*SYM-POWMOSN
.SUBCKT 30N15B 10 20 30
* TERMINALS: D G S
* 30 Volt 15 Amp Low Side Driver MOSFET
M1 1 20 3 3 DMOS L=1U W=1U
RD 4 1.35
LS 3 30 1N
LD 10 4 1N
.MODEL DMOS NMOS (LEVEL=3 VTO=3.5 KP=0.5)
.ENDS 30N15B
```



0.35 Ohms series resistance added to L2 to reduce output power to match tested values. The correct way is to reduce the K constant, away from the ideal value of 1, in the mutual coupling directive, but that induces leakage inductance and throws off the resonant frequency which requires adjustment of all the PULSE statements.

V1 is applied to the Vcc pins and is simulated at 10 to 28 V.

M1, M2 represent one driver output stage and M3, M4 the second output stage.

The full-bridge includes the addition of another totem-pole stage on the former ground side of the resonant components. Also, since the resonant components are no longer ground referenced, the autoformer is now converted to a standard transformer configuration to isolate the floating tank circuit from the ground referenced load.

Two sub-circuit statements are for MOSFETs M1, M2, M3, M4, which represent the upper and lower switches in the output stage of the MOSFET driver. Two statements are used to account for the slight differences in the drain to sources resistance. They are also used to include the parasitic inductance of the drain and source bond wires.

V1 is the power supply voltage from 10 to 28 V.

V2, V3, V4, V5 are the pulsed input signal which, when combined, form the input section of the driver. Four pulse statements have been added to provide the inverted signals required to drive the output stages.

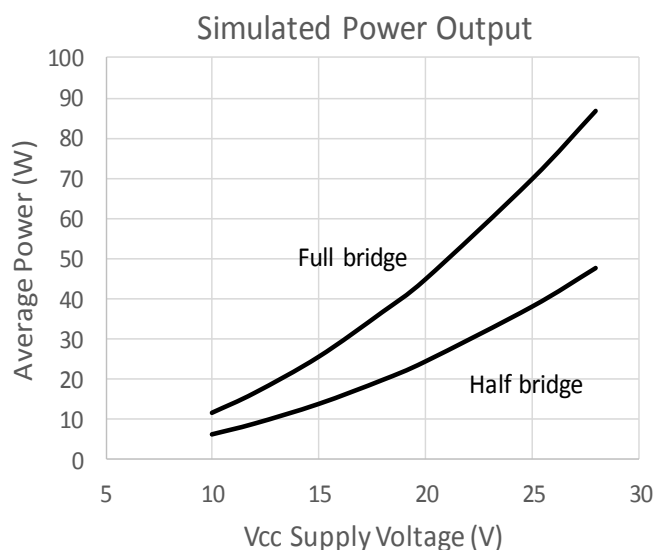
C1 and L1 components for the series resonant tank. The values shown are for frequency of 7 MHz.

L2 and L3 represent the transformer with the “K” constant or coupling variable defined with ideal coupling value of 1. This negates the leakage inductance term from the simulation. The inductance values are large enough as to not influence the resonant frequency, while the ratio represents the impedance ratio 1 to 25, not the turns ratio of 1 to 5.

R1 is the output load and is equal to 50  $\Omega$  for all simulation runs.

### Simulation Results

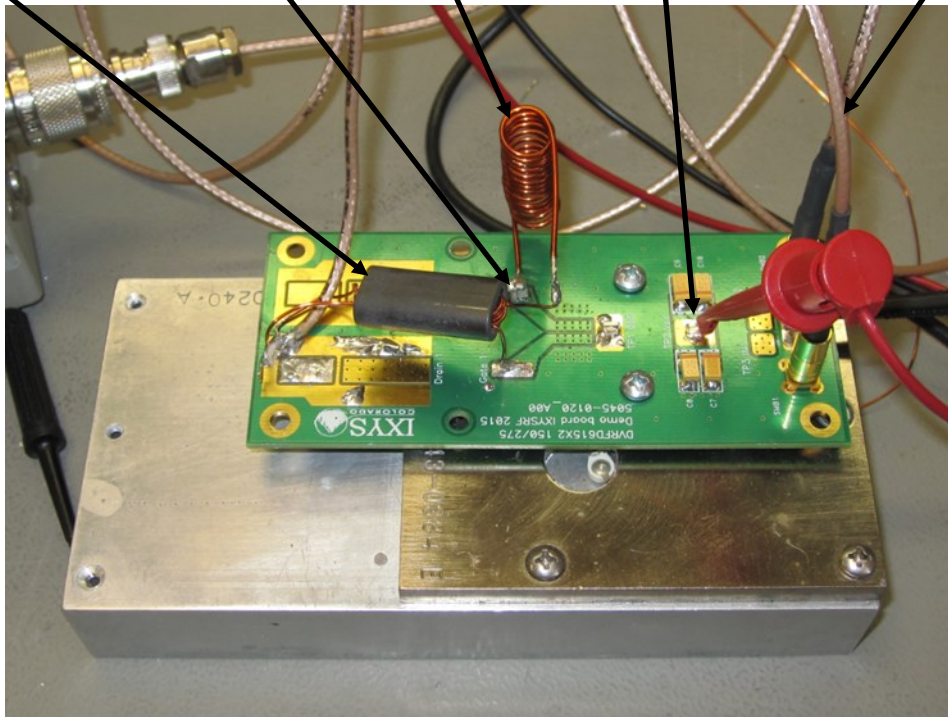
The following chart indicates simulation results for the resonant half-bridge and full-bridge at the 7 MHz operating frequency. It is noted that the simulated power output of the half-bridge circuit compares very favorably to the tested output from the previous DEIC420 power output chart and application note. Since the simulated data matches the DEIC420 operation, the half-bridge schematic is expanded to a full-bridge, simulated, and then constructed to test actual operation.



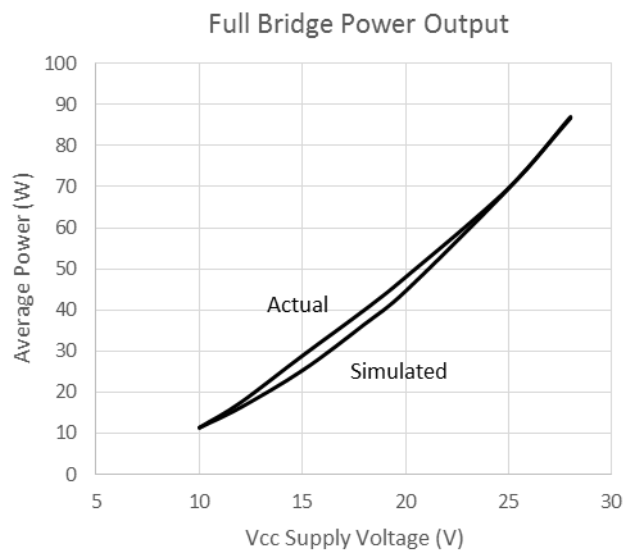
### Circuit Performance

The DVRFD615X2 gate driver demonstration board pictured below is used as the foundation with which to make component connections and test measurements. Two complementary input signals drive the input pins of the IXRFD615X2. Power was coupled to load using coax cable soldered to secondary of the output matching transformer. A laboratory power supply is used to supply 10 to 28 V to the circuit board.

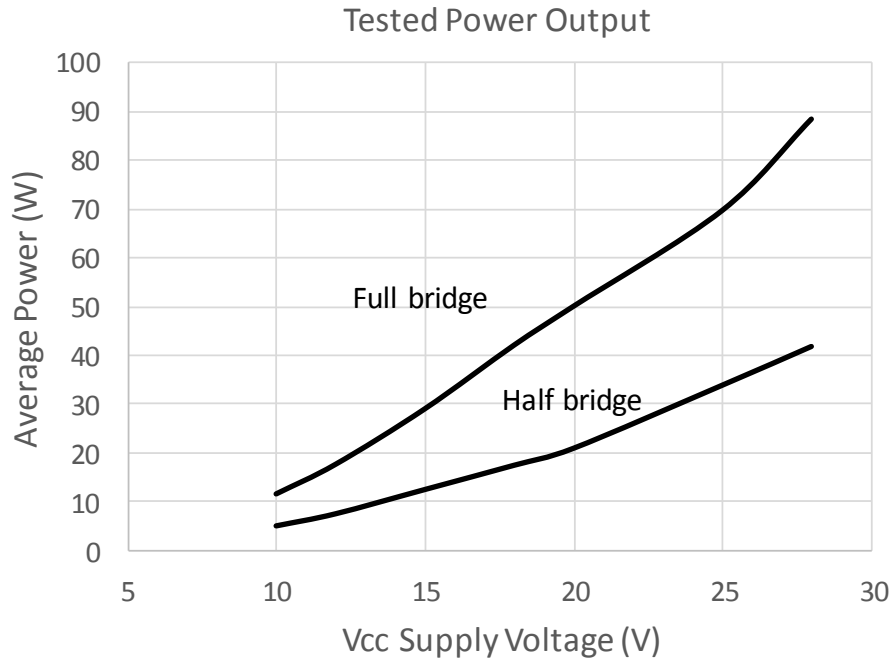
Output transformer      Resonant capacitor and inductor      Power connection      Input signal cables



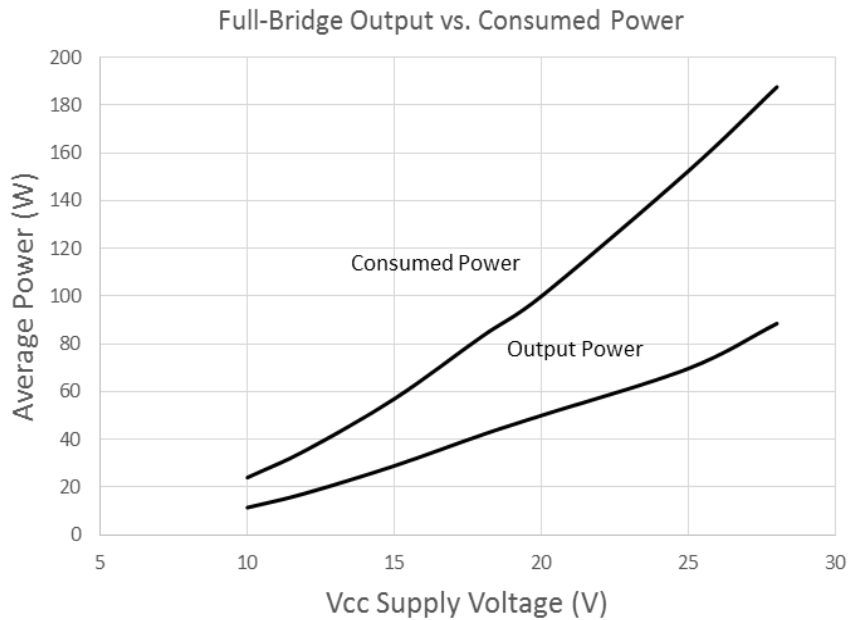
The following chart compare the operating power output for the simulated and also the constructed circuit; results are favorable to each other. It should be noted that there were no attempts to optimize dead time for the signal generator used to drive the actual circuit and so it should be anticipated that there can be losses due to current shoot-through.



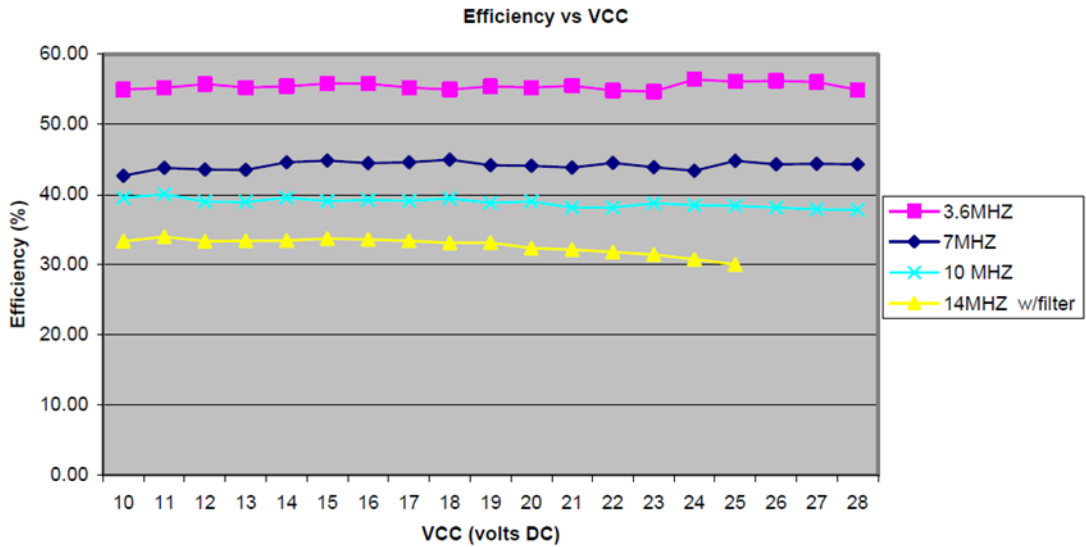
The following chart compares actual tested output power for both half and full bridges. The half-bridge power output was duplicated from previous application note. It can be seen that power output is roughly double with the full bridge.



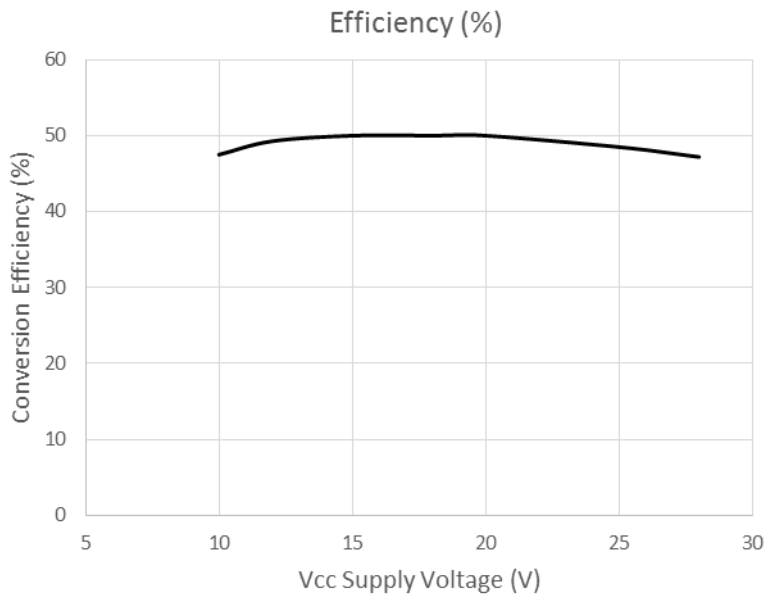
The following chart compares full-bridge output and consumed power.



A plot of the original Efficiency vs. Vcc for the half-bridge at 7 MHz indicates approximately 45% power conversion efficiency.

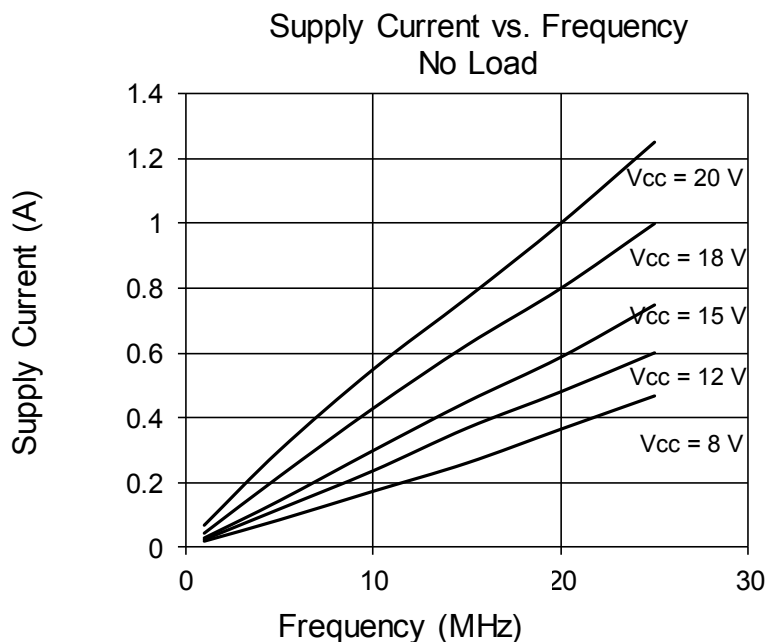


A plot of the efficiency for the full bridge in operation follows.



It can be seen that for either the old or new application note that the power conversion efficiency is low compared to the typical expectations for switching power converters which is 80% or more. This is due to the non-trivial power consumed by the driver itself and the low voltage at which the resonant circuit is operated.

The following chart plots the power consumption for each half of the IXRFD615X2 with no attached load at various Vcc supply values for comparison.



### Conclusion

This application note was intended to demonstrate additional uses for the IXRFD615X2 beyond standard gate drive duty. It also was to compare output power differences for a single driver used in a half-bridge configuration versus the dual driver in a full bridge by way of SPICE simulation and actual construction and testing of the circuit. It was found that the full bridge produces double the power output for any given power supply voltage over the half-bridge single driver circuit. The doubling of the power is a direct result of applying double the voltage across the load by way of the full bridge operation and does not require additional components to do so. This compact, easy to build circuit can be used with a wide range of resonant components for additional frequencies of interest.

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