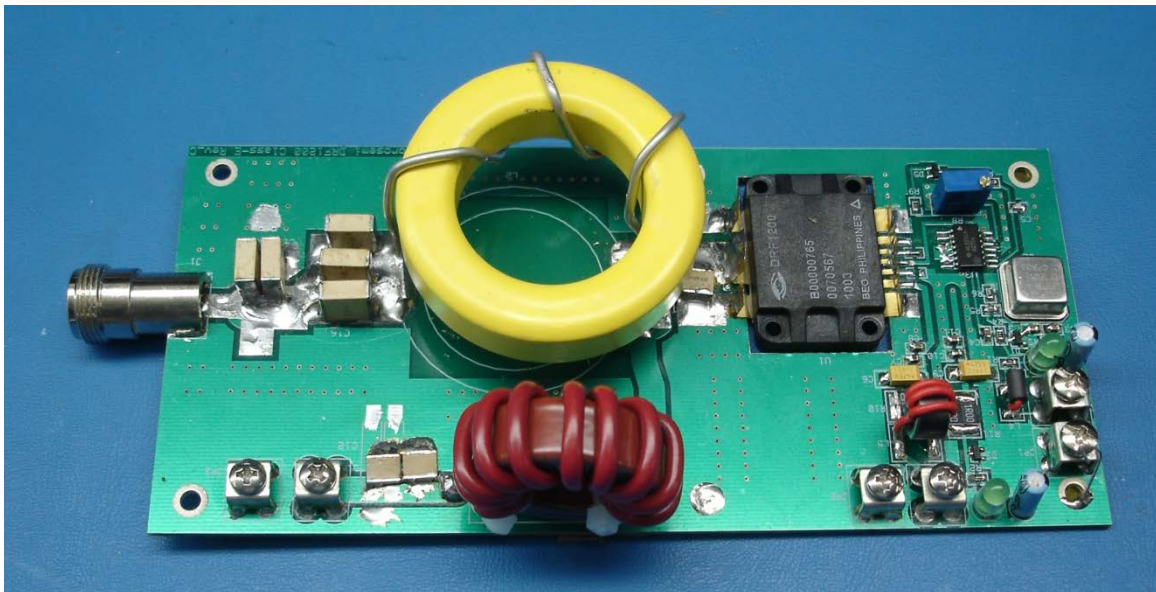


27.12 MHz, CLASS-E, 400W RF Generator using a Microsemi DRF1200 Driver/MOSFET Hybrid

Overview

The DRF1200/Class-E 27M Reference design is available to expedite the evaluation of the DRF1200 Driver MOSFET hybrid. This Application Note or Reference Design Kit does not represent a finished commercial-ready design. It is only a teaching tool to demonstrate the capability of the DRF1200 under 50 Ohm, flat line condition. Each reference design kit has been verified to perform to the specifications of the application note. By purchasing the reference design kit the user takes full responsibility for repair and any modification. No warranties, repair and returns will be accepted.

**The reference design kit contains lethal voltages and high power RF.
Use safety precautions.**



Introduction

This application note discusses the design procedures and test results for a 27.12MHz, 400W min., Class-E generator ideal for ISM applications. To achieve high efficiency and low cost, a Microsemi DRF1200 Driver/MOSFET was selected. The DRF1200 can generate over 400W of operating output power and consists of a MOSFET driver, high power MOSFET and internal bypass capacitors in an air cavity flangeless package. The flangeless package was designed to optimize reliability, provide increased flexibility while still providing a low cost solution. A reference design board (DRF1200/CLASS-E 27M) is available for purchase to facilitate the immediate evaluation of the principles of this application note.

To optimize efficiency performance, a CLASS-E RF generator was chosen. It is essential that care is taken to use adequate circuitry, clean PCB layout and good ground connections on the PCB to ensure proper output waveforms.

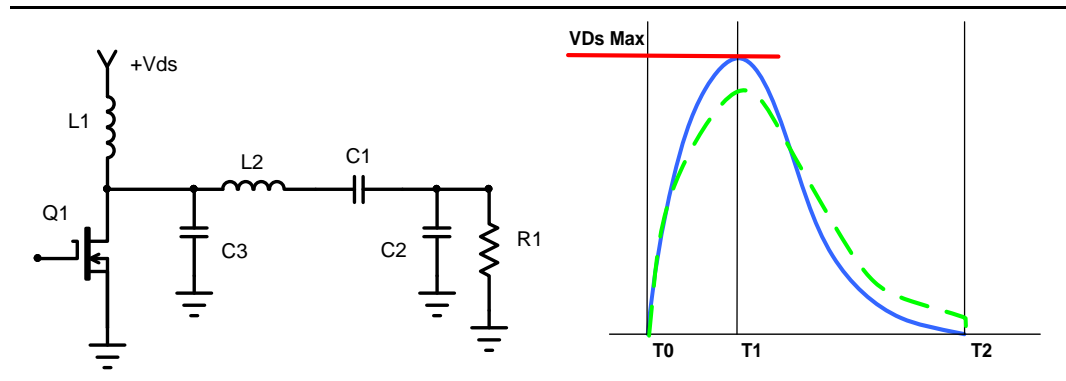


Figure 1 - Simplified Class-E circuit and waveform

Figure 1. L1 is a RFC (RF Choke) that when Q1 opens causes the voltage across Q1 (Vds) to swing in excess of PS HV. C3 is selected so that combined with the Coss of Q1 the drain wave form is optimally tuned as shown by the solid blue line. The dashed green line represents a suboptimum tune. See References. L2 and C1 form a resonate circuit. C2 is the Load capacitor. An external load resistance R1= 50Ω is used in this application and for the purpose of this discussion.

Design Considerations

The following issues were considered in the design of a high efficiency, high power RF generator.

1. Class-E operation for high-efficiency.
2. Adequate output matching circuit. Matching tools were used to achieve the required power and efficiency.
3. Parts that are capable of handling RF output over several kW. This includes the bypass capacitor in the DC circuit and selecting a toroidal inductor and capacitors for output matching circuit.
4. Water cooling system is highly recommended for testing.
5. PCB designed for good ground connections, especially for the output matching circuit.
6. PCB lay-out optimizing the isolation between power output and input signal generation circuit.

Overall Concept

This high efficiency RF power generator uses a DRF1200 to minimize layout parasitic and optimize efficiency for CLASS-E operation.

1. RF pulse generator circuit

The pulse oscillator and pulse control circuit is designed to create an ISM frequency of 27.12MHz and adjust the pulse width and phase according to circuit power requirements.

2. RF output matching circuit

The matching circuit was calculated with a RF matching software tool to maximize power transfer to 50 Ohm load. The circuit was then tuned using the inductor, capacitor and RF choke coil (RFC).

Circuit Descriptions

1. RF Pulse Generation

The Pulse generation circuit employs 27.12MHz TCXO and Flip Flop IC to adjust Pulse Width from 8nS to 18nS at the signal input of DRF1200. For this application, the pulse width is set at 10~14nS. To minimize conductive EMI, it is crucial to use a good ground plane layout with respect to the signal lines.

2. RF Output Matching

The DRF1200 has a switching speed of 3~4nS, BVds of 1KV and Ids of 13A max. To achieve high efficiency operation, the RF generator uses Class-E operation. At full power, the efficiency is approximately 75~80% at 27.12MHz. The MOSFET output capacitance was considered when tuning the external shunt capacitance to get the desired performance. See DRF1200 data sheet for output capacitance. The RF output matching circuit was designed using a RF matching tool and was optimized to achieve maximize power transfer to 50 Ohm Load. The output matching circuit is a series resistive circuit combined with a reactive circuit consisting of an "L" match Toroidal Inductor and Capacitors in series and shunt to ground.

3. DC Supply

The PS HV DC supply input circuit utilizes a RFC and by-pass capacitors to minimize interference with AC signal. The RFC was calculated to be approximately 1k Ohm impedance at 27.12MHz using 15~20 turns of 18AWG wire with metal powder core. The By-pass capacitor should have a minimum 1kV rating.

Test Requirements

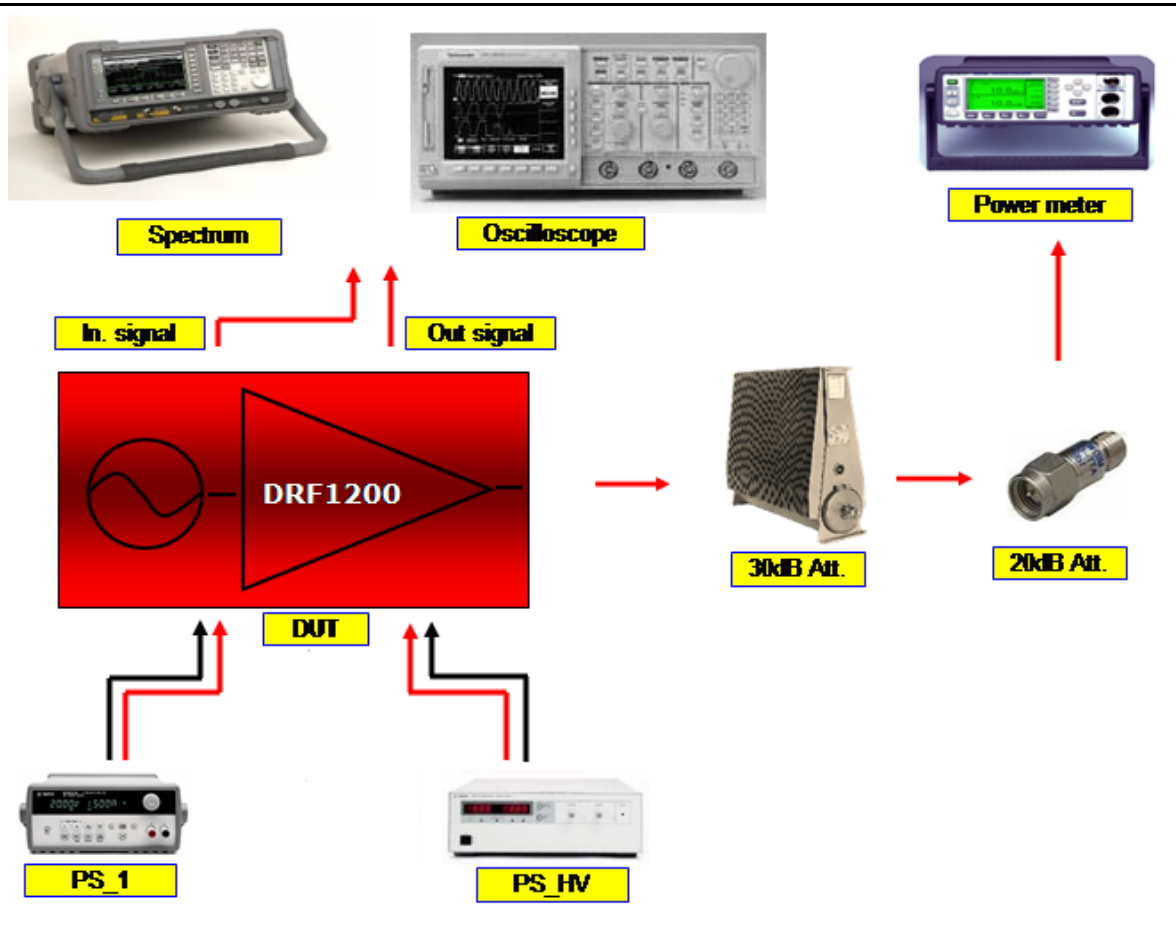


Figure 2 · STM SD3933

1. Hardware and power sequencing requirements
 - Cooling requirement: Testing is recommended to be performed using a water cooling system.
 - Sequential steps for Turn-On/Turn-Off of Power Supplies.
 - a. Turn on Driver power supply PS_2 (10V via JP1).
 - b. Then, turn on MOSFET supply (PS HV) and slowly increase to 50V (via JP2).
 - c. Then, turn on SW1 on the pulse circuit.
 - d. While monitoring the RF power from power meter and output waveform of the Drain, ramp up MOSFET power supply (VDD) to the values per Table 1 making sure that output is stable for each supply voltage before proceeding to the next higher voltage.
 - To turn-off, turn power supplies off in the reverse order.
If RF output waveform, Vds and/or RF power level from power meter fluctuate, immediately shut down VDD for safety, and determine fault before resuming test.

Performance

1. Data Summary

VDD, V	IDD, A	Pout, W	Efficiency, %
100	1.56	100	64
120	1.67	140	70
140	1.8	183	73
160	1.94	231	74
180	2.09	282	75
200	2.25	337	75
210	2.36	371	75
220	2.44	401	75

Table 1 - Power Sequencing Data Summary

Table 1 shows the effects of varying the PS HV(VDD)/IDD on MOSFET current, RF power and efficiency, The chart of Efficiency vs. Pout is shown in Figure 3. The efficiency is calculated using RF power output and DC input power of the power MOSFET.

2. Chart of data sheet

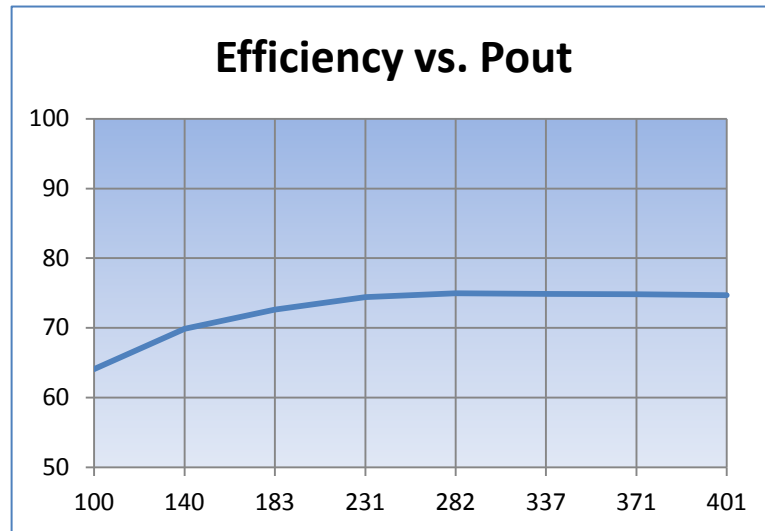


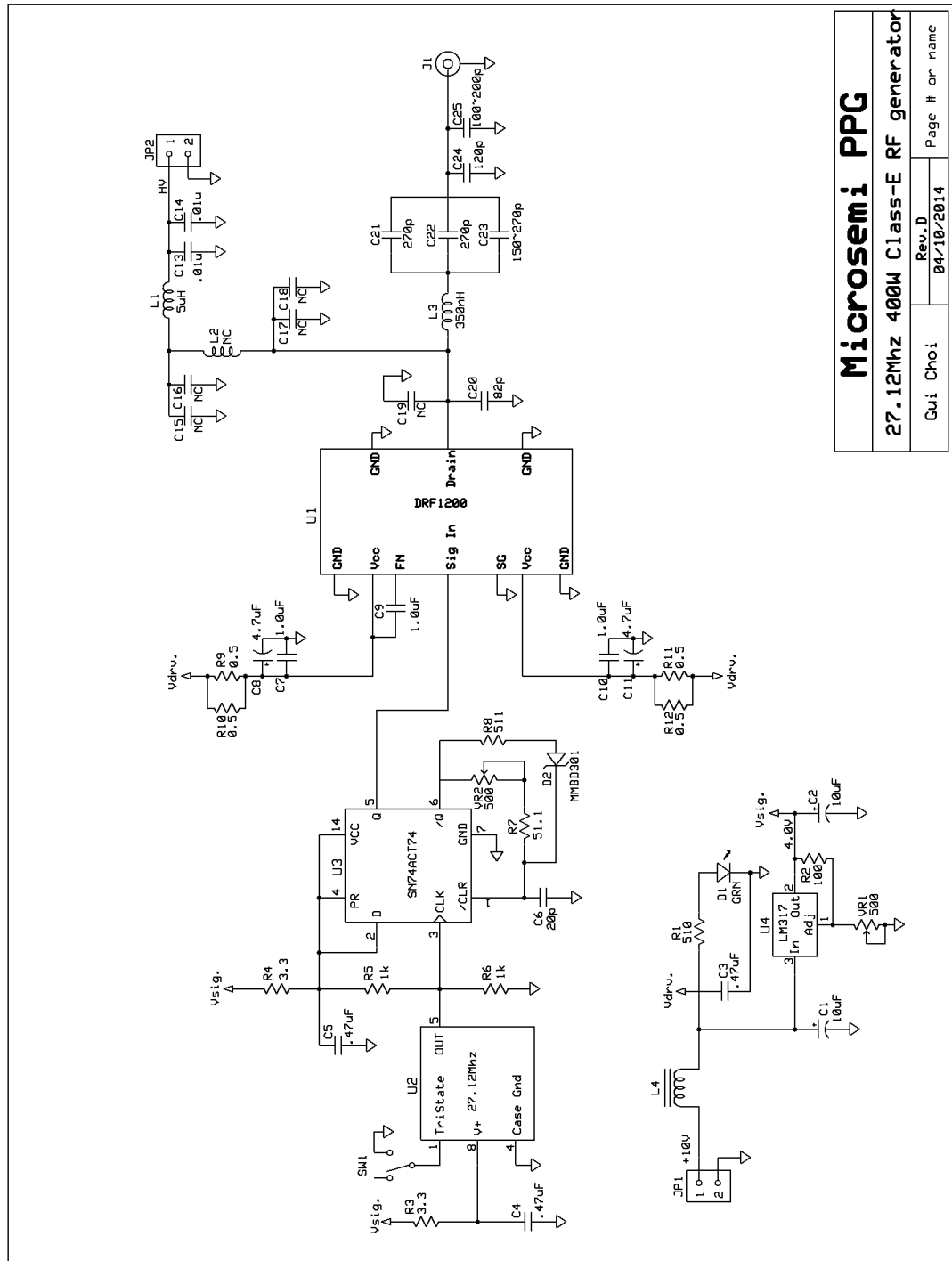
Figure 3 - Efficiency vs Pout

Summary

This Application Note is for a reference design using a DRF1200 as a CLASS-E RF generator. The high performances DRF1200 Hybrid was used because it includes both the driver, Power MOSFET, and by-pass capacitors optimized to reduce inductance and achieve a single low cost solution. A reference design board is available to demonstrate this high efficiency of 75~80%, Pout 400W min., Freq 27.12MHz RF generator.

The critical aspects such as the layout of components for efficient power generation, testing, and water cooling requirements are also discussed.

Appendix I. Overall Schematic



Microsemi PPG	
27.12MHz 400W Class-E RF generator	
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Gui Choi	04/10/2014

Figure 4 - Overall schematic

Appendix II. PCB Lay-out

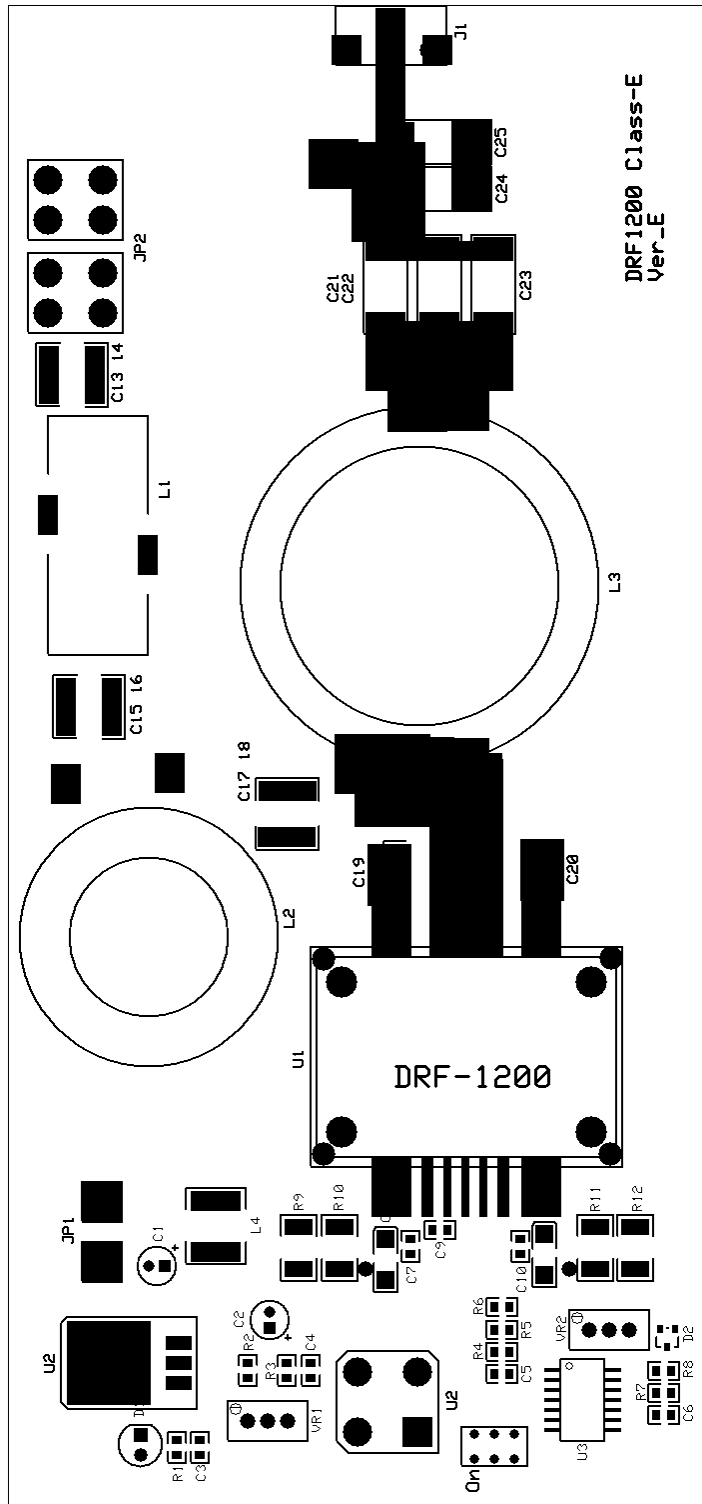


Figure 5 · PCB Lay-Out

Appendix III. Parts List

Part ID	Description	Size	Supplier	Supplier PN	Manufacture	Manuf. PN
U1	RF MOSFET Hybrid	T3B	Microsemi	DRF1200	Microsemi	DRF1200
C1	10uF/50V		Digi-key	445-2903-ND		
C2	10uF/35V(Cer. cap)		Digi-key	pcc2183ct-nd		
C3	.47uF/50V(Cer. Cap)	805	Digi-key	490-3328-1-ND		GRM21BR71H474KA88L
C4	.47uF/50V(Cer. Cap)	805	Digi-key	490-3328-1-ND		GRM21BR71H474KA88L
C5	.47uF/50V(Cer. Cap)	805	Digi-key	490-3328-1-ND		GRM21BR71H474KA88L
C6	20pF/100V(Cer. Cap)	805	Newark	55J5746	AVX	08051A200JAT2A
C7	1.0uF/50V(Cer. Cap)	805	Digi-key	587-1438-1-ND	Taiyo Yuden	GMK212BJ105KG-T
C8	4.7uF/35V(Tant cap)	6032-28	Digi-key	478-1717-1-ND	AvX	TAJC475K035R
C9	1.0uF/50V(Cer. Cap)	805	Digi-key	587-1438-1-ND	Taiyo Yuden	GMK212BJ105KG-T
C10	1.0uF/50V(Cer. Cap)	805	Digi-key	587-1438-1-ND	Taiyo Yuden	GMK212BJ105KG-T
C11	4.7uF/35V(Tant cap)	6032-28	Digi-key	478-1717-1-ND	AvX	TAJC475K035R
C13	0.01uF/1KV	Cer. Disc	Allied Elec.	507-0721	Vishay	562R5GAS10
C14	0.01uF/1KV	Cer. Disc	Allied Elec.	507-0721	Vishay	562R5GAS10
C15	NC					
C16	NC					
C17	NC					
C18	NC					
C19	NC					
C20	82PF/2500V	3838	ATC	700C820JW2500X	ATC	700C820JW2500X
C21						
C22	Tuning 700~800pF	3838	ATC	100E Series		
C23						
C24	Tuning 220~320pF	3838	ATC	100E Series		
C25						
R1	510ohm/1/8W	805	Digi-key	P510ATR-ND	Panasonic	ERJ-6GEYJ511V
R2	100ohm 1/8W	805	Digi-key			
R3	3.3ohm 1/8W 5%	805	Digi-key	P3.3ACT-ND	Panasonic	ERJ-6GEYJ3R3V
R4	3.3ohm 1/8W 5%	805	Digi-key	P3.3ACT-ND	Panasonic	ERJ-6GEYJ3R3V
R5	1.0K ohm 1/8W 1%	805	Digi-key	P1.00KCCT-ND	Panasonic	ERJ-ENF1001V
R6	1.0K ohm 1/8W 1%	805	Digi-key	P1.00KCCT-ND	Panasonic	ERJ-ENF1001V
R7	51.1ohm 1/8W 1%	805	Digi-key	P51.1CCT-ND	Panasonic	ERJ-6ENF51R1V
R8	511ohm 1/8W 1%	805	Digi-key	P511CCT-ND	Panasonic	ERJ-6ENF5110V
R9	0.5ohm 1/2W 5%	2522	Newark	61M7618		
R10	0.5ohm 1/2W 5%	2522	Newark	61M7618		
R11	0.5ohm 1/2W 5%	2522	Newark	61M7618		
R12	0.5ohm 1/2W 5%	2522	Newark	61M7618		
VR1	POT 500ohm 1W	3/8" sq	Digi-key	3292W-501-ND	Bourns	SM:3269W-1 501
VR2	POT 500ohm 1W	3/8" sq	Digi-key	3292W-501-ND	Bourns	SM:3269W-1 501
D1	LED, green	5mm	Digi-key	P375-ND	Panasonic	LN31GPH
D2	30V/300mA(Sch.)	SOT23	Digi-key	MMBD301LT1GOSCT-ND	On Semi.	MMBD301LT1G
J1	RFout port		Newark	12M4398	Bomar	161V504E
JP1	DC Terminal					
JP2	DC Terminal		Allied	839-0309	Keystone	8191
L1	RF Choke w/ T106-2 AWG16		Fair-Rite Alpha	T106-2 AWG16	Fair-Rite Alpha	T106-2 AWG16
L2	Jumper					
L3	Toroid Inductor		Micrometals Alpha	T225-6 289	Micrometals Alpha	T225-6 289
L4	Toroid RFC 1T AWG22		Allied Elec. Digikey	2643001301 A2016R-100-ND	Fair-Rite Alpha	2643001301 3051RD005
U2	LM317 Adj. regulator	TO-263	Newark	41K4661		
U3	27.12 MHz Osc	Half	Allied Elec.	EP1100HSTSC-27.12M	Ecliptek Co.	EP1100HSTSC-27.120M
U4	Dual Flip-Flop IC		Digi-key	296-13131-1-ND	TI	SN74ACT74NSR

Figure 6 - Parts List

References

- Application Note: DRF1200 Class-E 13.56Mhz – Gui Choi
- Solid State Radio Engineering – Herbert L. Krauss and Charles W. Bostian
- Application Note: Simple and Inexpensive High Efficiency Power Amp using New APT MOSFET – Kenneth Dierberger 1994
- Application Note: PRF-1150 1KW 13.56MHz Class E RF Generator Evaluation Module – Matthew W. Vanis