UNDERSTANDING RING GENERATORS

A Ring Generator (RG) is an electronic power device used in the telecom industry to generate the ringing signal for telephones. It is a DC/AC inverter that accepts a usual DC input voltage of 48V and produces an output AC voltage from 120 to 300V peak-to-peak. The output frequency range is from 17Hz to 70Hz. Most high-quality generators have an isolated output and their peak-to-peak voltage is centered around 0V, in other words, the output voltage swings as much negative as it does positive with respect to ground. It is designed to have the same characteristic as any household AC outlet, the only difference is the AC outlet provides 110 to 220VAC at 60Hz or 50Hz. The ring generator typically provides 45 to 90VAC at different frequencies.

The low frequency is needed for electromechanical bell telephones. Old telephone sets equipped with these mechanical bells use a large inductor (electromagnet) to drive the hammer, as is shown in Figure 1.

When the local telephone company sends a ringing signal to its customer, the electromagnet pulls the ferrometallic hammer which then hits the bell. For frequencies above 25Hz, this electromechanical bell cannot follow the frequency of the ringing signal and no sound is produced. Modern telephones have low-power piezoelectric bells and can ring at higher frequencies. The relatively high output voltage is needed due to the signal attenuation from the telephone company to the customer premises. The resistive and parasitic capacitance losses in a few miles of copper wire will inhibit the telephone from ringing if a lower amplitude voltage signal is used. The shape of the output voltage of a high quality ring generator is a sine wave with low harmonic distortion. Other less expensive ring generators have wave shapes which approximate sine waves or even square waves for applications where the harmonic distortion of the signal is not critical.

In the United States, the RG output voltage required to ring a telephone set is 40Vrms. The loading of the ring generator by one telephone set is represented by a series connection of a capacitor of 8µF and a resistor of 6830Ω. The series capacitance of 8µF is the parasitic capacitance of a twisted pair of telephone wire and the resistance is the wire resistance of that twisted pair. In other countries, different output voltages and loading are used. In Germany, for example, 4 telephone sets or 4 REN (Ringer Equivalent Number) have an impedance of 450Ω+3.4µF which translates to an impedance of 1800Ω+0.85µF for one telephone set. In Germany, the RG must be able to deliver 30mA peak current to a load of 4 REN. For a 20Hz RG, the required V_{OUT} peak is given by: $V_P=I_P(Z_L)$, and for 4 REN: V_P=30mA(450Ω+3.4µF) = 30mA(450+2342) = $83.75V_{PEAK} \cong 60Vrms$.

The capacitance of the REN must be charged and discharged to the peak-to-peak voltage for any cycle. The output power of the RG loaded with few REN is given as P = VI cos θ. θ is the phase angle between the voltage and the current through the REN. Cos θ is also known as the power factor which can vary between 0 and 1. For resistive load, cos θ = 1 (voltage and current are in phase) and capacitive load cos θ = cos 90° = 0 (current leads voltage by 90°).

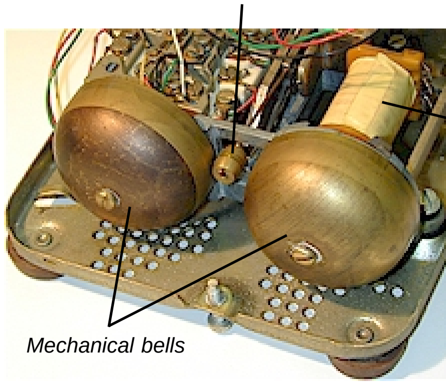

FIGURE 1. Electromechanical bell telephone

The power factor (PF) is also given by the ratio of the true power over the apparent power:

$$PF = \frac{P}{T} = \frac{P}{\sqrt{P^2 + Q^2}}$$

where Q = VI sin θ = reactive power and
P = VI cos θ = true power

The power factor must be taken into account for efficiency calculations.

The impedance of a capacitor at AC steady state operation is given:

$$Z(j\omega) = R(\omega) + jX(\omega)$$

$$PF = \frac{\text{Power loss}}{\text{Apparent powering}} = \frac{I^2R}{I^2|Z|} = \cos\theta$$

The series resistance or ESR = RS + RP of the capacitor (see Figure 2) is very small with respect to the RL connected in series with the capacitor. Typical values for ESR at 20Hz frequencies are a few ohms and the lead inductance is zero.

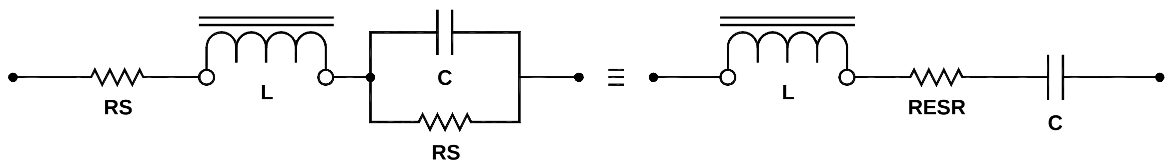

FIGURE 2. Capacitor Equivalent Circuit

For the following PF calculation, the RESR will be the total RL + RESR of the capacitor which will be RL = R.

The magnitude of $Z(j\omega) = |Z| = \sqrt{R^2 + X^2} = \sqrt{R^2 + \frac{1}{\omega^2 C^2}}$ *or* $\sqrt{R^2 + \left(\frac{1}{\omega C}\right)^2}$

then $PF = \frac{I^2R}{I^2|Z|} = \frac{R}{|Z|} = \frac{R}{\sqrt{R^2 + \left(\frac{1}{\omega C}\right)^2}}$

Dividing both numerator and denominator by R, ($\omega = 2\pi f$):

$$PF = \frac{1}{\left(\sqrt{R^2 + \left(\frac{1}{\omega C}\right)^2}\right)\Big/R} = \frac{1}{\sqrt{\frac{R^2}{R^2} + \left(\frac{1}{R\omega C}\right)^2}} = \frac{1}{\sqrt{1 + \left(\frac{1}{2\pi fRC}\right)^2}} = \cos\theta$$

The Dissipation Factor $DF = \frac{\text{Power loss}}{\text{Reactive power stored}} = \frac{I^2R}{I^2X} = \frac{R}{X} = \cos\theta$ = t and δ

EFFICIENCY MEASUREMENTS

A Ring Generator requires carefully set-up and accurate test equipment in order to measure its efficiency. Two power meters must be used: one on the input for input power measurement and one at the output. If only one meter is available, the input and output power must be measured under the same operating conditions (e.g. input voltage, output voltage, frequency and loading). The power meter must operate down to 10Hz and have an accuracy of 1% or better. he input power to the Ring Generator is not only the Vdc×Idc product, but also the Pdc+Pac. The Pac is due to the Iac component of the input current.

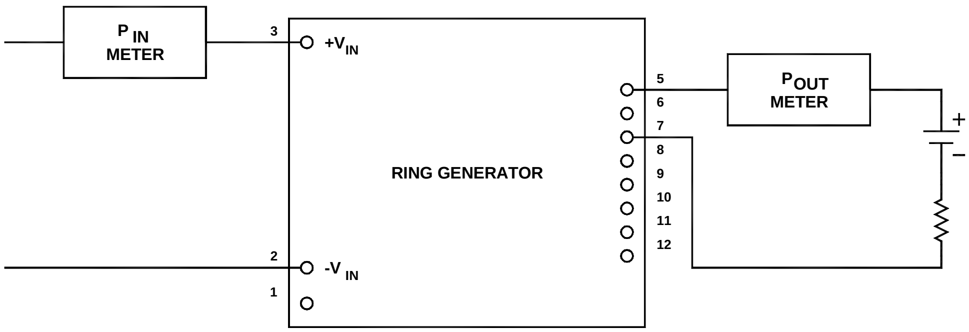

FIGURE 3. Ring Generator Power Measurement Setup

If a true power meter is used (e.g. Voltech 300) for power measurement, the efficiency is given as:

$$e\% = \frac{P_{OUT}}{P_{IN}} * 100$$

The power factor of the output impedance and the output filter capacitor of the Ring Generator reduces the efficiency of the RG3000. The same module operates at 85% efficiency when used as a 50W DC/DC Converter and can go as low as 65% depending on the PF and sine wave frequency when used as a Ring Generator. The following two examples illustrate the effect of the output capacitor in the Ring Generator and the power factor. Assume that a Ring Generator has an output capacitor of 1µF, 250V output, $200V_{PP}$ and an output frequency that varies from 18 to 60Hz. Calculate the power dissipated on the output capacitor at 18Hz and then at 60Hz. The energy (E) needed to charge the capacitor is given as:

$$E = \frac{1}{2}CV^2 = \frac{1}{2}(1\times10^{-6})(40000) = 0.02\text{joules}$$

$$P = \frac{dE}{dt} = \frac{E}{\frac{\tau}{2}} = 2EF \qquad \textit{where } \tau = \text{period} = \frac{1}{F}$$

$$P_{18Hz} = 2E*F = 2*0.02*18 = 0.72W$$

$$P_{60Hz} = 2*0.02*60 = 2.4W$$

EXAMPLE

The Ring Generator is loaded with a 100µF capacitor in series with 500W resistance. Calculate the PF and P_{OUT} for 18Hz and 60Hz.

$$PF_{18} = \frac{1}{\sqrt{1 + \left(\frac{1}{2\pi fRC}\right)^2}} = \frac{1}{\sqrt{1 + \left(\frac{1}{6.28*18*500*100*10^{-6}}\right)^2}} = \frac{1}{\sqrt{1 + 0.031}} \cong 0.985$$

$$PF_{60} = \frac{1}{\sqrt{1 + \left(\frac{1}{6.28*60*500*100*10^{-6}}\right)^2}} = \frac{1}{\sqrt{1 + 0.0028}} \cong 0.998$$

The load impedance is given as: $Z \cong RL + \frac{1}{2\pi fC}$

$$Z_{18} = 500 + 88.5 = 588.5\Omega$$

$$Z_{60} = 526.5\Omega$$

the output power as: $P_{OUT} = VI \cos\theta$

$$P_{OUT} = V_{rms}*I_{rms} \cos\theta = \frac{V_{rms}2}{R} \cos\theta$$

$$P_{OUT\ 18Hz} = \frac{70^2}{588.5}(PF) = \frac{70^2}{588.5}(0.985) = 8.2W$$

$$P_{OUT\ 60Hz} = \frac{70^2}{526.5}(0.998) = 9.3W$$

THERMAL CONSIDERATION

The low efficiency implies that more power is dissipated in the unit when it is operated as a Ring Generator. As a result of this, the case temperature will rise faster. To prevent any thermal runaway of the unit, the thermal protection circuit is located at the output section and is designed to turn on when the case temperature reaches 90°C (with an ambient temperature of 60°C) and forces the unit to stop transferring power to the output. When the unit is operated as a 50W DC/DC Converter, its case temperature can go as high as 105°C with an ambient temperature of 85°C before the unit will turn off. The location of the thermal protection circuit, the lower efficiency of the Ring Generator, and the location of the power component inside the unit produce this temperature differential. The thermally conductive potting material is the only medium to conduct heat from the heat source to the case, but the thermal gradient and the location of the power sources make it impossible for the multiple applications to have the same turn off temperature point.

Note that for the DC/DC Converter application, the heat source is the power transistor located on the input side of the unit; for the Ring Generator application with low PF, the heat source is the power transistor of the linear amplifier located at the output side of the unit.

WARNING! **WE STRONGLY RECOMMEND THAT YOU DO NOT OPERATE THE UNIT ABOVE THE SPECIFIED TEMPERATURE RANGE FOR A GIVEN APPLICATION. USE FORCED AIR OR A HEATSINK IN APPLICATIONS WHERE THE OPERATING TEMPERATURE MAY EXCEED SPECIFIED LIMITS.**