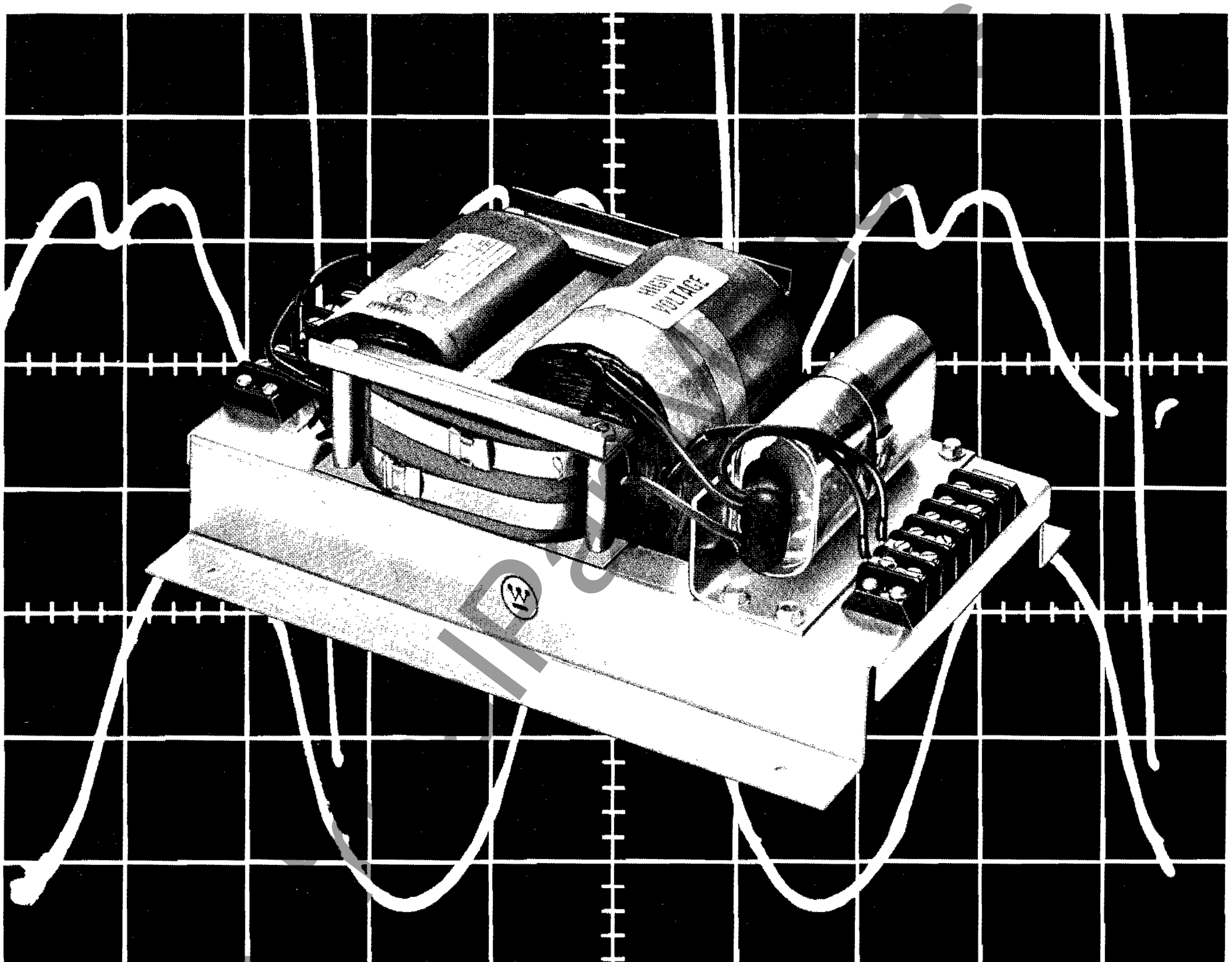
Westinghouse

Type SW Transformers



The Westinghouse Type SW Transformer is a Passive Electrical Interference Suppressor, Ac Voltage Stabilizer and Power Line Filter for Protecting Sensitive Circuits and Equipment

Application

The Westinghouse Type SW Transformer is a simple, rugged ac power conditioner for general purpose "on site" and OEM use to protect against line-borne transient overvoltages, harmonics and transient discontinuities in the input ac.

Primarily a power line filter and interference suppressor, the Type SW also provides good load voltage stability (±1%) for long-term input voltage swings (±10%), together with a sinusoidal output. This transformer is highly effective as a transient or electrical-noise suppressor.

Typical applications are industrial control systems, numerical control circuitry, computer power supplies, medical and laboratory electronics, photo labs, and other locations where sensitive circuitry and equipment require protection.

Type SW Transformers are available in power ratings of 120, 250, 500, and 1,000 va at 60 Hz. Input and output nominal voltages are conventional.

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Operating Characteristics

Filtering Ability

The Westinghouse Type SW Transformer falls into that group of devices and circuits known as parametric amplifiers and oscillators. This family is characterized by their ability to selectively amplify or operate on only pre-set frequency and provide extremely high rejection of all other frequencies.

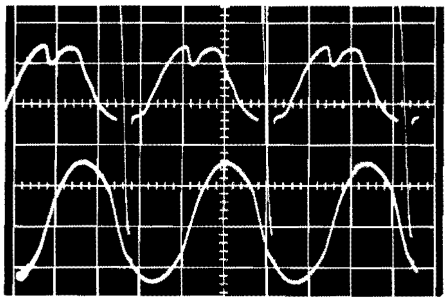

Figure 1. Overvoltage Transients

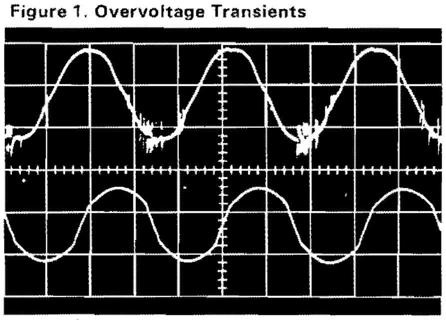

Figure 2. High Frequency Noise

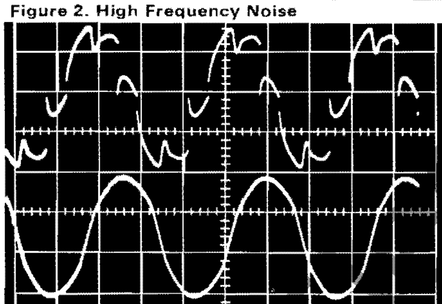

Figure 3. Distortion and Transient Discontinuities due to Cyclically Switched Loads

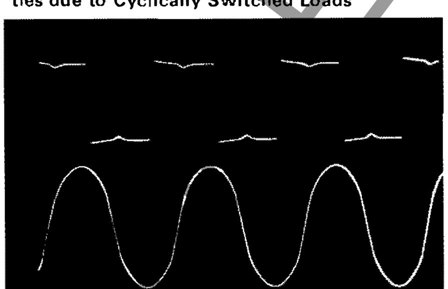

Figure 4. General Filtering Ability

Shown left, below, are some typical input/output oscillograms showing the rejection capability of the device. All waves are 60 Hz., 115 volts, rms.

Overvoltage Transients (Fig. 1)
Here repetitive 600 v (peak) high power transients are being applied. Measurement shows attenuation greater than 60 db. for these high voltage spikes.

High Frequency Noise (Fig. 2)
Here random bursts of high frequency pulses are being applied in each negative half cycle of the input. There is no discernable breakthrough in the output.

Distortions and Transient Discontinuities due to Cyclically Switched Loads (Fig. 3)
As can be seen, the effects of this very common problem are completely eliminated in the output.

General Filtering Ability (Fig. 4)
This can be well demonstrated using the classical square wave input. Note the excellent filtering performance.

For any further information on the filtering performance, please contact your Westinghouse representative, or the Specialty Transformer Division, Greenville, Pa.

Output Voltage Stability

Nominal output voltage for the standard range has been set to the generally acceptable industry standard of 120 v. Manufacturing tolerances will set an actual output voltage within ±1% of this nominal. Variation from this factory setting with the specified change of input voltage (stability) will be within ±1%. All voltages to be measured with a true rms meter.

Output Voltage Regulation

IR drops in the windings will produce some change of the output voltage with changing load (regulation). With the standard range, load regulation is better than ±1½% N.L.-F.L.

Typical Stability/Regulation curves are shown in Figure 5.

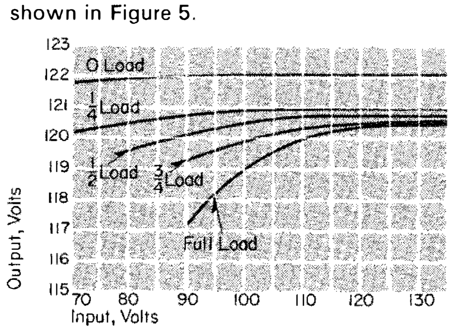

Figure 5. Regulation and Stability

Overload and Low Input Voltage Characteristics

Overload

Unlike conventional transformers, the Westinghouse Type SW Transformer does not need output fusing to protect the load or transformer. When the output current exceeds approximately 1.25 times full load (the actual value is slightly input voltage dependent), the device will automatically switch off, dropping the output voltage to a very low level. Under shortcircuited load conditions the load fault current is limited to approximately 25-50% of full load current. Removal of the overload will provide an automatic switch return of the output voltage to the correct value. The Type SW Transformer will feed a short circuit indefinitely taking only a fraction of the normal no load current from the input supply.

Figures 6 and 7 show typical overload and input under voltage characteristics.

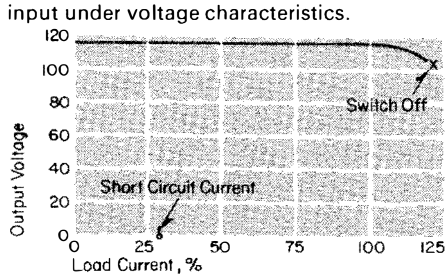

Figure 6. Overload Characteristics

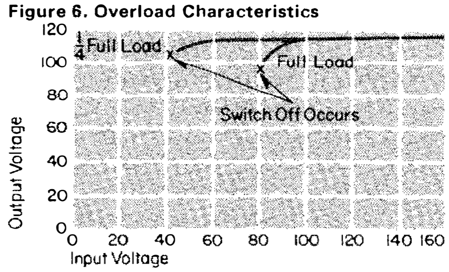

Figure 7. Undervoltage Characteristics

Undervoltage

Unlike conventional transformers and ferroresonant voltage stabilizers, the Type SW Transformer will not "start" or provide load voltage unless the input voltage is within a pre-set design band. The standard range is designed to operate over the range 105-125 v. As long as the input voltage is at or above the minimum, the unit will "start", that is, the output will suddenly jump from almost zero to the correct specified value.

Once started, the unit will maintain output voltage with even a transient loss of the input voltage. Sustained reduction of input voltage will, however, cause an abrupt "switch off" action. The voltage level at which switch-off occurs depends on load.

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Overvoltage on the Input
A sustained voltage on the input in excess of the design range will merely result (as for a conventional transformer) in excessive magnetizing current being drawn from the supply. *The output voltage, however, will not be affected.*

Derating for a Wider Range of Input Voltages or Improved Stability
As can be seen from Figure 7, reduction of load will provide a wider operating voltage range and improved stability. A point of caution here: the "switch on" voltage will only change by about 10% from N.L. to F.L. so starting must be carried out up near the minimum design range level.

Effect of Load Power Factor and Input Frequency Variations
Load power factor does affect the actual terminal output voltage as shown in Figure 8. However, stabilization at this new level will be very nearly equal to that at unity P.F.

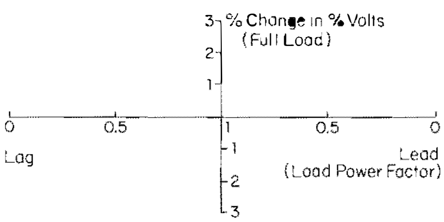

Figure 8.

As the device is essentially a high Q oscillator, the output voltage is dependent on the operating frequency. With the Type SW Transformer the output voltage will change approximately 1½% for every 1% change in input frequency.

Response Time
The Type SW Transformer provides almost instantaneous response to changes in input voltage and load as the corrective action is carried out electrically and not mechanically. Typical transient response characteristics are shown in Table 1.

Table 1

Transient Change	% Peak Voltage Excursion	Response Time	Total Recovery Time
0-115 v Input (No Load)	20%	2 Cycles	10 Cycles
0-115 v Input (Full Load)	10%	1 Cycle	6 Cycles
0-100% Rated Load	10%	1 Cycle	3 Cycles
100-0% Rated Load	15%	2 Cycles	6 Cycles

Output Voltage Waveform Harmonic Content
The standard range of Type SW Transformers is designed to provide an essentially sinusoidal waveform containing not more than approximately 5% Total Harmonic Distortion (T.H.D.) at full load. There is some increase in the T. H. D. with decrease in load.

Voltage Drift with Time
The voltage drift with time of the Type SW Transformer is negligible.

Ambient Temperature
All Westinghouse Type SW Transformers are designed for continuous operation within −25 to 40°C ambient temperature. There is a small change of output voltage level of approximately 0.02%/°C for variations in ambient temperature within this range.

Warm Up Characteristics
The output voltage level is factory adjusted to approximately 1½% higher than the rated level to compensate for the change in voltage that occurs while the unit is reaching normal operating temperatures.

Parallel Operation
Units of the same nominal output voltage can be paralleled to provide increased power capability. There is no deterioration in performance with such connections. The combined rating is the sum of the individual device ratings.

Three Phase Operation
The Type SW Transformer can be connected for three phase, four wire operation with the input connected Wye or Delta. Performance line/neutral will be as for any single phase units. Performance, line to line, will depend somewhat on individual loads as there is a small phase shift of each with the change of input voltage and load.

Phase Shift of Output
As can be seen from Figures 1, 2, 3 and 4, the output voltage waveform is shifted approximately 90° from the input (a characteristic requirement for parametric oscillators of this type). This shift varies slightly over the full range of load and input voltage conditions. It is sufficiently stable to provide (using a Scott/T connection) a very reasonable one to three phase converter.

Efficiency
Approximate full load efficiencies of the standard range of Type SW Transformers depends slightly upon rating but at rated load, nominal input varies between 75-85%.

Principle of Operation
The principles and design of an electromagnetic device which employs non-linearities of the magnetic core to provide its unique characteristics are much more complex than conventional transformer design.

The operation of the Type SW Transformer can, however, be explained in a simplified, non-quantitative, non-mathematical manner as follows.

Consider the simple coil, capacitor combination shown in Fig. 9.

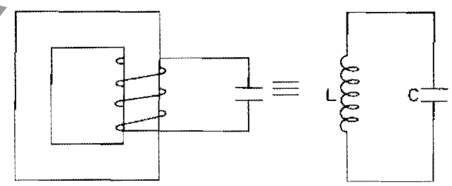

Figure 9.

If we assume that the coil and capacitor have zero resistance, then the shock excitation of this parallel combination (that is by momentarily connecting a battery in parallel – not shown) will initiate an oscillation which will be at a frequency $\left(\frac{1}{2\pi\sqrt{LC}}\right)$.

This oscillation can be maintained (and increased in amplitude) if energy can now be introduced into the circuit at some point in each cycle.

Suppose we could, by some external manner, suddenly increase the inductance L just at the instant when the current in the circuit was at maximum; that is, when the capacitor voltage is zero. Since the energy stored is proportional to LI^2, the energy stored in the field must increase, at the expense of the external mechanism changing the inductance. This increased energy will be transferred to the capacitor as an increase in voltage after another quarter cycle. Since, at this latter instant the current in the circuit is now zero we can change the inductance back to its original value without affecting any energy level. Obviously we can repeat this procedure another quarter cycle later on; that is, energy can be passed into a tuned circuit by the rhythmic variations of one of the parameters (inductance) of the circuit. This is called a parametric oscillation and is shown in Figure 10.

The inductance goes to its low value at every current zero and the tuned circuit oscillation is at one half of the frequency that the inductance is being changed. Alternatively we can say that the oscillation is pumped at twice the operating frequency.

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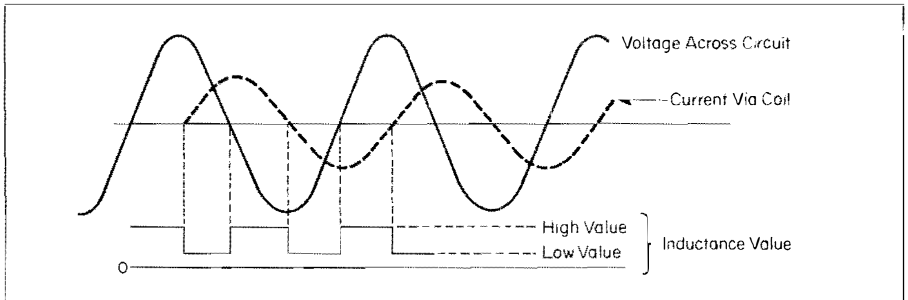


Figure 10.

The next problem is a practical method of obtaining this inductance variation.

Inductance of a winding is given by $L = 3.2\, N^2 A\, 10^{-8}\, \mu / l$

A = Area of iron in square inches
l = Length of magnetic path in inches
μ = Permeability of magnetic core
N = Turns

All the terms are constants with the exception of μ, the permeability of the core. For conventional core material permeability decreases with increasing flux density, so a simple way to vary the effective inductance of our coil is to, in some way, locally change the flux density in some part of the core independently of the flux caused by the oscillation. Let us connect another core, coil, battery and switch to the original core as shown in Figure 11.

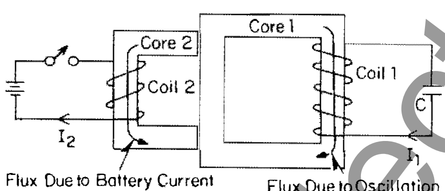


Figure 11.

From Figure 10 we see that we would like to drop the inductance of Coil #1 down to its low level at the current zero of the oscillation. In that case let us close the switch at that instant. The battery current will produce a flux which will traverse Core #2 and part of Core #1. The net permeability of Core #1 will be reduced and the inductance of Coil #1 will drop, as required. A quarter cycle later, at the oscillation current maximum, we can open our switch. The flux due to the battery current will die away, the permeability of that part of Core #1 which was traversed by both fluxes will now rise and the inductance of Coil #1 will also rise, as required. Energy is extracted from the battery as I_2 decays and is then passed into the capacitor in the next quarter cycle.

The switch is obviously impracticable so we can make an equivalent switch by connecting an ac supply of the same frequency as the oscillation to Coil #2. This applied ac voltage will produce a magnetizing current lagging by 90°. If this magnetizing current reaches its zero at the instant that the oscillating current is maximum, the inductance of Coil #1 will rise, as required, and we will obtain our "pump" of energy as LI^2 is increased.

Since the input ac voltage and current differ in phase by 90°, the input ac current zero corresponds to input voltage maximum and the "energy" pulse appears as an input current pulse at input voltage maximum. The input and output currents and voltages are thus as shown in Figure 12.

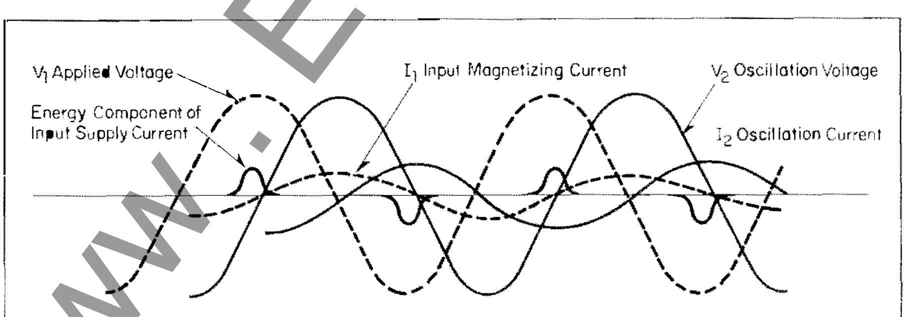


Figure 12.

Inductance is not dependent on the polarity of the applied fluxes. It thus goes through two complete cycles during each cycle of the input, as required by Figure 10.

Note that we have a 90° phase shift between input and output voltages.

With care in the design and proportioning the core we can also dispense with the requirement of shock exciting the tuned output circuit and make the unit self starting. One practical embodiment of the design is shown in Figure 13.

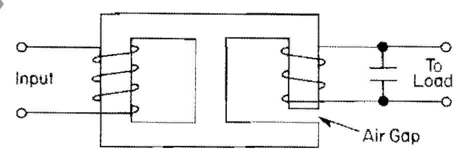
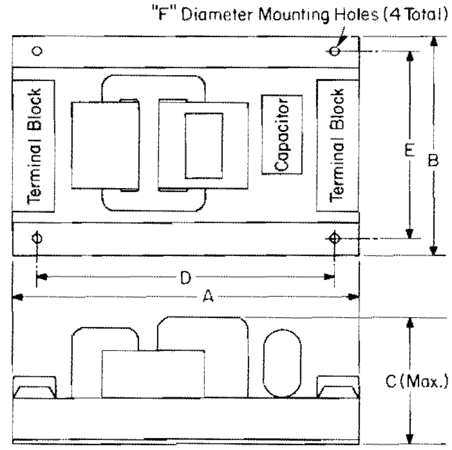


Figure 13. Simple Practical Realization of Power Oscillator and Filter

Dimensions



VA Rating	Dimensions, In. A	B	C	D	E	F
120	11½	7½	4¾	10	6½	5/16
250	13½	9½	6	11	8½	5/16
500	15¼	10⅝	6¾	13	9½	5/16
1000	18	11⅝	7	16	10½	5/16

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