NEGATIVE-IMPEDANCE CONVERTERS (NIC) FOR VHF THROUGH MICROWAVE CIRCUIT APPLICATIONS

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The negative impedance converter (NIC) is an active circuit element which has been increasingly useful in low frequency applications. It is a 2 port device which converts any load impedance at one port to an input impedance -Z as seen at the other port.[1,2] The NIC can be used to synthesize negative impedances and admittances which are then used to generate transfer functions or impedance functions which are not physically realizable without active circuits.[1-4] We have developed two types of NIC circuits suitable for VHF and microwave applications. The first type of NIC is based upon the idealized circuit shown in Fig. 1. Particular care has been taken in the design and layout of this circuit to minimize stray reactances which might reduce the frequency response of this NIC realization. The transistors used in this circuit are NEC 2SC 989's which are relatively inexpensive and have an f_T of 3 GHz. Figure 2 is a sketch of the layout of a practical realization of the RF portion of this NIC. Figure 3 demonstrates that the NIC can indeed neutralize a 22 pf capacitor up to 120 MHz. Figure 4 shows the effect of temperature variations on a lossless single-pole L-C filter which used an NIC to generate a -R which cancelled the loss in the inductor. The loaded Q of the tuned circuit is 100. Without the NIC, the loss of the tuned circuit was 8 dB. The noise figure of the filter and NIC was 17 dB and the in-band third order intercept was -12 dBm.

The measurements that we have made on the NIC indicate that it is mainly the phase shift around the feedback loop which degrades the NIC performance so that a resistance rotates to a negative inductance rather than a negative resistance. Extrapolating the performance of the present circuit, 12 GHz f_T transistors will enable one to build NIC circuits of this type up to perhaps 0.5 GHz.

The second type of NIC is essentially bandpass in its behavior, making use of time delay to obtain the 180^o phase shift necessary for the operation of this particular circuit. Figure 5 shows a simplified schematic of the new NIC (NUNIC). Note that this circuit cannot perform as an NIC at low frequencies; in fact, it is a cascode amplifier. Over a moderate bandwidth the 180^o phase shift due to the unavoidable time in the circuit and the transistors is equivalent to a unity gain phase inverter, resulting in feedback of the proper phase for NIC action. Over an octave with a resistive load on the NIC, a good equivalent circuit for the input impedance would be a parallel resonant circuit having a negative Q of 2. One could use this circuit as an NIC over an octave without being too much bothered by the reactance slope of the NIC itself. A more accurate equivalent circuit may be obtained by computer simulation which is particularly useful when multi-octave usage of the NIC is anticipated. Using 3 GHz f_T transistors (NEC 2SC 1090) and using simply a 100 Ω resistor as a load the circuit will generate a broadband negative resistance from 0.5 to over 2 GHz. Figure 6 shows a plot of $1/\Gamma^*$ measured for this circuit.

Unavoidable cumulative time delays around the feedback loop in an NIC limit its usable bandwidth, regardless of its center frequency. Within its usable band an NIC can be used to broadband a load, or to raise the Q of a filter. However, such problems as stability, added noise, and distortion require simple solutions before the NIC will be widely accepted as a microwave circuit element.

This work has been supported by contract under DAAB07-70-C-0044. We would also like to thank Eldon Fernandes and Glen Tomlin for their measurements and construction work.

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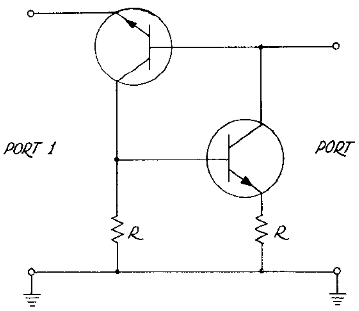

IDEALIZED NIC CIRCUIT

FIGURE 1

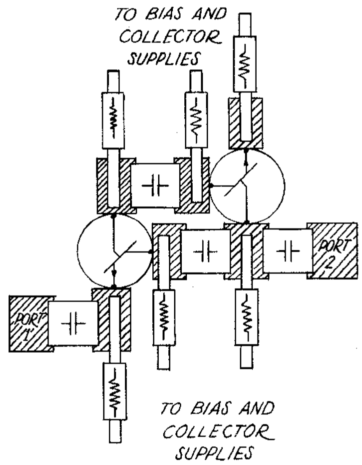

FIGURE 2
NIC LAYOUT

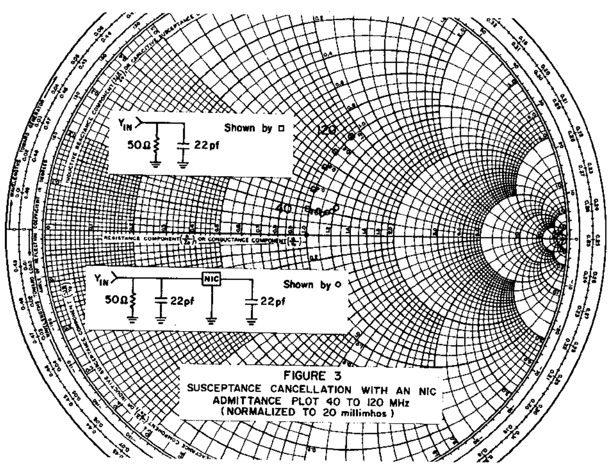

FIGURE 3
SUSCEPTANCE CANCELLATION WITH AN NIC
ADMITTANCE PLOT 40 TO 120 MHz
(NORMALIZED TO 20 millimhos)

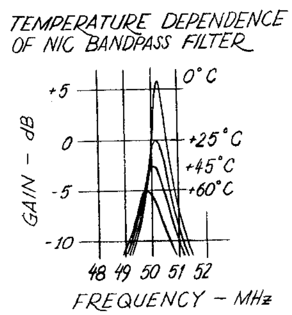

FIGURE 4

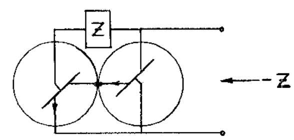

FIG. 5 SIMPLIFIED NUNIC CIRCUIT

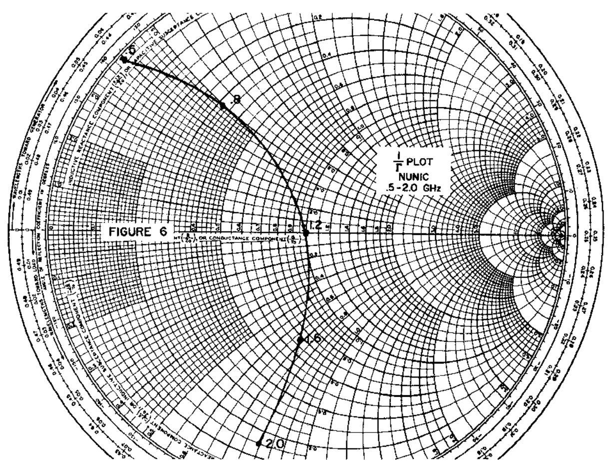

FIGURE 6