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THE MEASUREMENT OF A TELEPHONES' MINIMUM SIDETONE IMPEDANCE ... Zs0. A NEW METHOD.

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1. INTRODUCTION.

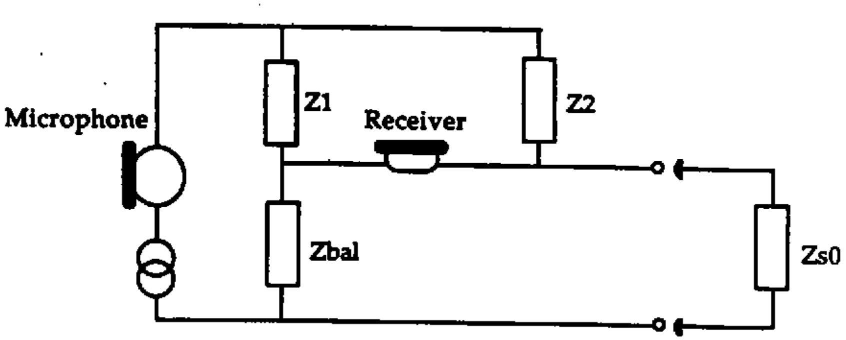
Zs0 is the abbreviation for the complex impedance, which when connected across the two wire port of an analogue telephone, results in complete suppression of local electrical sidetone. Because sidetone plays an important part in the subjective performance of a telephone connection and is sensitive to line impedance, it is possible to improve the performance range of a given telephone by specifying and controlling this quantity during manufacture. Some telephones exhibit values of Zs0 which have negative real components of impedance. This makes the physical realisation of a Zs0 network impossible. In any case the measurement is tedious. The method described here synthesises the required impedance by using an agile source of alternating emf. By this means it is possible to suppress the sidetone by up to 80 dB over all four quadrants of the complex impedance plane. Once this condition has been achieved it is a simple matter to calculate the value of Zs0.

Four methods are presently in use [1]. All these methods have the disadvantage that the measurement and subsequent calculation are not made at the point of zero sidetone. Thus errors can creep in due to non- linearities in the telephone.

The equipment described here provides the actual circuit termination condition for zero sidetone for any quadrant of the complex plane. Since TIGGER [2] systems provide the kernel for telephone transmission objective measurements, it is a logical step to integrate the Zs0 measurement into this facility, with all the advantages that compatibility and uniformity bring.

2. THE WHEATSTONE BRIDGE ... A QUICK RECAP.

Simple two wire telephones can be represented by a Wheatstone bridge shown in figure 1 below.



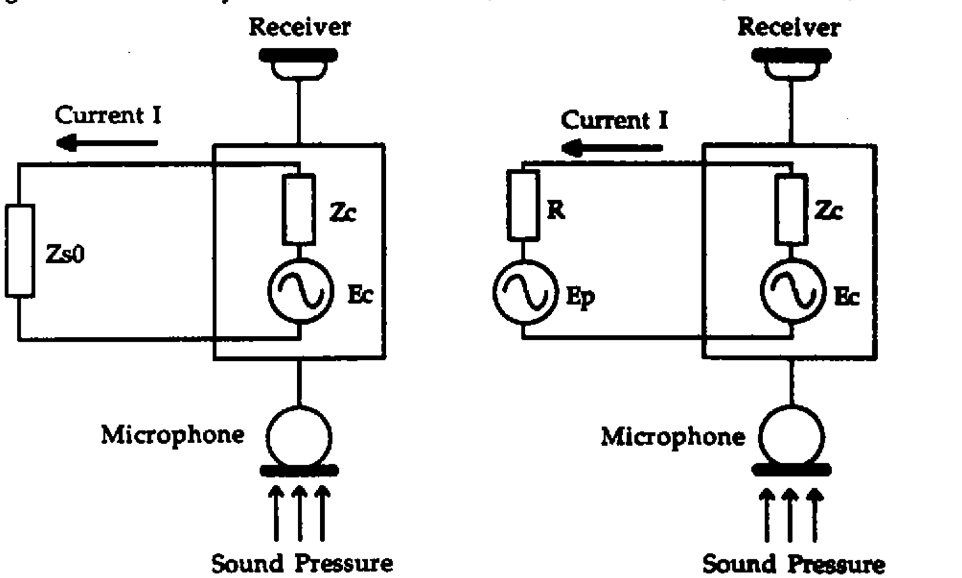
Simple Telephone as a Wheatstone Bridge

Figure 1.

The classic equation for a Wheatstone Bridge at balance is Z1/Zbal = Z2/Zs0. Rearranging the equation gives $Zs0 = (Z_{bal} * Z_2)/Z_1$. The product of Z bal and Z_2 can give rise to a terminating condition of a negative real impedance in some telephones. This can be seen by multiplying the terms fully. Multiply a+jb by c+jd: the result is (ac-bd) +j(ad+bc). Thus if the product bd is greater than the product ac, the resultant Zs0 impedance for bridge balance will have a negative real component, and will not be practically realizable. If a positive real component is an energy absorber, then logically a negative real component is a an energy source. Herein lies the solution.

3. REALISING THE SOURCE

Figure 2 demonstrates how a source of emf can be used to encourage the same current to flow from the telephone terminals as would flow if the appropriate Zs0 were connected. The emf setting at which the sidetone is zero is monitored by stimulating the telephone microphone with an appropriate sound pressure and measuring the sound pressure attained in an artificial ear, sealed to the receiver earcap. Alternatively, it is also possible to inject a signal in series with the handset microphone to remove seismic transmission through the handset. Zero sidetone gain is more usually known as GmeST = 0, (Gain mouth to ear, SideTone).



Telephone terminated with Zs0

Telephone terminated with emf source to encourage identical current

Figure 2.

We are now armed with the necessary information to calculate Zs0, but the emf source has to be manually adjusted. The next stage is to let the computer do the work and set the emf automatically. What is required is a device that can take an AC input and derive an emf output with a variable amplitude and phase relative to that input at a given frequency, (programmable transfer function). Such a device did not exist and so the following scheme was adopted.

4. THE HARDWARE.

Instead of thinking in terms of amplitude and phase, it is more useful to deal in rectangular co-ordinates in the following way. Imagine a voltage vector on the complex plane which has to be placed in any position on that plane. If the vector is constructed from the addition of two vectors which are mutually at right angles, and can each take on any positive or negative value, then we have the basis of the required device, known as the Zs0 processor.

Figure 3 shows the practical realization of this approach:

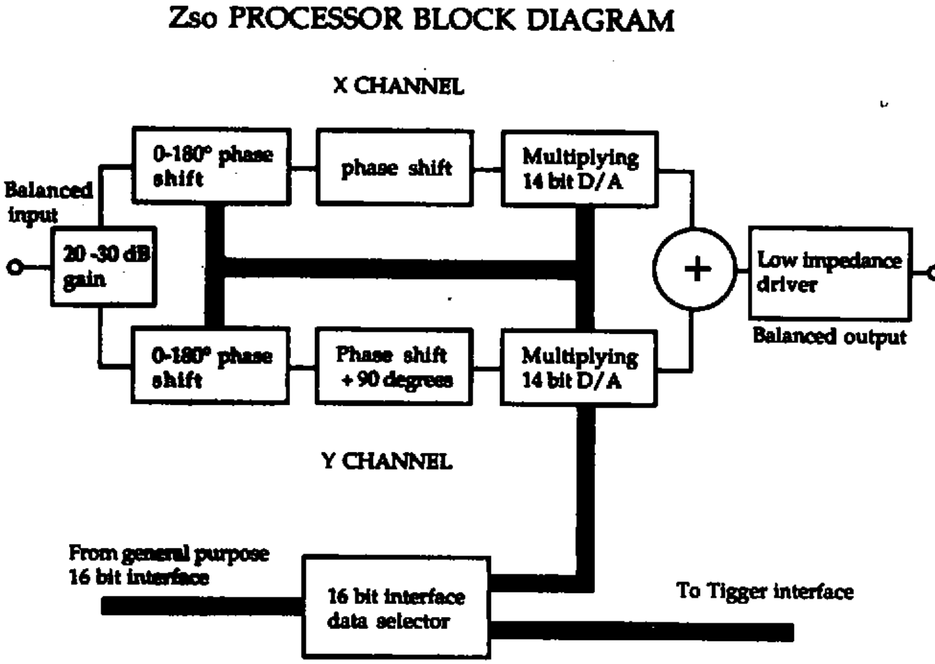


Figure 3.

The broad lines in the diagram indicate the digital control lines which are connected to the computer's 16 bit interface. The 14 bit D to A's used are designed for microprocessor applications and the data is loaded into the registers in two bytes. A requirement of integration into the TIGGER system is that the Zs0 hardware is transparent to the TIGGER system while standard TIGGER software is run. Thus a data selector is included to control this aspect. Bit 15 (the sign bit) is always set to 0 in the TIGGER software and so this is set to 1 in the Zs0 software to connect the processor into circuit. A single printed circuit board has been designed to accommodate these functions.

5. CALIBRATING THE PROCESSOR.

As it stands, the processor circuit described will not provide the programmed transfer function required, we don't know the overall gain and the 90° phase shift circuit is accurate to only +/-5°, and so a method has been devised for calibrating the circuit. The software scales the complex number written to the processor to be between -1 and 1. Figure 4 below shows the calibration technique.

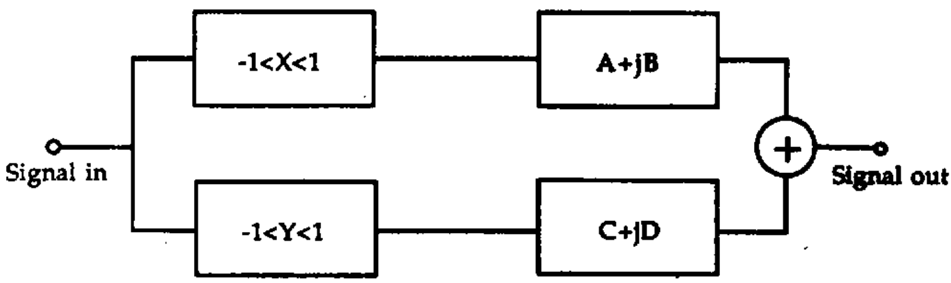


Figure 4.

If we let the transfer function Signal out / Signal in be E+jF, and X,Y the values written to the Zs0 processor; then $E+jF = X(A+jB) + Y(C+jD)$

This gives rise to the simultaneous equations : $AX+CY = E$ and $BX+DY = F$

Thus $Y = (BE - AF) / (BC - AD)$ and $X = (E - CY) / A$

By setting Y to 0 and X to 1, A+jB can be determined, similarly by setting X to 0 and Y to 1, C + jD can be determined. These are the coefficients which allow the processor to generate a target vector. It is important to note that A+jB and C+jD need not be gain/loss/phase shift in the processor itself but can be (and are) anywhere between the points of measurement, eg telephone, artificial ear, microphone preamplifier etc. The net result of this procedure is that we now have a powerful routine for setting the transfer function of the processor and associated circuitry. The associated circuitry in this case is the telephone receive path and the artificial ear / amplifier.

6. REALISING THE MEASUREMENT.

Figure 5 shows the basic layout for this method of the measurement of Zs0. All the equipment is available as part of the TIGGER system, and the processor output is connected into the circuit by attaching it to the Frequency Response Analyser Channel 1 input. This can then be switched around the circuit.

Zs0 MEASUREMENT CIRCUIT BLOCK DIAGRAM

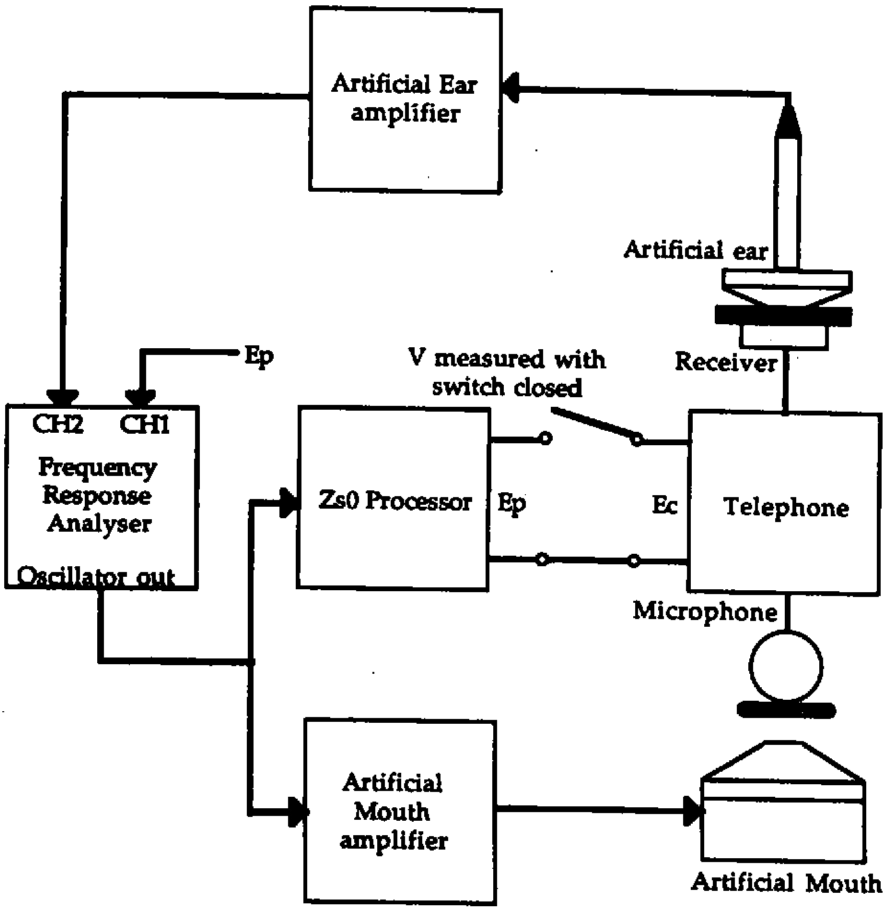


Figure 5.

7. CHECKING THE MEASUREMENT ACCURACY.

Generally, modern telephones are designed to have a return loss within 20dB of an 'ideal Zs0' from 300 Hz to 3150 Hz. This ideal is formed by a parallel combination of 0.18 μF and 1500 Ω in series with 270 Ω. It is good practice to have a measuring system an order of accuracy greater than that desired result, and so a minimum return loss of 40dB has been sought.

In order to check this accuracy a Calibration telephone with a known Zs0 has been built along the lines of the Wheatstone circuit in figure 1. The Zs0 has been designed to be 1000 Ω +j0 Ω. Using 0.1 % resistors the Calibration telephone has a Zs0 of 1000 Ω +/- 0.3 %. This gives an expected return loss (re 1000 Ω +j0 Ω) of 56.5 dB minimum. In practice this value is not achieved over the full frequency range due to resonances in the constant current telephone D.C. feed circuit. The Calibration circuit provides an essential check that the measurement system is working satisfactorily.

8. RESULTS.

A reference Zs0 measurement (RES/CAP) was made using resistance and capacitance decade boxes. The settings were then measured on a precision component bridge to obtain the true values.

CATGIT [3] is an alternative measuring system that switches actual resistors and capacitors into the circuit under computer control.

A précis of the results is shown below in table 3.

TELEPHONE	FREQUENCY 630 Hz		1250Hz		2500Hz	
I = 40 mA	Real Imag	RL	Real Imag	RL	Real Imag	RL
Telephone A						
RES/CAP	469.0-j644.5	11.9	489.0-j507.3	24.5	387.0-j370.1	25.9
Zs0PROC	470.2-j641.3	11.9	489.8-j506.7	24.5	385.3-j368.8	26.2
CATGIT	462.3-j643.4	11.7	488.1-j514.4	25.0	382.1-j371.6	26.3
Telephone B						
RES/CAP	1056.0-j760.9	29.3	607.0-j646.3	25.1	360.0-j397.9	24.1
Zs0PROC	1052.3-j752.4	29.7	608.2-j643.2	25.2	358.2-j396.3	24.3
CATGIT	1032.2-j769.4	31.7	589.5-j641.1	26.6	353.8-j399.9	23.9
Telephone C						
RES/CAP	1091.0-j789.5	26.1	622.0-j646.3	24.2	378.0-j335.1	30.7
Zs0PROC	1085.4-j785.4	26.5	619.1-j643.4	24.5	376.1-j334.1	31.2
CATGIT	1065.3-j794.1	27.7	605.7-j644.9	25.3	375.8-j334.8	31.3

Table 1.

RL = Return Loss relative to the "Ideal" network.

9. CONCLUSION.

A system has been designed and built which will interface easily with a TIGGER system and enable Zs0 measurements to be made with much greater accuracy than before. The overall accuracy is dependent solely on the tolerance of a single resistor and of the voltage measuring device. Good correlation has been achieved against resistance capacitance measurements, the average difference between the two methods is 0.3%. Greater accuracy can be obtained if desired, by increasing the integration time of the voltage measurements. A useful increase in the speed of measurement has been achieved, especially when the package is used for development rather than specification control.

10. REFERENCES.

[1]: SABINE E. : "Methods for measuring Zs0" : Internal BT document : July 1986

[2]: WARD H.F. & CROSS R.C. : "TIGGER, An Automatic Test System for measuring the Transmission Performance of Telephones" : [UDC No 621.395:621.396.218:681.31] : IBTE Journal, Vol2, Part 2 : July 1983.

[3]: WEBB P.K. : "Computation of the Characteristics of Telephone Connections". : Internal BT document : March 1978 : (CATGIT is the equipment based on this report).