

## TECHNICAL MEMORANDUM

Subject: 555 PBX—the attendant’s telephone set circuit

Issue: 4

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### 1 INTRODUCTION

The attendant’s telephone set in the 555 PBX is of the anti-sidetone type. This memorandum discusses its circuitry and operation.

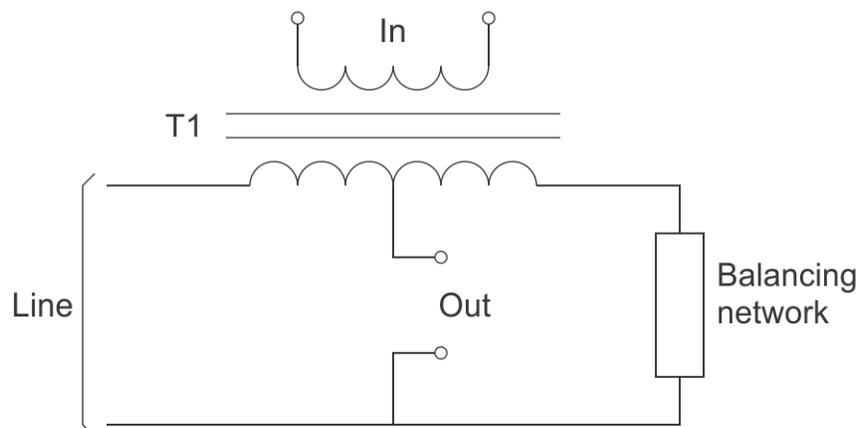
### 2 ABOUT THE READER

It is assumed that the reader has a general familiarity with the matters of sidetone, sidetone reduction, and the general role of hybrid coil circuits (“hybrids”).

### 3 THEORY OF THIS HYBRID CIRCUIT

#### 3.1 The circuit and its behavior

This figure:



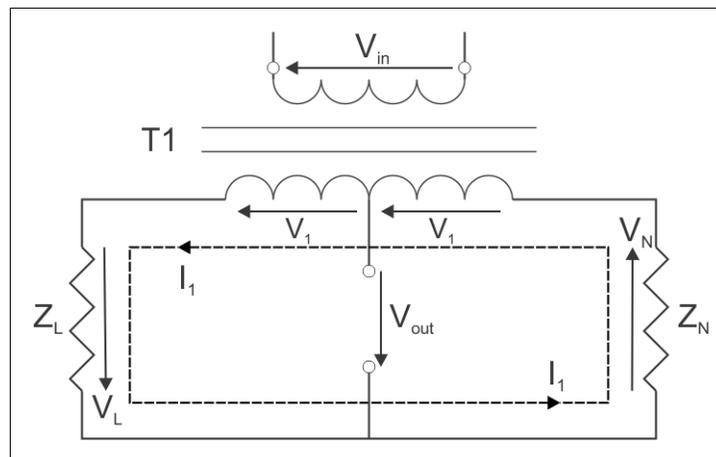
shows the hybrid coil setup of interest here. It is of the “single-coil” type, meaning that it utilizes only one repeating coil (transformer).

Assuming the impedance of the balancing network is precisely the same as the impedance of the line, then:

- For a signal arriving into the line port, half the signal power is delivered to the Out port and half to the In port (the latter power is absorbed by the circuit feeding the In port, and is wasted).
- For a signal sent into the In port, half the signal power is delivered to the Line port and half to the balancing network (the latter power is wasted). Importantly, none of that signal power is delivered to the Out port. This is the central feature of all hybrid coil circuits.

### 3.2 Proof

In proving the latter point of behavior, I will work from this figure:



As to the arrows indicating voltages, the sign convention is that value is the voltage at the head of the arrow with respect to the tail of the arrow.

Note that the voltages and current here are AC, and all the letter symbols represent phasor (“vector”) quantities. I do not here follow the convention of using bold symbols (or other markings) for phasor quantities.

I assume a signal with voltage  $V_{in}$  is presented to the In port, which goes to the primary of transformer T1.

The secondary winding of T1 is center-tapped, thus in effect becoming two identical windings. They both develop identical voltages I will write as  $V_1$ . This develops a current around the loop,  $I_1$ , which is given by:

$$I_1 = \frac{2V_1}{Z_L + Z_N} \quad (1)$$

But since we assume here that  $Z_L = Z_N$ , that becomes:

$$I_1 = \frac{V_1}{Z_L} \quad (2)$$

That current develops voltage drops  $V_L$  and  $V_N$  across the line (viewed here as its impedance,  $Z_L$ ) and the balancing network, with impedance  $Z_N$ , respectively. Since here we assume that  $Z_L = Z_N$ , those voltage drops are given by:

$$V_L = V_N = -I_1 Z_L \quad (3)$$

the minus sign coming from the convention I have used for the direction of  $V_L$  and  $V_N$ .

Substituting, we find that:

$$V_L = V_N = -V_1 \quad (4)$$

We can see that the output voltage,  $V_{out}$ , is given by:

$$V_{out} = V_L + V_1 \quad (5)$$

Substituting, we find that:

$$V_{out} = 0 \quad (6)$$

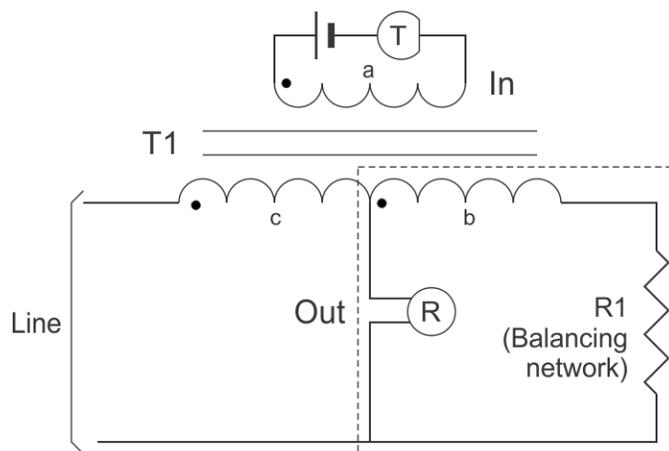
*Quod erat demonstrandum.*

That is, for a “perfectly balanced” hybrid of this type, none of the input signal appears at the output port.

## 4 THE ACTUAL CIRCUIT

### 4.1 Basis premise

The attendant’s telephone set circuit in the 555 PBX utilizes that hybrid coil circuit. We see the basic circuit here in an illustrative context:



The dots show the ends of the windings that, at any given time, have the same polarity.

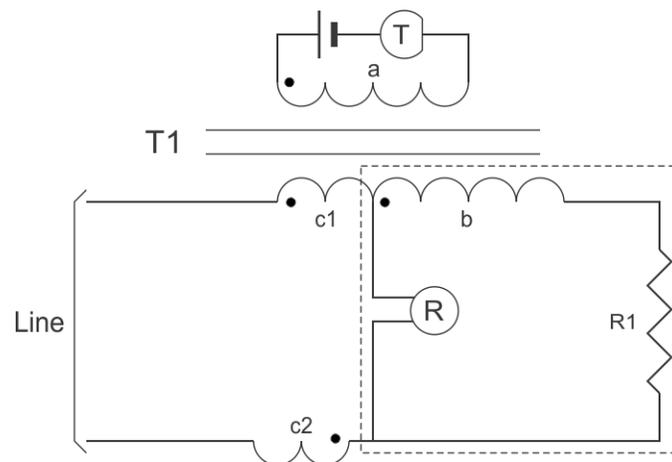
The "input" to this hybrid is from the transmitter (T) of the attendant's telephone set (a headset, handset, or such), energized by the battery, into winding "a" of the transformer (T1), the "input" to this hybrid.

The "output" of this hybrid goes to the receiver (R) of the attendant's telephone set.

Resistor R1 is the "balancing network". Its role is to approximate the expected impedance seen at the line terminals (on the left). But here the overall design is intentionally such that the expected "balance" of the hybrid will not be "nearly perfect". This way some of the speech signal from the transmitter will reach the receiver, producing some "sidetone", a moderate degree of which is actually desirable.

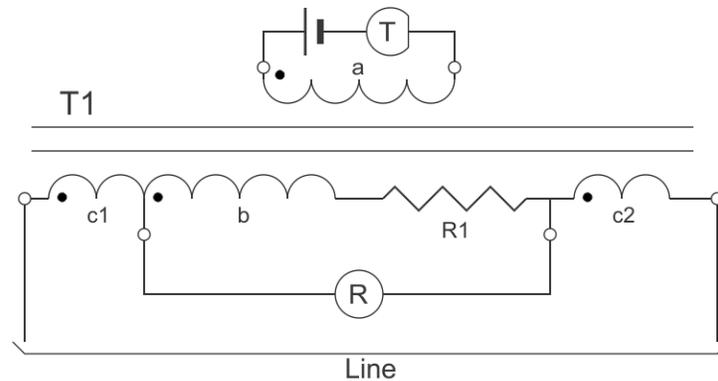
A problem with this circuit as seen here is that there will inevitably be capacitance to ground from the collection of apparatus shown inside the dashed line. Since this all "hangs" on one side of the line, the resulting unbalance of the admittance to ground on the two line conductors can lead to noise from "longitudinal" voltages or currents that may be induced onto the line.

To mitigate this, a small change is made in the circuit, as we see here:



Transformer winding "c" is now divided into two parts (labeled "c1" and "c2"). and c2 is moved to the other side of the line, which doesn't really change the operation of the circuit. But it leads to an approximately "balanced" situation in the sense just discussed (not the same as the "balance" of the hybrid).

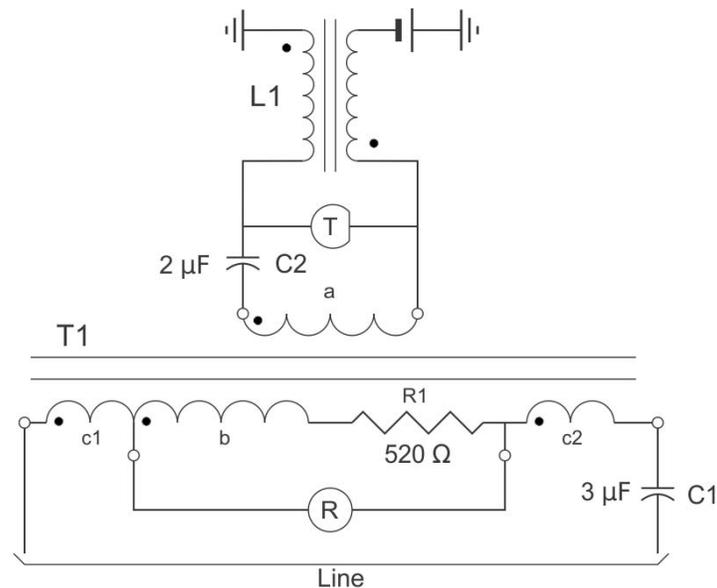
We can relate this circuit to what we may see on actual circuit schematic drawings by redrawing it this way:



Note that this is electrically equivalent to what we saw just above. But this presentation better fits the reality of implementation, and follows more closely how that is shown on various official drawings.

For example, in the implementation in the 555 PBX, balancing network resistor R1 is actually inside the transformer (which is in fact nomenclatured as an “induction coil”, out of historical continuity). R1 is actually implemented as a non-inductive winding of the transformer, made of resistance wire, “doubled over” so it has no inductive effect nor inductance.

I have so far shown this circuit in a simpler way than how it is actually implemented in the 555 PBX, the objective being to make most clear the principles involved. But here we see the actual details of the circuit more nearly as implemented:



Firstly, we note that the connection to the line is through a capacitor, C1. This is because at the point at which this circuit connects to the line there may be a DC voltage between the line conductors, and we do not want this circuit disturbing that.

Secondly, we see that the DC that energizes the transmitter of the attendant's telephone set does not pass through winding "a" of transformer T1. One reason why not is that such a DC current could partially saturate the core of transformer T1, which could compromise its handling of speech signals. Another reason is that the actual arrangement better accommodates the need, in some applications, to be able to "mute" the attendant's transmitter without making a "pop" on the circuit (this not further discussed here).

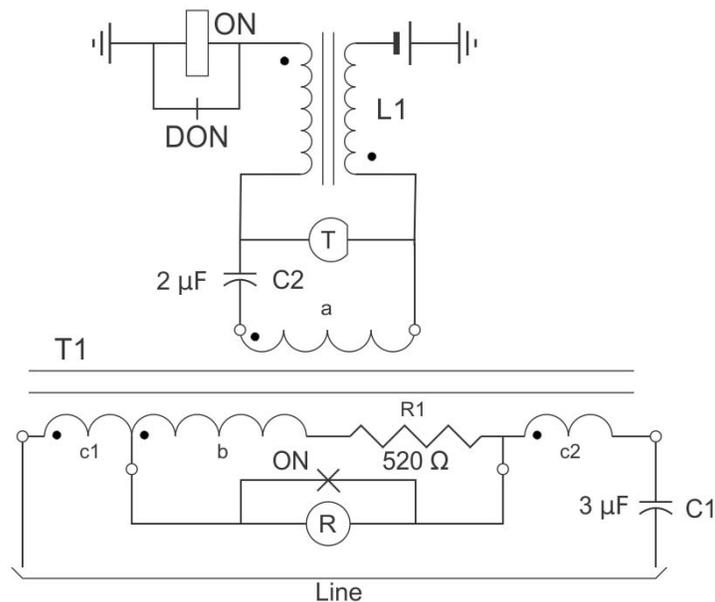
Rather, the DC current is fed to the transmitter through an inductor, L1 (in fact one with two windings, so as to scrupulously follow the obsession with balance). The inductance prevents the AC signal developed across the transmitter from being "shorted out" by the path back to battery and ground.

That AC signal is coupled through capacitor C2 to winding "a" of the transformer, where it acts just as we saw in the earlier simplified illustrations.

## 5 DIALING—EFFECTS ON THE ATTENDANT'S TELEPHONE CIRCUIT

In this section I assume that the position dial is of the rotary (pulse) type.

We see the pertinent additional circuit elements in this figure:



We note that now the ground side of the battery feed to the transmitter is through the winding of a relay, ON ("off normal"), but that is initially short-circuited by the dial off-normal break contact, DON. When the dial is "wound up" (moved "off normal") DON opens. The current through the transmitter battery feed circuit is now through the coil of relay ON, which operates.

A make contact on relay ON short-circuits the receiver, muting it to prevent the attendant from hearing the (loud) clicks that otherwise would come from the dial pulsing in the line circuit.

We do not see the circuit arrangements for the actual dial pulsing, nor for other circuit rearrangements that occur while the dial is off-normal, since those are beyond the scope of this memorandum.

Of course, when the dial returns to normal, contact DON closes, the winding of relay ON is now again short-circuited, and it releases. The short circuit around the winding makes the relay a little slow to release. This is intended, so that the receiver circuit is not enabled until after the transients from the other circuit rearrangements being restored have finished.

## **6 REFERENCES**

The information in this memorandum is primarily based on an analysis of BTL circuit schematic drawing SD-66520-01, Issue 24 (1972-08-16), in particular the attendant's telephone circuit per Figure O.

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