A Group Listening-In Application for the MC33215

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INTRODUCTION

The MC33215 is developed and optimized for use in fully electronic telephone sets with both handset and handsfree operation. A mode for group listening–in operation is not incorporated, but can easily be built, and is described in this application note.

BACKGROUND

In general, there are three types of off–hook operation of a corded telephone: handset mode, handsfree mode (also called speakerphone mode), and group listening–in mode (to be referred to as GLi in this application note). In handset mode the subscriber uses only the handset microphone and earpiece, while in handsfree mode the base microphone and speaker are used. In group listening–in mode both the handset and the base are used; to be more precise, the handset and the loudspeaker of the base.

The MC33215 (see Figure 1 for a simplified block diagram) has two different modes of operation fully incorporated: handset mode and handsfree mode, selected via the SPS pin. Independent of these two modes, the loudspeaker can be enabled and disabled via the LSM pin. Thereby a GLi application can be created by selecting the handset mode and enabling the loudspeaker.

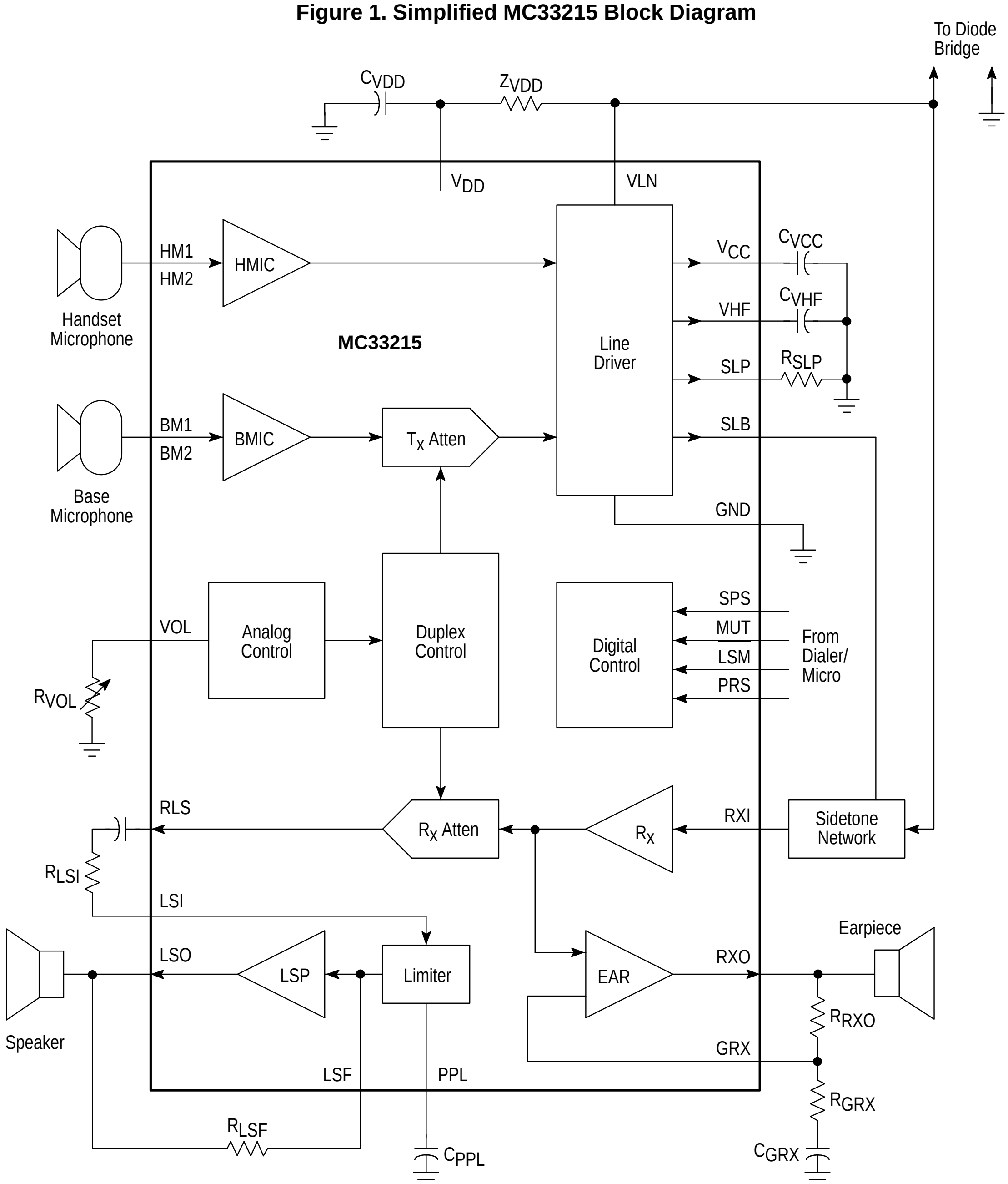
By selecting the handset mode, the signal path from RXI to RLS is muted, since the receive attenuator/amplifier is muted. The receive signal therefore has to be coupled in at LSI via an additional signal path to make it audible at the loudspeaker.

In GLi applications, howling can result from too high a gain in the loop which includes the various amplifiers, sidetone path, and the acoustical coupling between handset microphone and loudspeaker. Therefore a circuit has to be added which reduces the loudspeaker gain when howling is detected.

A last point which needs attention is the volume control. In the MC33215, the volume of the loudspeaker signal is controlled via the VOL pin, which controls the receive attenuator/amplifier via the duplex controller. This is done to have a correct switching behavior in the handsfree mode under different volume settings. Because the receive attenuator/amplifier is muted in the handset mode, the VOL pin no longer has an effect. An additional circuit must take the information from the VOL pin to control the loudspeaker gain in the GLi mode.

In the following sections, the points noted above are discussed, and each partial solution is presented to create the GLi application. These solutions are then tied together in the section entitled **"Gluing it all together"**.

Figure 1. Simplified MC33215 Block Diagram



BUILDING BLOCKS FOR A GROUP LISTENING–IN APPLICATION

As already noted above, to build a GLi application the following four steps have to be performed:

1. Select handset mode and activate the loudspeaker amplifier.
2. Create a receive signal path to the loudspeaker amplifier input.
3. Add a howling limiter acting on the PPL pin.
4. Add a volume control for the speaker.

These four steps are discussed below.

1) Mode Selection

For the GLi application the handset mode of the MC33215 has to be selected and the loudspeaker amplifier has to be activated per Table 1.

Table 1. Logic Table for the Different Operating Modes

Mode in Off–Hook	SPS	$\overline{LSM}$
Handset	0	0
Group Listening–In	0	1
Handsfree	1	1

This still leaves open the possibility to have the privacy mode selected via the PRS pin, or to perform DTMF dialing by taking the MUT pin low. In that case, a confidence tone is audible on both the earpiece and the loudspeaker.

If an application is built with the W91530A Winbond dialer (supplied on the MC33215 demoboard), the correct logic levels can be obtained with the interface circuit shown in Figure 2. This circuit is based on the idea that the Hookswitch is open when the handset is on the base, and closed when lifted off the base.

2) Receive Signal Path for the Loudspeaker

In speakerphone mode the signal at RLS is applied to the loudspeaker amplifier input LSI via a series RC network. This LSI input acts as a summing node since the overall loudspeaker amplifier structure is of the inverting voltage amplifier type.

In the handset mode used for the GLi application, the receive attenuator/amplifier is muted, meaning there is no receive signal present at the RLS pin. To create a second signal path for receive, the signal at either RXI or RXO has to be applied to LSI via a series RC network. The extra network will have no effect on the loudspeaker gain in speakerphone mode since LSI is a summing node.

The signal at RXO is chosen for two reasons: a) The overall gain from the line to RXO for receive signals equals 0 dB, as does the gain from the line to the RLS output, and b) By using the signal at RXO, the line length regulation, or AGC, is effective. In principle the same network used between RLS and LSI will suffice due to the similar signal levels.

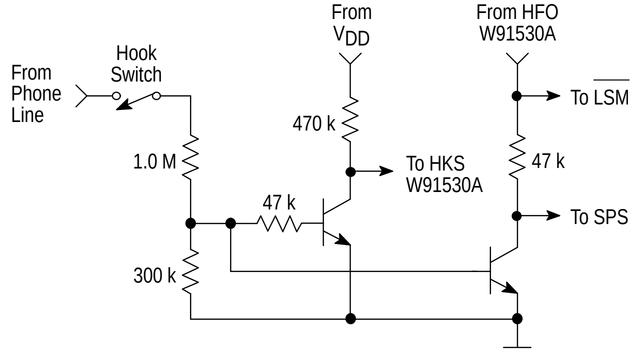
It has to be noted that an earpiece transducer acts not only as a speaker but also as a microphone. In normal handset operation this will cause no problems since RXO is simply an amplifier output. However, in the proposed GLi setup, any sound reaching the earpiece transducer creates a signal that is coupled via the series RC network to the loudspeaker amplifier. This creates an additional acoustical coupling which influences both GLi and handsfree operation. For GLi operation this can be considered as a secondary problem because the main acoustical coupling is between the loudspeaker and the handset microphone. During handsfree operation however, the handset is placed on the base and thus the earpiece is close to the loudspeaker. This leads to both unwanted switching behavior, and possible howling. To suppress this, the signal path between RXO and LSI has to be muted during handsfree operation. This is done by splitting the gain setting resistor into two parts, and shorting the tap to ground via a transistor during handsfree operation.

3) Howling Limiter

Howling in a GLi application will occur only when the handset microphone is very close to the base loudspeaker, which occurs while taking the handset off–hook and on–hook. During normal conversation the handset is far from the base and no howling will occur. There are two types of solutions which deal with howling: one which avoids howling, and one which limits the howling.

Howling can be avoided only if, under all conditions, the total loopgain stays below 0 dB. This is implemented, for example, by means of a duplex controller in the handsfree application. The duplex controller monitors the transmit and receive signals and amplifies the signal which is the largest while reducing the smallest one. This is called half–duplex operation. For the GLi application this is not feasible because this would mean that not only the loudspeaker gain will be reduced but also the gain from handset microphone to the line. Since during GLi operation the performance of the handset part may not be degraded with respect to a pure handset operation, this type of solution is to be avoided.

Figure 2. Interfacing the Winbond 91530A Dialer with the MC33215



NOTE: Pin names refer to the MC33215 except where noted.

Howling can be limited, rather than eliminated, by reducing the loudspeaker gain whenever howling is detected. This means that during the gain reduction of the loudspeaker amplifier a small howling residue will be present to keep the gain reduced. The advantage of this solution over the duplex controller is that the handset operation is not affected and, if howling is properly detected, the loudspeaker gain is reduced only during the on–hook and off–hook transitions, and not during normal GLi operation.

A howling signal can be distinguished from speech by a few general characteristics. The most significant are its high amplitude, and its higher frequencies in the speech band. Based on this, a howling limiter can be implemented by filtering the line signal with high pass filters, and by reducing the loudspeaker gain as a function of the signal level. This basic approach can be improved by including timing and multiple howling detect thresholds.

In the above it is mentioned that the phone line signal can serve as the input for the howling limiter. This is preferably not done because the line signal includes both the transmit and the receive signal. It is possible that a high level dial tone can be mistaken for a howling signal. It is therefore better to monitor only the transmit signal coming from the microphone. The signal from the microphone itself is a very low level, but an amplified version of it is available at SLP and SLB. Here the signal is roughly 1/15th of the transmit signal at the phone line, and contains none of any receive signal. Because SLB is a buffered version of SLP, the SLB signal is preferably used to feed the howling limiter.

A howling limiter must act on a point where it can reduce the loudspeaker gain. On the MC33215, this is the PPL pin. This pin is normally part of the peak limiter, which avoids clipping of the loudspeaker output signal by reducing the loudspeaker gain when appropriate. The amount of gain reduction is determined by the voltage at PPL (see Figure 3), while the capacitor is used for timing.

When using the PPL pin for reducing the gain under howling condition, the peak limiter behavior must stay unaffected.

There are several ways to implement the howling limiter based on the presented information. The circuit proposed in Figure 4 is believed to be the most cost effective one while still providing satisfactory performance.

Figure 3. Speaker Amplifier Gain Change versus Voltage at PPL

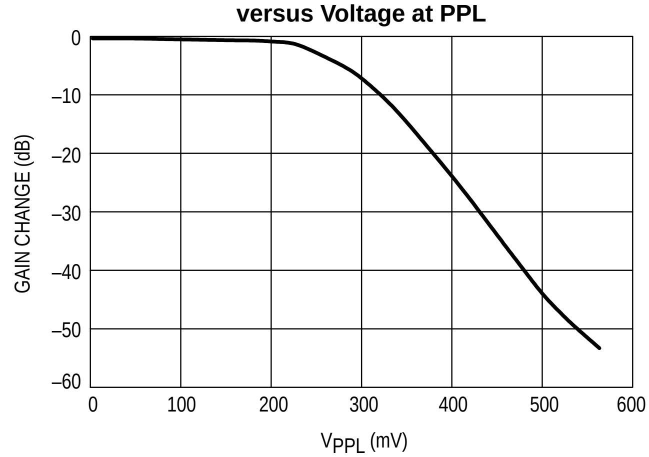
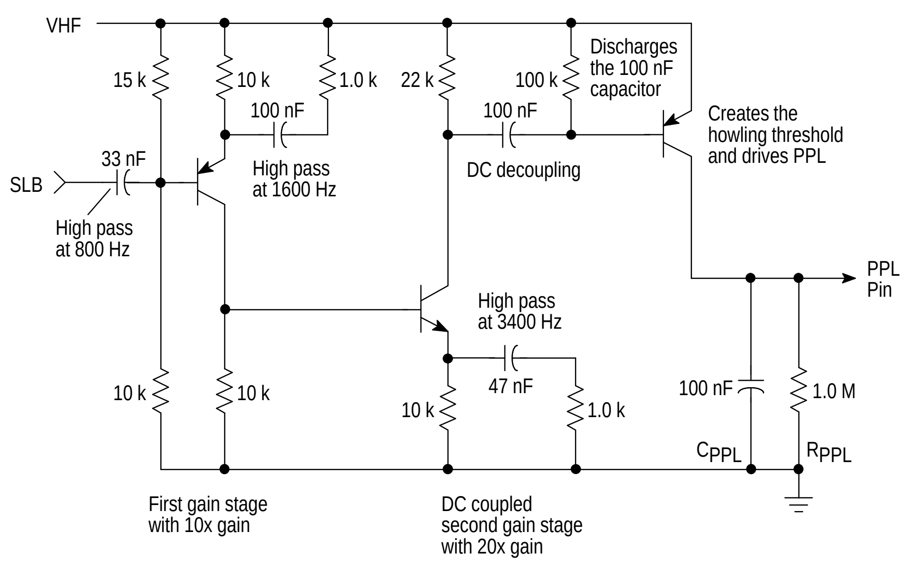


Figure 4. Anti–Howling Limiter



The resistor R_{PPL} and the capacitor C_{PPL} are those normally connected to the PPL pin per the MC33215 data sheet.

The signal from SLB is amplified in two gain stages which are dc coupled to keep the number of components to a minimum. The amplifier includes three high pass filters. Although in the ideal case the gain should be 46 dB, the practical gain is below 40 dB. When the amplified SLB signal is able to turn on the output transistor, the capacitor C_{PPL} will be charged via this output transistor and, as a result, the loudspeaker gain will be reduced. The howling limiter will activate the PPL pin when the signal at the output of the amplifier (the second transistor) equals 1.0 Vbe, which is ≈ 600 mVp. With the amplifiers providing 40 dB gain, this equals ≈ 65 mVrms on the phone line.

Due to the time constant created by C_{PPL} and R_{PPL}, the gain will be periodically reduced and increased dependent on the acoustical conditions. This will lead to the 'sick–bird' or 'tweetie–bird' sound where a variation of the howling level is perceived in the loudspeaker. Due to this effect, the average signal on the line during howling will be less than the howling threshold. In practice this will be half the value or less.

4) Volume Control

The volume control provided for the speakerphone circuit cannot be used for GLi operation, since it operates via the duplex controller. The gain reduction (at RLS) as a function of the voltage at the VOL pin (during normal handsfree operation) is given in Figure 5.

The gain reduction shows a logarithmic characteristic, as is the case for the PPL pin. The differences between the PPL pin and the VOL pin are the offset which is present in the PPL pin curve, and the slope of the gain reduction. With the circuit of Figure 6, both gain reduction curves are matched.

By adding an offset of around 700 mV to VOL, and dividing the sum by approximately 2.5, the resulting voltage can be used as the bias voltage for the 1.0 MΩ PPL discharge resistor.

As a result, with 0 mV at VOL (R_{VOL} = 0 Ω), the voltage at PPL will be 280 mV, giving a small reduction in the total receive gain of about 6.0 dB. This should be taken into account when setting the gain. For increasing voltage at VOL, PPL will also increase but with a slope which is a factor of 2.5 lower. The total will give the correct relation. An overall error in volume reduction speakerphone mode versus listening–in mode was measured to be less than 1.0 dB in the 30 dB range.

Figure 5. Speaker Volume Reduction versus Voltage at VOL

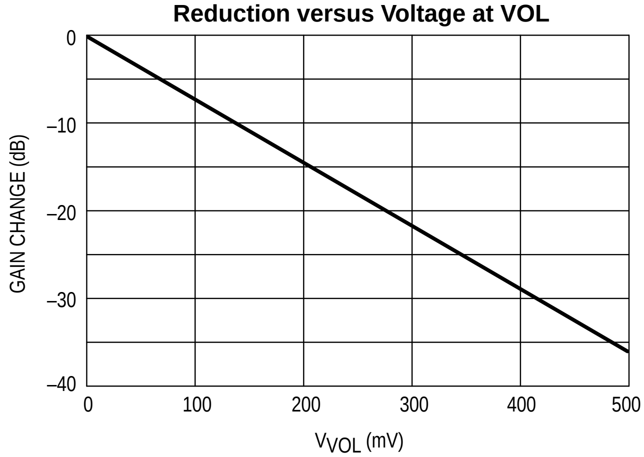
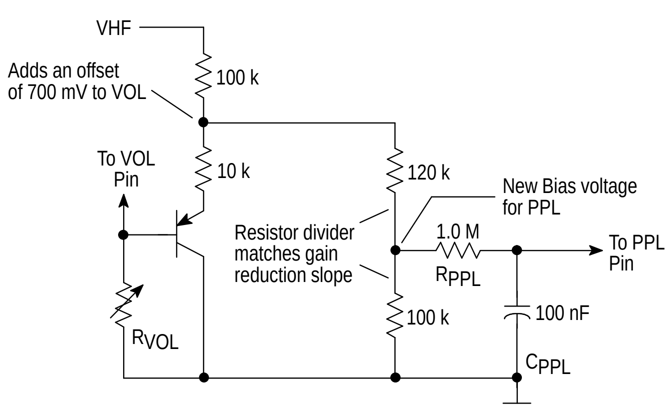


Figure 6. Interfacing VOL to PPL



GLUING IT ALL TOGETHER

The previously presented building blocks can be glued together, with the resulting schematic shown in Figure 7. The correct gain settings are applied, and correct signals paths are established, both during speakerphone and DTMF dialing mode. Also, the howling limiter is connected to the PPL pin via the volume control adapter circuit to reduce the amount of logic needed to switch off both blocks.

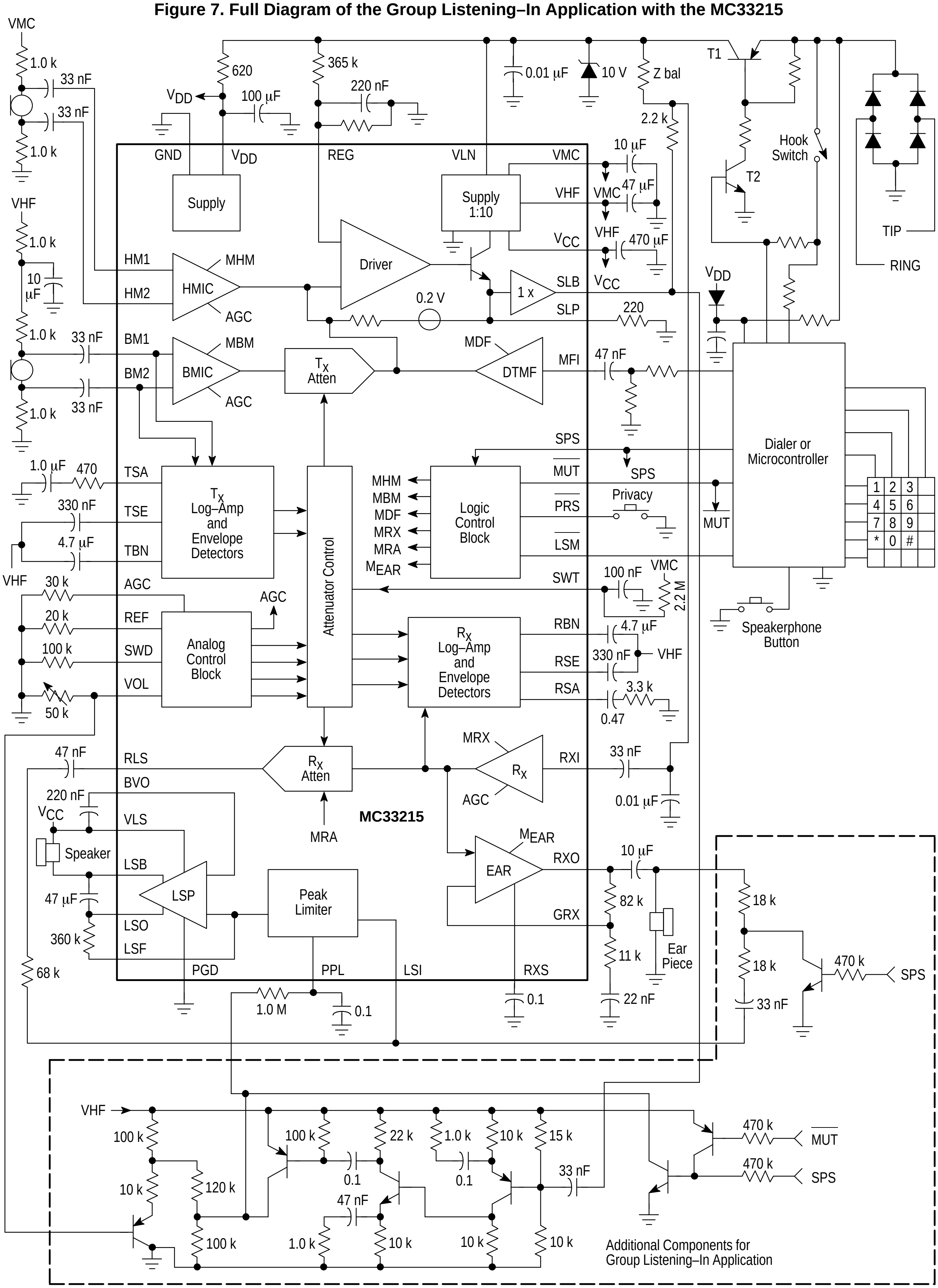
In the handset application (SPS = low, LSM = low) the loudspeaker amplifier is not active and the extra circuitry has no effect. The impedance of the network at the RXO pin towards the LSI pin is not seen because it has a much higher impedance than the earpiece.

In a GLi application (SPS = low, $\overline{\text{LSM}}$ = high) the loudspeaker is active and the howling limiter and volume control circuit are active. During DTMF dialing however, when MUT = low, the howling limiter is disabled since a DTMF signal can be misinterpreted as howling. At the same time, the effect of the volume control setting on confidence tones is canceled, which is desired. The gain setting is such that no difference in loudness is heard between speakerphone and listening–in usage for both normal speech and confidence tones. Because the additional volume control circuit reduces the gain by (nominally) 6.0 dB, the impedance of the network from RXO to LSI must be half the value as that from RLS to LSI.

In the basic application the loudspeaker gain is 26 dB higher than the earpiece gain, while the confidence tone gains differ 20 dB. This means that in the listening–in application, the confidence tone level will be 6.0 dB higher than in speakerphone mode. On top of that, by disabling the volume control circuit during dialing, the gain from RXO to LSO is raised another 6.0 dB. To equalize all the gains, the values of the networks have to be scaled. In Figure 7, the gains from the phone line towards transducers (earpiece and speaker) are kept the same as in the basic application. However, the confidence tone level in the earpiece is lowered by 6.0 dB while on the loudspeaker it is increased by 6.0 dB. If in a certain listening–in application the howling limiter is not required, the circuitry can simply be left out, as well as the logic driven by the MUT signal.

In speakerphone mode (SPS = high, $\overline{\text{LSM}}$ = high), the howling circuit, and the circuit at the VOL point in Figure 7 are disabled, as well as the path from RXO to LSI.

Figure 7. Full Diagram of the Group Listening–In Application with the MC33215



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