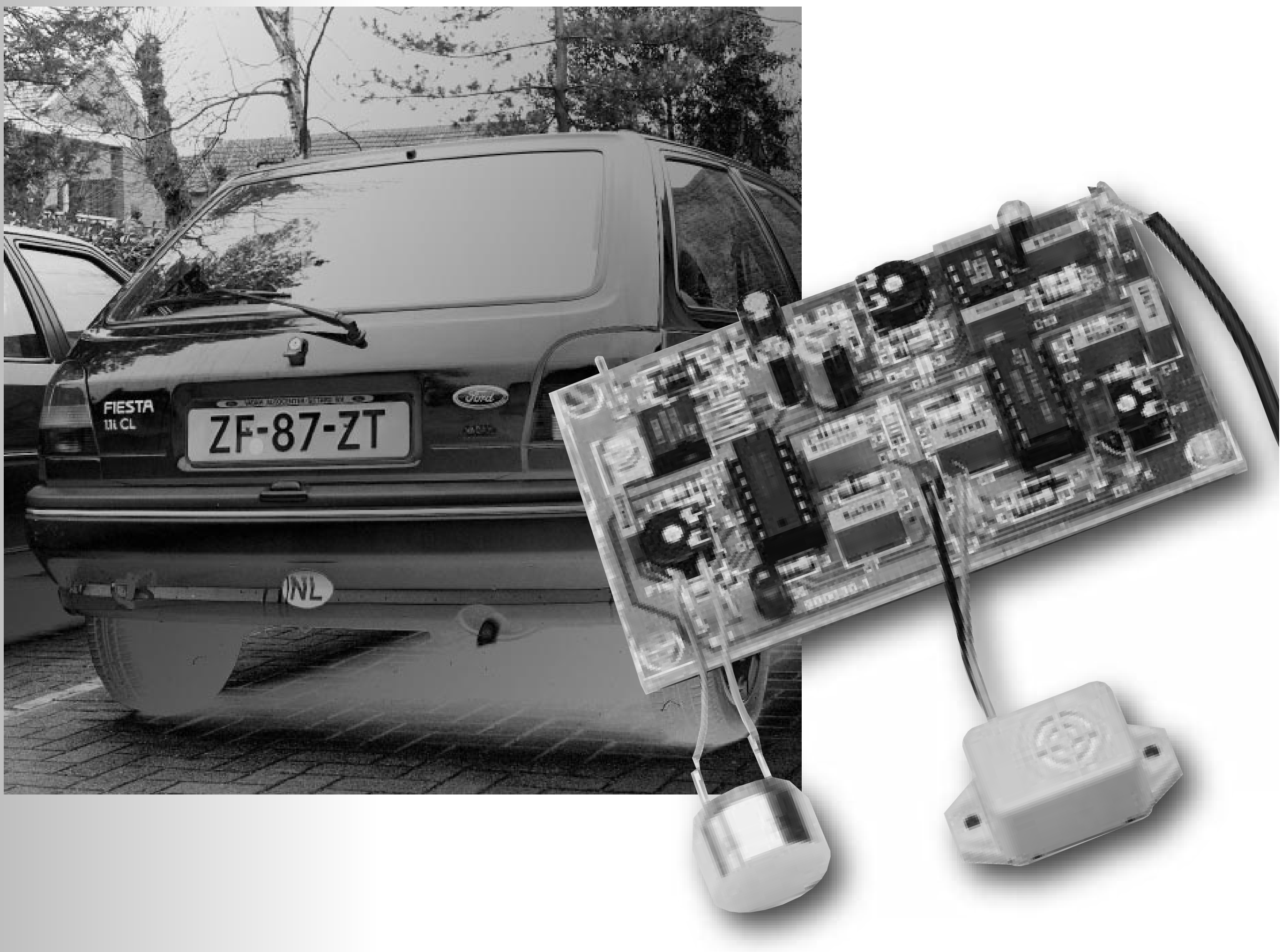
parking sonar

range monitor to make parking safer



Parking in crowded streets often causes one's car to bump into another one. Even though this normally happens at very low speeds, it should be avoided. The range monitor is an aid to 'keeping an eye' on the distance between the bumper of your car and that of the one behind you. It is a compact device that may prevent angry faces.

Design by H Bonekamp

At some time or another, we all have to park our car in a crowded street or car park. Now, parking is something that many of us never master well and consequently tends to make us nervous. The fear is that we will bump our car into the one behind the space we have selected. An aid to warn us when we get too close to that vehicle is, therefore, very welcome.

The circuit described in this article is a fairly straightforward design that actuates an alarm when there is an obstacle at a preset distance of 30–300 cm from the bumper of a vehicle in which it is fitted. Such a distance is fine in all practical conditions. It takes over from a human 'aid' who indicates by means of hand signals how far you can reverse your car.

THE DESIGN

The range monitor is based on ultrasonic transducers: a sender and a receiver. It makes use of the natural property that sound travels through air at a virtually constant speed of 340 m s^{-1}. Any obstacle will reflect the sound emitted by the transmitter, which is then intercepted by the receiver. A measurement of the interval between the time the sound is sent and the time the echo is received enables the distance to be computed.

The block diagram of the monitor is shown in **Figure 1**. The frame generator produces rectangular pulses in a fixed rhythm. The width of the pulses determines the duration of the frame. The intervals between the pulses are long enough to prevent signal echoes from interfering with the frames.

The frames are 'modulated' by a 40 kHz signal produced by a second generator. The modulated pulses are then applied to the transmit module. The frequency of 40 kHz is not chosen randomly, but is equal to the resonance frequency of the transducer.

The timing diagram in **Figure 2** clarifies the process. The output of the frame generator and the signal applied to the transmit module are waveforms 1 and 2 in this diagram.

To ensure that an alarm is actuated when an obstacle is present at a certain distance, say, 50 cm, the receive frame must have some relation to the transmit frame. This is arranged by passing the output of the frame generator through a delay line and converting the consequent signal to a pulse whose width determines the window. See signals 3 and 4 in the timing diagram. Note that only signals that fit within the window can be intercepted.

The reflected signal (or echo) is intercepted by the receiver and applied to an amplifier., which not only raises the level of the signal but also functions as band-pass filter. The resulting signal is compared with a fixed voltage: the output of the comparator is signal 5 in the timing diagram. Note that this is identical to signal 2 but shifted in time.

The detector eliminates as many spurious inputs as possible by checking the number of received 40 kHz pulses. Each receive frame should contain at least five of these pulses. If this is not so, the detector treats them as noise, whereupon a new cycle is started at the arrival of the next pulse from the frame generator. Only when at least five 40 kHz pulses are detected will the output of the detector become active. The lighting of an LED and/or the sounding of a buzzer then indicate that the minimum set distance has been reached and that the driver should stop.

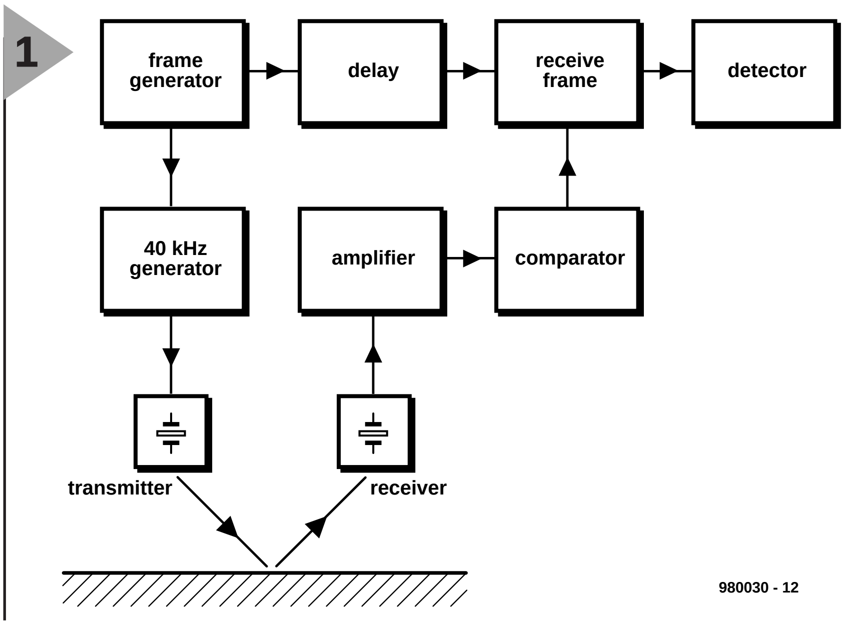


Figure 1. Block diagram of the parking sonar. The distance is computed from the time delay between the transmitted and received pulses.

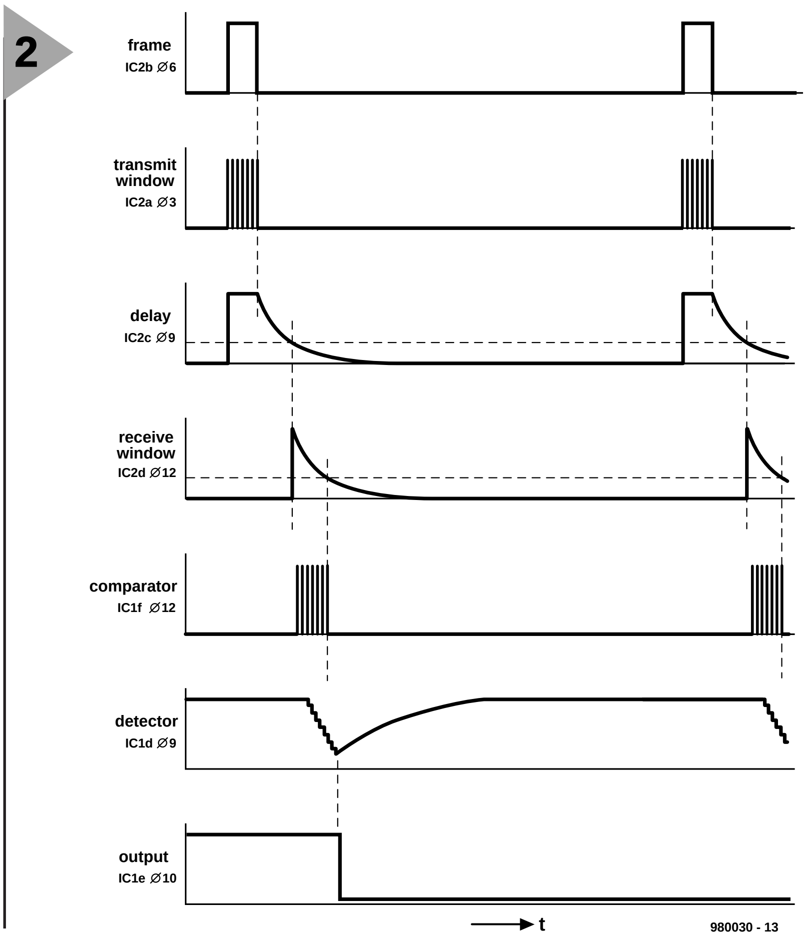


Figure 2. Timing diagram of the parking sonar.

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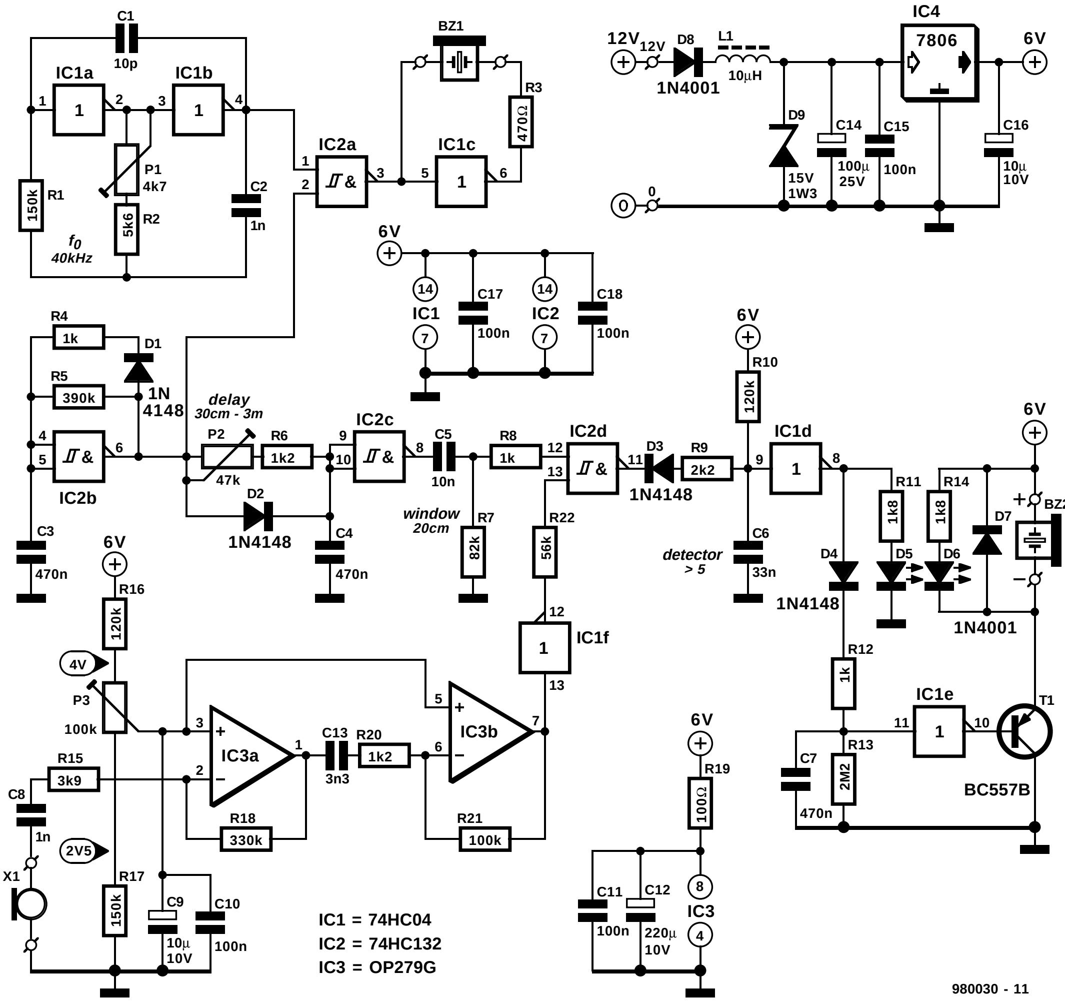

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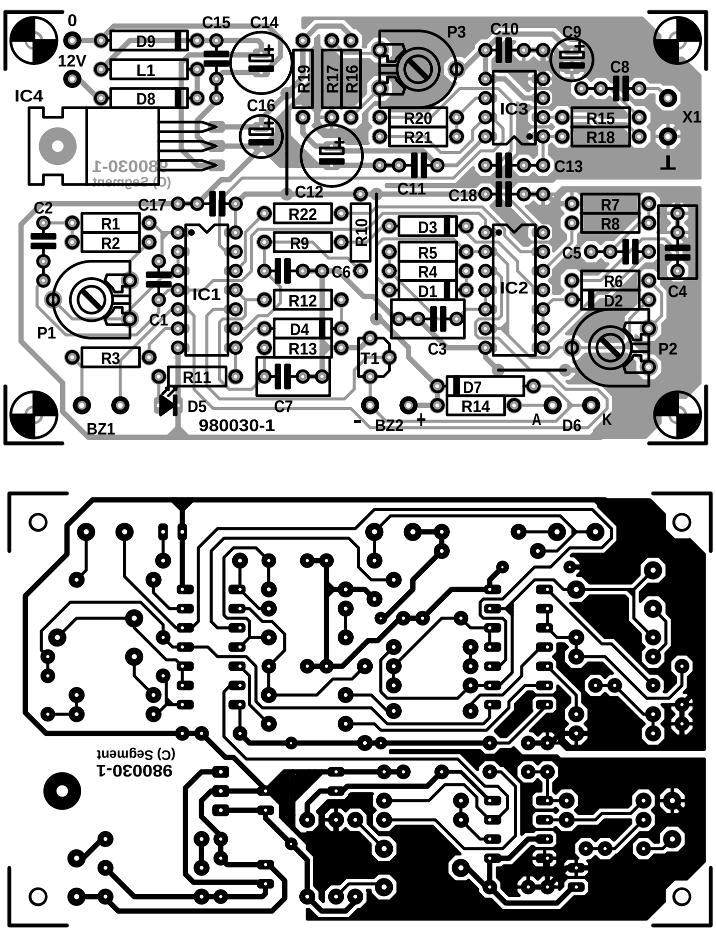

Figure 3. Complete circuit diagram of the parking sonar. The transducers are X_1 and Bz_1, while Bz_2 and D_6 are the indicator elements.

Figure 4. Printed-circuit board for the parking sonar.

Parts list

Resistors:
R_1, R_{17} = 150 kΩ
R_2 = 5.6 kΩ
R_3 = 470 Ω
R_4, R_8, R_{12} = 1 kΩ
R_5 = 390 kΩ
R_6, R_{20} = 1.2 kΩ
R_7 = 82 kΩ
R_9 = 2.2 kΩ
R_{10}, R_{16} = 120 kΩ
R_{11}, R_{14} = 1.8 kΩ
R_{13} = 2.2 MΩ
R_{15} = 3.9 kΩ

CIRCUIT DESCRIPTION

The circuit diagram of the range monitor is shown in **Figure 3**.

The frame generator is based on gate IC_{2b}. It is a simple oscillator that produces pulses at a frequency of about 10 Hz. Network R_4-C_3 determines the width of the pulses and thus of the transmit frame. The pulse interval is determined by network R_5-C_3. The duration of each frame is equal to a period of the frame generator output.

The stability of the 40 kHz oscillator is rather better than that of the frame generator, which is why it is based on two op amps, IC_{1a} and IC_{1b}, and the frequency can be fine-tuned with P_1.

The outputs of the two generators are combined by IC_{2a}, which ensures that the transmit frame is modulated ('filled') with ultrasonic pulses. The resulting signal is applied to the transmit module, Bz_1, via IC_{1c} in a sort of bridge circuit.

The delay line, consisting of IC_{2c}, P_2, R_6 and C_4, is essential for the correct functioning of the monitor. The distance between transmitter and obstacle is set to between 30 cm and 3 metres with P_2.

The output signal of gate IC_{2c} is differentiated by network R_7-C_5, whereupon, in conjunction with the hysteresis of gate IC_{2d}, it determines the width of the receive frame.

Resistor R_8 limits the current through IC_2.

The receiver module is indicated in the circuit diagram by X_1. It is followed by two amplifier cum band-pass filter combinations, based on IC_{3a} and IC_{3b}. These op amps are arranged to give an amplification of ×50 each at 40 kHz.

Variable potential divider R_{16}-P_3-R_{17} enables setting IC_{3a} and IC_{3b} to a reference voltage that ensures that inverter IC_{1f}, which operates as a comparator, obtains the correct bias voltage. In this way, P_3 sets the sensitivity of the circuit. Resistor R_{22} and the input capacitance of IC_{2d}, form a low-pass filter for the comparator output.

To prevent false alarms, the output of detector IC_{1d} can change state only when the receive frame contains at least five 40 kHz pulses. This is effected by applying the signal to network D_3-R_9-R_{10}-C_6 after it has passed through the receive frame. This ensures that the input voltage of IC_{1d} will be sufficiently low to cause its output to change state only after five pulses have been received (penultimate signal in the timing diagram).

When a suitable signal is received that fits in the receive frame, a short positive pulse appears at the output of IC_{1d}. At the same time D_5 lights briefly. The function of this diode is limited,

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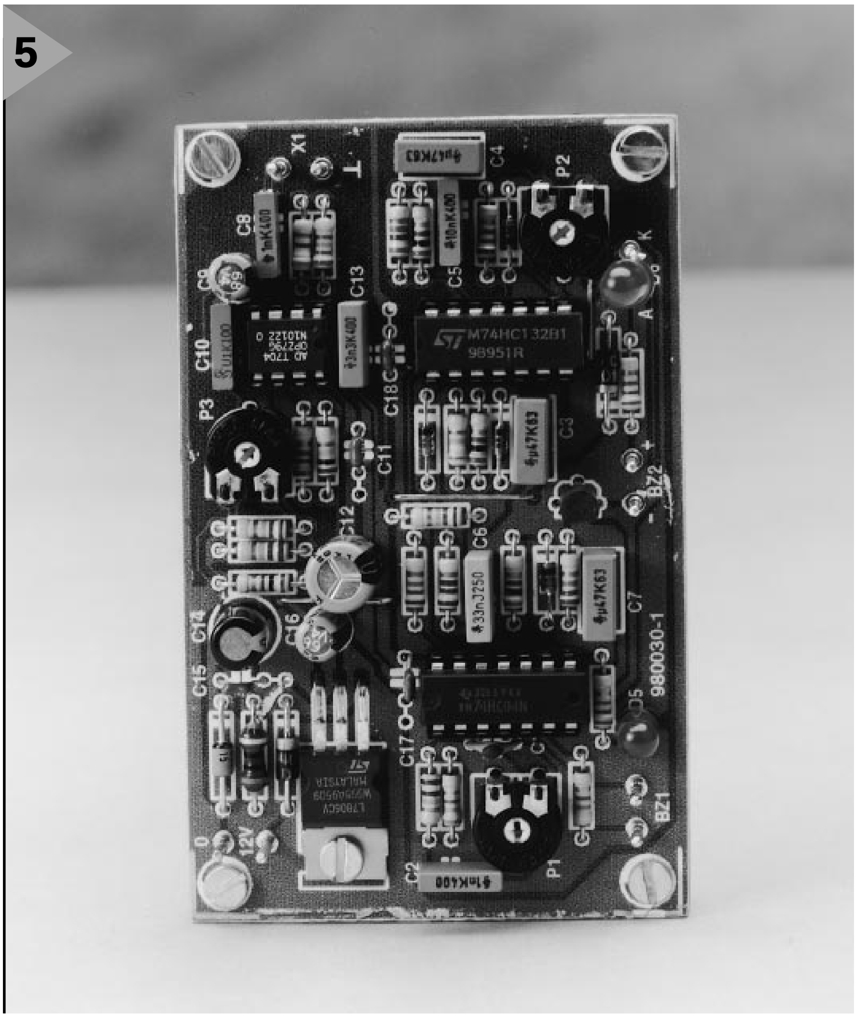

Figure 5. Photograph of the completed prototype. Because of the small current drain, regulator IC_4 does not need a heat sink.

R_{18} = 330 kΩ
R_{19} = 100 Ω
R_{21} = 100 kΩ
R_{22} = 56 kΩ
P_1 = 4.7 kΩ preset potentiometer
P_2 = 47 kΩ preset potentiometer
P_3 = 100 kΩ preset potentiometer

Capacitors:
C_1 = 10 pF
C_2, C_8 = 0.001 µF*
C_3, C_4, C_7 = 0.47 µF*
C_5 = 0.01 µF*
C_6 = 0.033 µF*
C_9, C_{16} = 10 µF, 10 V, radial
C_{10} = 0.1 µF*
C_{11}, C_{15}, C_{17}, C_{18} = 0.1 µF high stability
C_{12} = 220 µF, 10 V, radial
C_{13} = 0.0033 µF*
C_{14} = 100 µF, 25 V, radial

* metallized polyester (MKT)

Semiconductors:
D_1–D_4 = 1N4148
D_5, D_6 = LED, red, low current
D_7, D_8 = 1N4001
D_9 = zener diode, 15 V, 1.3 W
T_1 = BC557B

Integrated circuits:
IC_1 = 74HC04
IC_2 = 74HC132 (SGS Thomson – see text)
IC_3 = OP279G
IC_4 = 7806

Miscellaneous:
L_1 = choke, 10 µH
Bz_1 = 400ET180 (Mercator)
X_1 = 400ER180 (Mercator)
Bz_2 = active buzzer, 5 V, $<$100 mA

however, to the calibration. To obtain a clear indication that a proper signal has been intercepted, the output pulse needs to be stretched and this is done by R_{12}-C_7-R_{13}. The stretched pulse is inverted by IC_{1e} (last signal in the timing diagram), whereupon an audible and/or an optical indication (by Bz_2 and D_6 respectively) are actuated.

Note that the receive frame can be widened or narrowed by adapting the value of R_7 as appropriate. For most situations, however, a width of 20 cm, as in the present design, is a good practical value.

The regulator circuit based on IC_4 ensures a stable 6-V power supply. Inductor L_1 and diode D_9 protect the supply lines against interference and overvoltage peaks.

Diode D_8 provides protection against wrong polarity of the 12-V lines. Note that these lines are best taken from the reversing lights.

CONSTRUCTION

The monitor is best built on the printed-circuit board in **Figure 4**, which is, however, not available ready-made. Populating the board should not cause any undue difficulties. Note that it is advisable to use a 74HC132 (IC_2) from SGS-Thomson since other makes may have a different hysteresis.

With the exception of the transducers, the indicator diode and the buzzer, all components are housed on the board.

To minimize any interference, it is essential that the monitor is housed in a properly earthed metal enclosure. The transmit and receive modules should be mounted at some distance from each other, preferably in or near the rear bumper or, in older cars, the rear spoiler. They must, of course, point in a direction immediately behind the vehicle. The transducers must be linked to the monitor (terminals X_1 and Bz_1) via lengths of screened cable (twin-core in case of the transmitter). The screens must be connected to the supply line earth.

It is advisable to keep the lines to the transmit module as far away as possible from the input amplifier to prevent transmit pulses being injected directly into the receiver.

Note that the case of the transmit module is connected internally to one of the terminals; it is, therefore, essential that the module is isolated from the monitor enclosure and/or the car chassis.

The transducers specified in the part list are both watertight.

The indicator diode and/or buzzer should, of course, be placed near the driver, for instance, in or near the instrument panel.

CALIBRATION

When the monitor is switched on, it will be active for about a second, which is the time needed by C_9 to get fully charged. No attempt has been made to eradicate this power-on indication since it tells the driver that the monitor is operating.

The three preset potentiometers are adjusted with the aid of a good multimeter.

1. Set the multimeter to an appropriate alternating voltage range and connect it across R_3. Short-circuit C_3 with a length of circuit wire. Turn P_1 until the meter reading is a maximum. Seal the preset with some nail varnish and remove the short-circuit from C_3.
2. Short-circuit terminals X_1 and turn P_3 until diode D_5 just goes out.
3. Place an obstacle at the desired distance from the rear bumper and adjust P_2 until diode D_5 begins to flash.

[980030]