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A SYSTEM FOR GATING SEGMENTS OF TAPED SPEECH WITH GREAT PRECISION

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The system was first published in the report of December 1975 of the Spring Symposium of the Dutch Association for Phonetic Sciences held at Utrecht on 12 June 1975.

1. GENERAL

The system essentially consists of a stereo tape recorder, a control unit and a storage oscilloscope.
The tape fragment carrying, on track I, the segment to be isolated is searched by manual operation of the recorder and subsequently 'underlined' by recording a pilot signal on track II. This signal is generated by the control unit as long as a push button is held depressed. The exact length of the pilot signal is immaterial so long as the particular segment is encompassed by it. When the control unit is switched to START the recorder starts to rewind and continues to do so until the complete pilot signal has passed (the tape remains pressed against the heads in REWIND mode). After this the control unit switches the recorder to PLAY mode, the recorded pilot signal serving as a time base generator to control a digital timing device.
A particular part ('segment') of the 'underlined' fragment can now be gated by defining it in terms of time and setting the timing device accordingly, using two sets of thumbwheel switches. As soon as the gating is finished the recorder rewinds until the complete pilot signal has passed again, after which the recorder stops.
If the start button is depressed again a new cycle is initiated.

2. TAPE RECORDER

The tape recorder we use in the system is a REVOX type A77, with remote control facility for all modes of tape transport and therefore not needing electrical modifications. The only required mechanical modification is the fitting of a small lever preventing the tape from being lifted off the heads during REWIND mode.

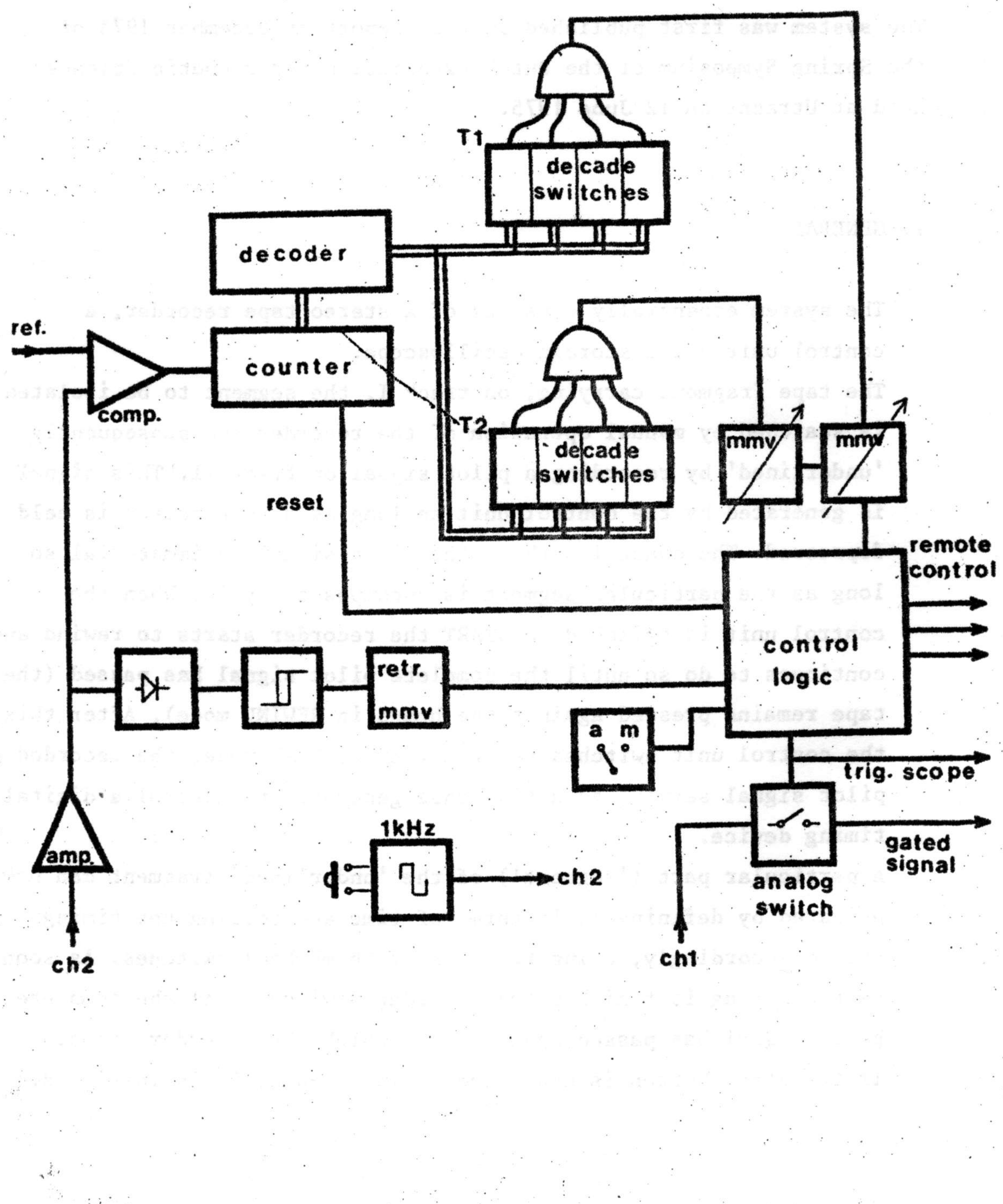

FIG. 1

3. CONTROL UNIT (see fig. 1)

The functions of the control unit are:

1. Generating the pilot signal;
2. Gating the segment in correspondance with the positions of the thumbwheel switches;
3. Controlling the tape recorder.

In addition the control unit triggers the storage oscilloscope at the beginning of the segment to be gated.
To describe these functions in some detail we start at the moment when the recorder, being in the PLAY mode, has reached the beginning of the pilot signal on track II.
The pilot signal after amplification drives an analog comparator which produces a square wave signal with a period coincidental with that of the pilot signal. Its amplitude and slope are so chosen as to ensure correct triggering of the digital counter. Every time when the pilot signal exceeds a fixed reference level the number formed by the counter is incremented by one. Thus the counter counts the periods of the passing pilot signal. Its frequency is 1000 Hz, hence the counter has a resolution of 1 msec.
The output of the counter is converted by the BCD/decimal decoder into a decimal presentation and fed to two sets of four decade switches (thumbwheel switches), one set defining T_1, the other T_2.
When the BCD number formed by the counter equals T_1, the corresponding monostable multivibrator (MMV) is started. The MMVs are adjustable from about 20 μsec to 1 msec, permitting fine control of T_1 and T_2.
As soon as the MMV under consideration goes low an analog switch is closed by the control logic causing the signal on track I to be transmitted to the oscilloscope. The digital control voltage of the analog switch is used for triggering the oscilloscope so that it starts to write the signal. At this moment the counter is reset and starts to count again from zero.

Up to this moment the control logic has only been open to the command coming from the MMV of the T_1 circuit.
From now on it is ready to receive a pulse from the T_2 circuit. Thsi MMV is started when the counter reached the number corresponding to T_2. When it goes low the track I signal is blocked by the analog switch, the recorder starts rewinding and the counter is reset to zero. The reset signal remains operative, inhibiting the counter during the rewinding of the tape.
Since the tape is not lifted off the heads during rewinding the control unit will receive the pilot signal again. The signal is rectified, shaped by a schmitt trigger and fed to a retriggerable MMV.
For the duration of the pilot signal the output of the retriggerable MMV remains high, because its time constant is always greater than any period of the pilot signal.
When the pilot signal has ceased (i.e. at the beginning of the pilot signal on the tape) the retriggerable MMV is allowed to go low and the control logic issues a stop command. A new START command will not be obeyed until approximately 1.5 seconds later, an interval sufficient to allow the tape to stop. If the recorder is started again the reset signal for the counter is cancelled. The control logic can now again admit the signal from the MMV of the T_1 circuit.
The distance between the new starting point and the beginning of the pilot signal is sufficiently long to allow initial irregularities such as poor contact between tape and head, excessive flutter, to be over when the pilot signal is reached, so that its beginning is well-defined.
(If T_1 and T_2 are inadvertedly so chosen that their sum exceeds the number of periods of the pilot signal, the rewinding starts at the end of the pilot signal).

4. PRECISION

It will be clear that the reliability and the precision of the system

are first of all dependent on the proper clocking of the counter. The moments of the triggering of the counter depend, for one thing, on the amplitude of the pilot signal.
Since this is produced by the recorder it is subject to considerable variations in amplitude caused by drop-outs.
The dependence of the triggering on the amplitude diminishes as the rise time of the pilot signal is diminished and as the reference voltage level of the comparator is set closer to zero. As for the latter, there is a limit caused by tape noise. A short rise time can be achieved by choosing a suitable wave form or a high frequency of the pilot signal. However, the higher the frequency the greater the effect of drop-outs; besides if the frequency becomes too high, the recorder cannot deal with the signal in the REWIND mode. Obviously a square waye signal should solve the problem.
Now the fundamental frequency of the square wave can be made 1 kHz causing one step of the counter to equal 1 msec.
The rise time is now determined by the frequency range of the recorder.

A 1 kHz square wave signal played back by the tape recorder will have a shape as depicted in fig. 2. It will be clear that when a drop-out occurs the slope steepness diminishes. Fig. 3 shows the area around zero magnified. It appears that a fixed trigger level is reached later when there is a drop-out. Summing up the precision now depends on the steepness of the pilot signal at the output of the recorder, the signal-to-noise ratio of the signal and the loss of amplitude as a result of the drop-outs.
When using a high quality recorder and high quality tape it is possible to attain without any difficulty a slope steepness of 1/25 of the maximum amplitude ($V_{o\ max}$) per µsec and a S/N-ratio of 55 dB.

In order to get an impression of the degree of inaccuracy we assume a loss of amplitude of 20 dB as a result of a drop-out of exeptional proportion and a trigger level of the comparator of, say, 30 dB below $V_{o\ max}$, a value well above the noise level.

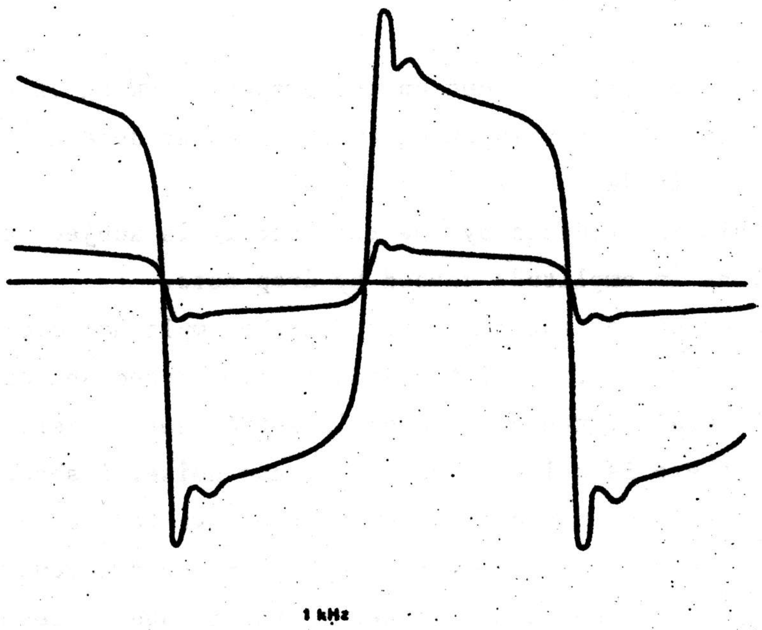

FIG.2

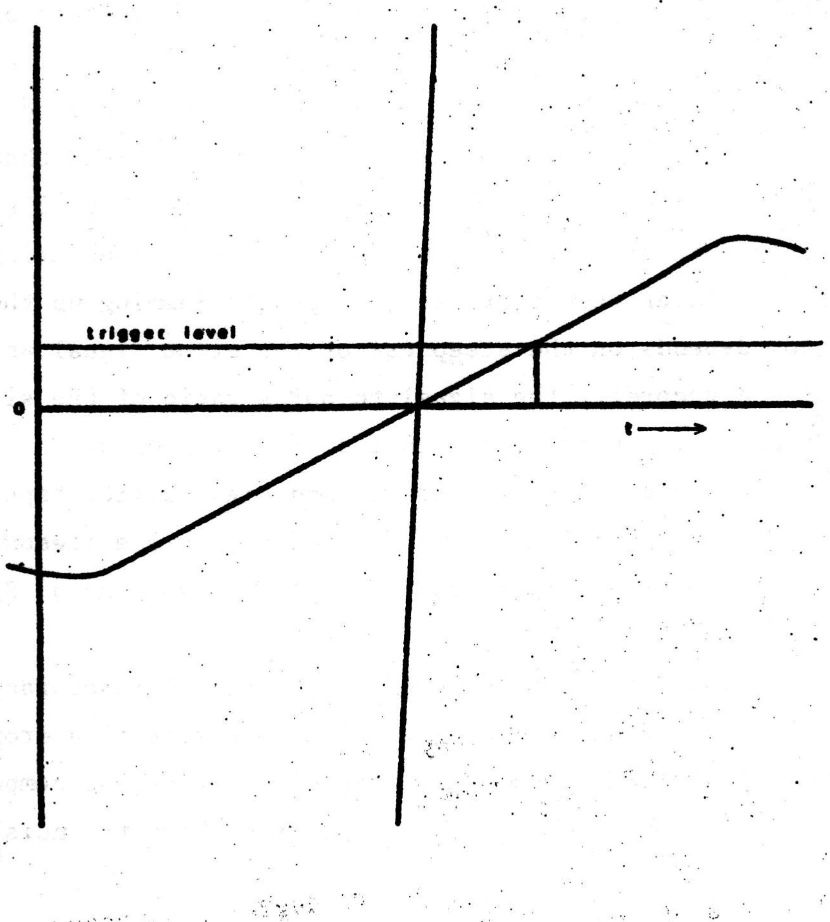

FIG.3

The steepness of the slope during this drop-out is
$1/10 \times 1/25 \times V_{o\ max} = 1/250 \times V_{o\ max}$ per µsec.
The trigger level of -30 dB approximates $1/32 \times V_{o\ max}$, so this level is reached after 250/32 µsec = 7.8 µsec.
In the absence of a drop-out the trigger level is reached after 25/32 µsec = 0.78 µsec. Therefore the inaccuracy is about 7 µsec.
When fine controlling T_1 or T_2 an additional inaccuracy results from speed variations of the tape. At a speed variation of 0.2% (which is greater than the figure for wow and flutter of the REVOX recorder) the maximum inaccuracy that can occur is 0.2% of 1 msec = 2 µsec.
Theoretically a further inaccuracy is caused by residual elongation resulting from (repetetive) playing, rewinding and stopping the tape. (Fluctuations in elongation as a cause of wow and flutter need not concern us, because they are covered by the 0.2% mentioned above).
If the residual elongation of 0.1% quoted for the tape we use (AGFA PE 36) is valid under our working conditions the inaccuracy under consideration is 1 µsec.
Summing up, the worst case inaccuracy of the system is approximately 10 µsec, irrespective of the place and length of the segment.
The precision was tested in practice: when a short segment was registered a hundred times on the storage oscilloscope using a time base of 100 µsec per cm (i.e. a 1 msec segment) all hundred representations of the segment coincided exactly.

At the moment the gating equipment at our institute comprises the following apparatus: tape recorder REVOX A77; control unit; loudspeaker; transient recorder (electronic signal memory) BIOMATION 802; oscilloscope TEKTRONIX RM 561A; strip chart recorder HOUSTON omniscribe 5000.
The transient recorder, when scanning its memory at very low speed, enables the relatively slow chart recorder to register the segments without distortion.
The tape we generally use is AGFA PE36.

Technical data

Range between beginning of the pilot signal and opening gate:	1 msec - 10 sec	
Range of segment length:	50 µsec - 10 sec	
Adjustment resolution:	c. 10 µsec	
Inaccuracy:	$<$ 10 µsec	
S/N ratio:	$>$ 58 dB	data of REVOX A77
Frequency range:	30-20.000 Hz	data of REVOX A77
Wow and flutter:	$\pm$ 0.08%	data of REVOX A77
Dimensions of control unit:	30 x 12.5 x 13 cm.	