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(54) Tape measuring device and method of measuring remaining time or elapsed time for a running tape

(57) A method of measuring remaining time or elapsed time for a tape running from a supply reel to a take-up reel comprises the steps of approximating a plurality of straight lines (ℓ_3, ℓ_4) to a characteristic curve (L_1) indicative of a correlation between the ratio of rotational periods of the supply and take-up reels and a remaining time or elapsed time. Clock pulse signals having a plurality of frequencies are generated in ratios corresponding to the slopes of the straight lines and remaining time or elapsed time is measured by counting the product of the ratio of rotational periods and the slopes of the straight lines, using the clock pulse signals and signals generated in response to rotation of the supply and take-up reels. There is also disclosed (Figure 2) a tape measuring device which uses this method for measuring remaining time or elapsed time for a running tape.

FIG. 1

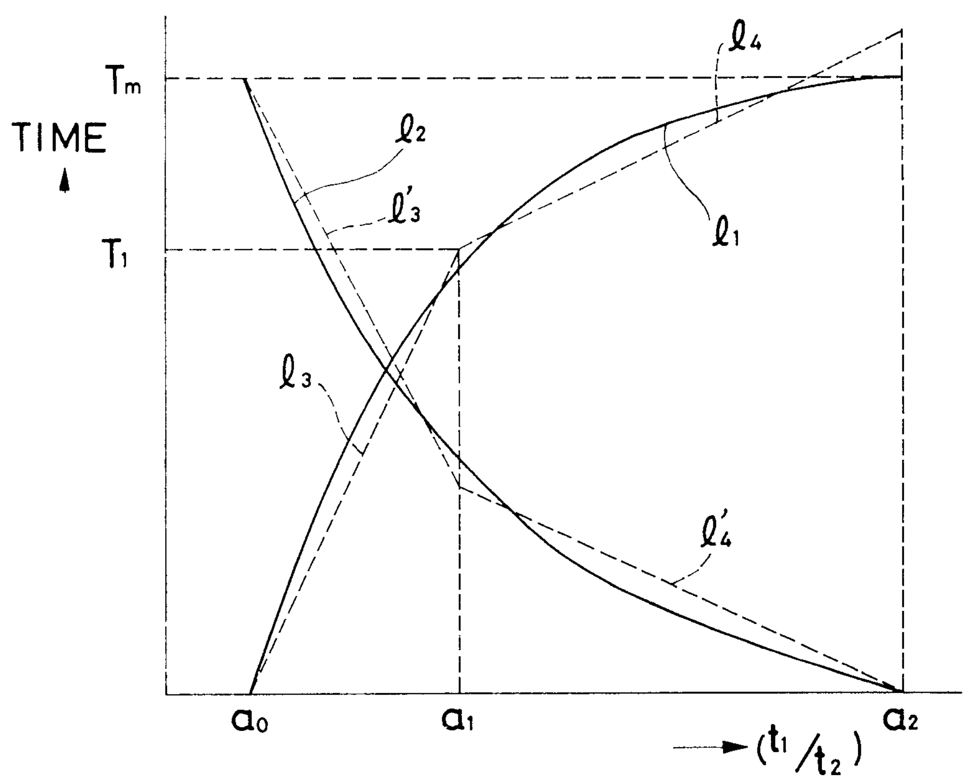

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FIG.1

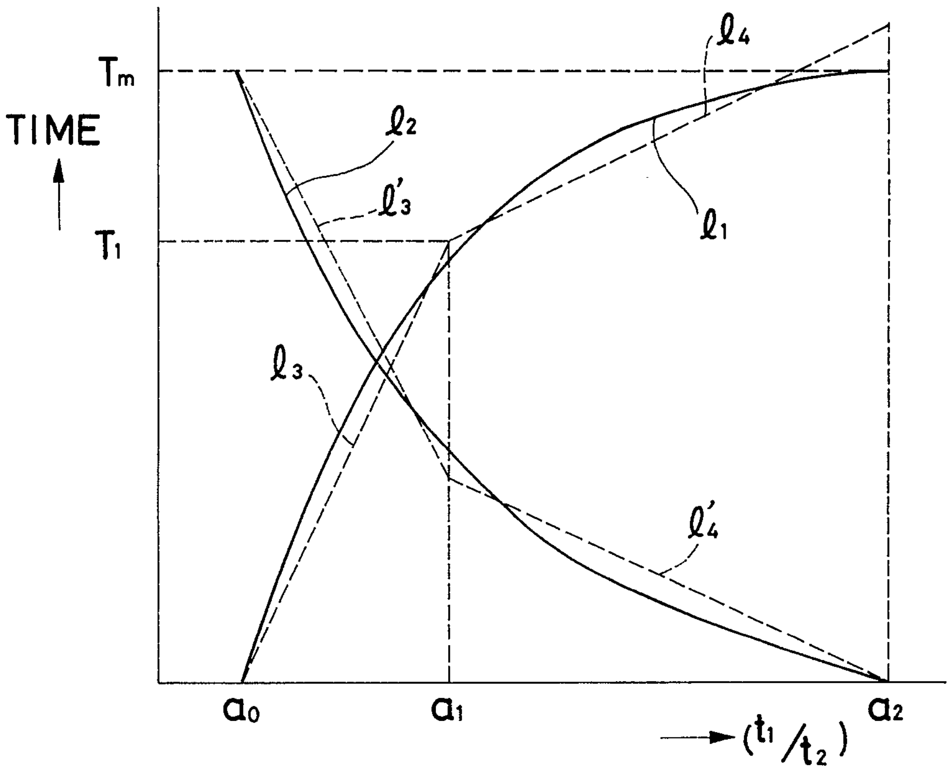
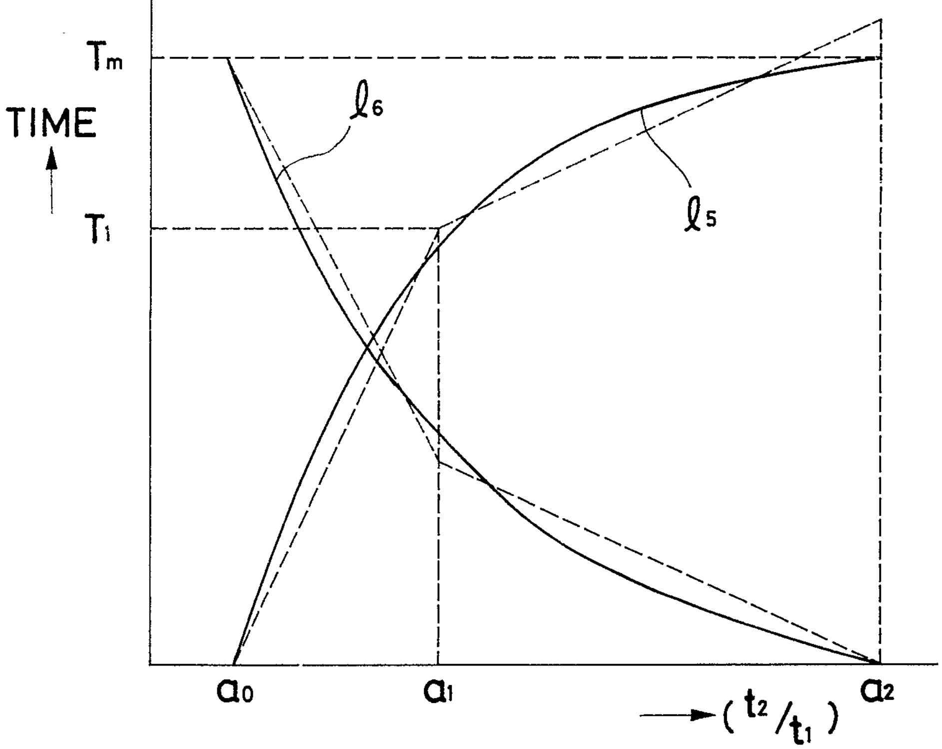
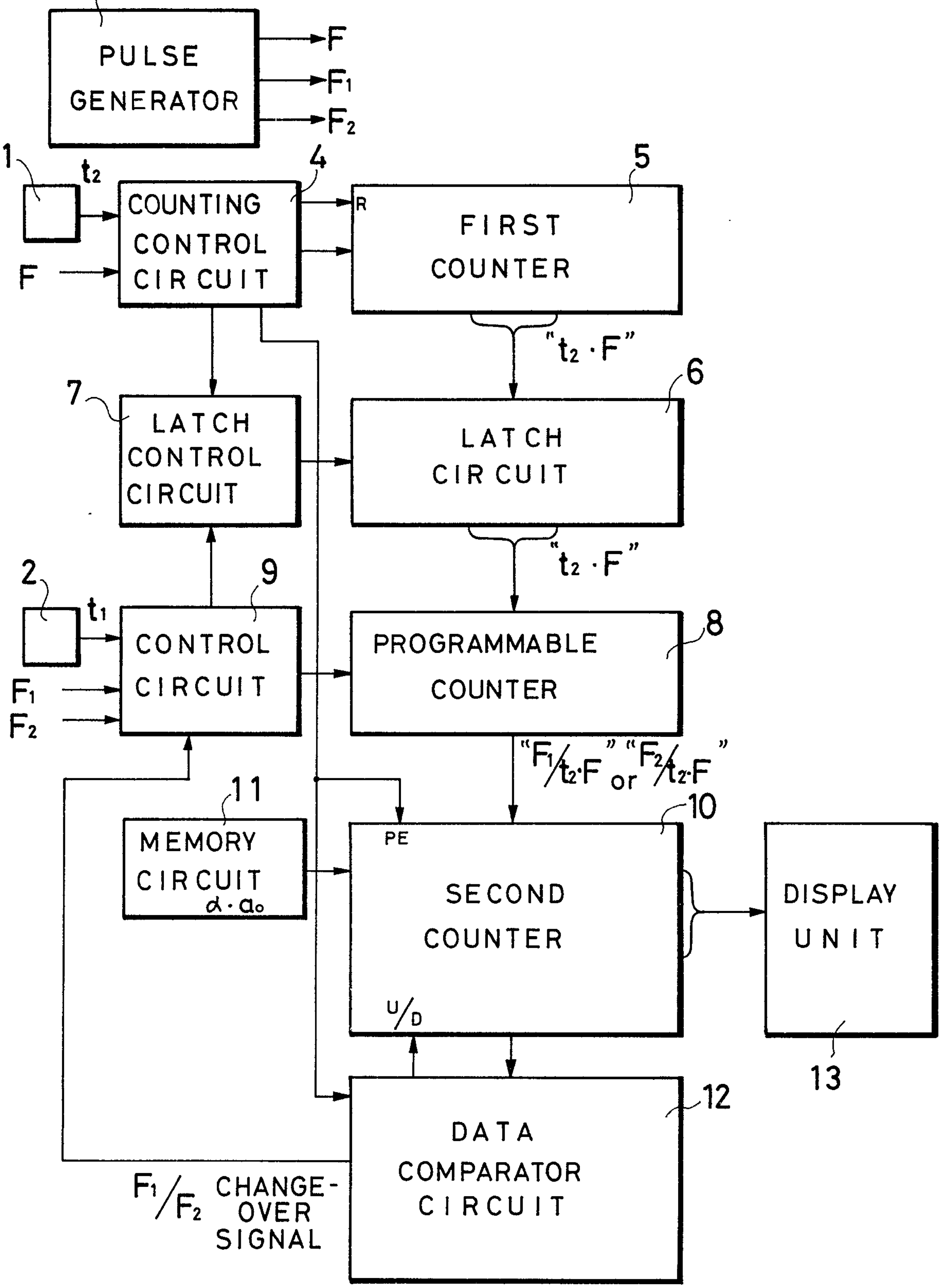


FIG.3





PULSE GENERATOR
F
F1
F2
COUNTING CONTROL CIRCUIT
t2
F
R
FIRST COUNTER
"t2 · F"
LATCH CONTROL CIRCUIT
LATCH CIRCUIT
"t2 · F"
t1
CONTROL CIRCUIT
F1
F2
PROGRAMMABLE COUNTER
"F1/t2·F" or "F2/t2·F"
MEMORY CIRCUIT
α · a0
PE
SECOND COUNTER
U/D
DISPLAY UNIT
DATA COMPARATOR CIRCUIT
F1/F2 CHANGE-OVER SIGNAL
1
2
3
4
5
6
7
8
9
10
11
12
13

FIG.2

SPECIFICATION

Tape measuring device and method of measuring remaining time or elapsed time for a running tape

This invention relates to tape measuring devices and to methods of measuring remaining time or elapsed time for running tapes e.g. magnetic recording tapes.

According to one aspect of the present invention there is provided a method of measuring remaining time or elapsed time for a tape running from a supply reel to a take-up reel, comprising the steps of: approximating a plurality of straight lines to a characteristic curve indicative of a correlation between the ratio of rotational periods of said supply and take-up reels and a remaining time or elapsed time; generating clock pulse signals having a plurality of frequencies in ratios corresponding to the slopes of said plurality of straight lines; and measuring said remaining time or elapsed time by counting the product of said ratio of rotational periods and the slopes of said straight lines, using said clock pulse signals and signals generated in response to rotation of said supply and take-up reels.

According to another aspect of the present invention there is provided a tape measuring device for measuring remaining time or elapsed time for a tape running from a supply reel to a take-up reel comprising: means for approximating a plurality of straight lines to a characteristic curve indicative of a correlation between the ratio of rotational periods of said supply and take-up reels and a remaining time or elapsed time; clock means for generating clock pulse signals having a plurality of frequencies in ratios corresponding to the slopes of said plurality of straight lines; and measuring means for measuring said remaining time or elapsed time by counting the product of said ratio or rotational periods and the slopes of said straight lines, using said clock pulse signals and signals generated in response to rotation of said supply and take-up reels.

The invention is illustrated, merely by way of example, in the accompanying drawings, in which:-

Figure 1 is a graph showing characteristic curves for the ratio of rotational periods of supply and take-up reels and a remaining time and elapsed time for a running tape;

Figure 2 is a block diagram of a tape measuring device according to the present invention; and

Figure 3 is a graph showing characteristic curves for the reciprocal of the ratio shown in Figure 1 and the remaining and elapsed times.

It is known in ordinary magnetic tape recording and playback apparatus that there is a certain correlation between the ratio of rotational periods of tape supply and take-up reels and the remaining or elapsed time for a running tape and the following equations can be produced:

$$L_1 \fallingdotseq \frac{\pi}{\triangle r}(r_1^2 - r^2) \qquad (1)$$

$$L_2 \fallingdotseq \frac{\pi}{\triangle r}(r_2^2 - r^2) \qquad (2)$$

$$r_1/r_2 = t_2/t_1$$

where, *r* is the radius of a hub of a supply reel and a hub of a take-up reel, r_1 is the radius of the roll of tape wound on the supply reel, r_2 is the radius of the roll of tape wound on the take-up reel, L_1 and L_2 are the lengths of tape on the supply and take-up reels respectively, t_1 and t_2 are the periods of rotation of the supply and take-up reels respectively, and $\triangle r$ is the thickness of the tape. The length of the remaining tape can be derived from the above equations as follows:

$$L_1 = \frac{\triangle r \cdot L_0 + \{1 - (t_1/t_2)^2\}\pi r^2}{\{(t_1/t_2)^2 + 1\}\triangle r} \qquad (4)$$

where L_0 is the total length of tape ($L_0 = L_1 + L_2$). The remaining time for the tape is given as follows:

$$T = L_1/v \qquad (5)$$

where *v* is the speed of travel of the tape. The remaining time is shown by a curve ℓ_1 in Figure 1, which shows graphically the relationship between the ratio (t_1/t_2) of the rotational periods of the supply and take-up reels and time.

The length L_2 of the tape that has been transferred can be derived as follows:

$$L_2 = \frac{L_0 \cdot \Delta r (t_1/t_2)^2 + \{(t_1/t_2)^2 - 1\}\pi r^2}{\{(t_1/t_2)^2 + 1\}\Delta r} \qquad (6)$$

The elapsed time is shown by curve ℓ_2 in Figure 1.

One method of measuring the remaining time or elapsed time would be to effect an arithmetic operation using equation (4) or (5) having measured the periods t_1, t_2. This, however, would require a computer, would require the measurement of the periods t_1, t_2 simultaneously and would take some time because of the arithmetic operation to be carried out. Moreover, an interface for allowing the result of the arithmetic operation to be supplied to a display device would be relatively complex and costly. Other arithmetic and control circuits would be necessary for simultaneous implementation of a tape counter, a timer switch, etc.

Another method of measuring the remaining time or elapsed time would be to prepare, in advance, a data table of numerical data from equation (4) or (6) and to read out of the data table such data which corresponds to a remaining time or elapsed time based on the result of experiment. This procedure, however, would need an extremely large data table, and hence would be expensive.

A method according to the present invention for measuring remaining time or elapsed time for running magnetic recording tape will first be described. For the measurement of remaining time, it is assumed that a curve ℓ_1 shown in Figure 1 is approximated by straight lines ℓ_3, ℓ_4 which have slopes α, β respectively. The remaining time T in the interval between a_0 and a_1 is expressed by:

$$\begin{aligned} T &= \alpha(t_1/t_2 - a_0) \\ &= \alpha(t_1/t_2) - \alpha \cdot a_0 \qquad (7) \end{aligned}$$

where a_0 is the minimum value of the ratio (t_1/t_2) of the rotational periods of the tape supply and take-up reel and depends solely on the overall length of the tape, the thickness of the tape, the diameter of the hubs of the reels and other factors.

With the ratio of rotational periods lying between a_1 and a_2, the remaining time is proportional to the slope β of the straight line ℓ_4.

Three frequencies F, F_1, F_2 ($F > F_1, F_2$) are produced which express the slopes α, β of the straight lines as follows:

$$\alpha = F_1/F, \beta = F_2/F$$

The remaining time in the interval between a_0 and a_1 can now be given as follows:

$$T = \frac{F_1}{F} \cdot \frac{t_1}{t_2} - \alpha \cdot a_0 \qquad (8)$$

The remaining time is measured using equation (8) as follows.

The frequency F is counted during the time t_2, and the value $t_2 \cdot F$ is used as a frequency division ratio of a programmable counter. The programmable counter is then supplied with the frequency F_1 or F_2 during the time t_1 to produce output pulses having a frequency of $F_1/F \cdot t_2$ or $F_2/F \cdot t_2$. The remaining time can be determined by counting with a counter, pulses having the frequency of $F_1/F \cdot t_2$ as long as the remaining time is less than T_1. When the remaining time exceeds T_1 and enters the area of the straight line ℓ_4, then the programmable counter is supplied with the frequency F_2. The consant $\alpha \cdot a_0$ in equation (8) is set in the counter in advance so that the constant $\alpha \cdot a_0$ will be subtracted from the content in the counter.

Thus, the remaining time can be determined simply by effecting a counting operation in a counter without requiring a complex arithmetic operation. Such an arrangement is capable of high-speed processing and is relatively inexpensive.

Referring now to Figure 2, there is shown one embodiment of a tape measuring device according to the present invention. Signal generators 1, 2 detect rotation of the supply and take-up reels, respectively to produce one pulse, for example, when each reel makes one revolution. A pulse generator 3 generates clock pulses having frequencies F, F_1, F_2 and a counting control circuit 4 allows passage of the clock pulses of the frequency F during the period t_2 of rotation of the take-up reel. The tape measuring device also includes a first counter 5, a latch circuit 6, a latch control circuit 7, a programmable counter 8, a control circuit 9, a second counter 10 which, in the illustrated embodiment, is a pre-settable up-down counter, and a memory circuit 11 for storing the constant $\alpha{\cdot}a_0$. A data comparator circuit 12, in which a remaining time T_1 is set for the point where changeover from the straight line ℓ_3 to the straight line ℓ_4 (Figure 1) is effected, serves to change frequencies of the clock pulses supplied to the programmable counter 8 and also to effect switching between count-up and count-down modes of the counter 10. The remaining time determined is indicated on a display unit 13.

Operation of the tape measuring device of Figure 2 is as follows. When one pulse is produced by the signal generator 1, the counting control circuit 4 generates a reset pulse to clear the counter 5 and to preset the constant $\alpha{\cdot}a_0$ in the counter 10. Simultaneously, the counter 10 enters a count-down mode in response to an output signal from the data comparator circuit 12.

The counting control circuit 4 also supplies clock pulses of frequency F to the counter 5 until the counting control circuit 4 is supplied with a next pulse from the signal generator 1. Contents $t_2{\cdot}F$ of the counter 5 is latched in the latch circuit 6 by an output from the latch control circuit 7, whereupon the frequency division ratio of the programmable counter 8 is set to be $1/t_2{\cdot}F$. A pulse which comes from the signal generator 2 after such a ratio setting operation enables the control circuit 9 to supply clock pulses of frequency F_1 to the programmable counter 8 during the time interval t_1. Since the frequency division ratio of the programmable counter 8 is $1/t_2{\cdot}F$ at this time, the programmable counter supplies pulses having a frequency of $F_1/t_2{\cdot}F$ to the counter 10 during the time interval t_1. As described above, the counter 10 has the constant $\alpha{\cdot}a_0$ set as an initial value and is in the count-down mode. Therefore, the counter 10 counts 0 when it is supplied with $\alpha{\cdot}a_0$ pulses. The content 0 of the counter 10 is detected by the data comparator circuit 12 and then causes the counter 10 to operate in the count-up mode. The above operation is tantamount to the subtraction of the constant $\alpha{\cdot}a_0$ in equation (8).

Thereafter, the counter 10 is responsive to pulses from the programmable counter 8 to count the remaining time along the straight line ℓ_3 shown in Figure 1. If the remaining time is less T_1, then clock pulses from the control circuit 9 cease before the counter 10 starts counting T_1, and the content of the counter 10 at this time is indicated as the remaining time by the display unit 13.

If, on the other hand, the remaining time is longer than T_1, then the data comparator circuit 12 generates a changeover signal when the counter 10 counts T_1 to cause the control circuit 9 to issue clock pulses having the frequency F_2. Thus, the programmable counter 8 produces pulses of a frequency of $F_2/t_2{\cdot}F$, and the counter 10 counts the remaining time along the straight line ℓ_4 in Figure 1. The content in the counter 10 is displayed as the remaining time by the display unit 13.

The above description has been directed to the measurement of remaining time. Elapsed time can also be measured on the basis of the curve ℓ_2 of Figure 1. For such a measurement, the curve ℓ_2 is approximated by straight lines ℓ'_3, ℓ'_4 having slopes $-\alpha$, $-\beta$ respectively. With an elapsed time having a maximum value Tm, an elapsed time T′ during the interval $a_0 - a_1$ can be expressed as follows:

$$\begin{aligned} T' &= Tm - \alpha(t_1/t_2 - a_0) \\ &= -\alpha(t_1/t_2) + Tm + \alpha{\cdot}a_0 \end{aligned}$$

Thus, the elapsed time can be determined in substantially the same manner as that for measuring remaining time, except that the memory circuit 11 stores a constant $(Tm + \alpha{\cdot}a_0)$ and the counter 10 is a down counter. More specifically, the constant $(Tm + \alpha{\cdot}a_0)$ is preset as an initial value in the down-counter. The elapsed time is measured along the straight line ℓ'_3 with clock pulses of frequenty F_1 being selected until the count in the down counter reaches T_1. When the elapsed time exceeds T_1, clock pulses of frequency F_2 are selected for continued measurement along the straight line ℓ'_4.

Whilst in the above embodiment the remaining time or elapsed time is measured using the ratio (t_1/t_2) of the rotational periods, the reciprocal (t_2/t_1) of the ratio may be employed for the measurement. For such measurement, the length L_2 of the tape that has been transferred and the length L_1 of the tape that has been left are expressed as follows:

$$L_2 = \frac{\triangle r{\cdot}L_0 + \{1 - (t_2/t_1)^2\}\pi r^2}{\{(t_2/t_1)^2 + 1\}\triangle r}$$

$$L_1 = \frac{(t_2/t_1)^2{\cdot}L_{\triangle r} + \{(t_2/t_1)^2 - 1\}\pi r^2}{\{(t_2/t_1)^2 + 1\}\triangle r}$$

The elapsed time is expressed as a curve ℓ_5 in Figure 3 (which is the same as the curve ℓ_1 in Figure 1), and the remaining time is expressed as a curve ℓ_6 in Figure 3 (which is the same as the curve ℓ_2 in Figure 1). Therefore the elapsed and remaining times can be measured exactly in the same manner as that for measuring the remaining and elapsed times in the foregoing embodiment by changing around the signal generators 1, 2 and by supplying the output from the signal generator 1 for the supply reel to the control circuit 9 and also supplying the output from the signal generator 2 for the take-up reel to to the counting control circuit 4.

Whilst the present invention has been described in relation to a characteristic curve approximated by two straight lines, it may be approximated by three or more straight lines for more accurate measurements, and unit intervals of time may be reduced as much as possible.

In the illustrated embodiments of the present invention, remaining time or elapsed time for a running tape is measured on the basis of the ratio of periods of rotation of supply and take-up reels irrespective of how fast or how slow the tape is running. Since no complicated arithmetic operation is needed and measurements can be effected simply by counting pulses, the tape measuring device can effect high speed processing and is less costly to construct. The tape measuring device is composed of a special purpose circuit which employs no microcomputer or microprocessor, it requires relatively simple interfaces with display and input/output devices, and a tape counter, a timer switch and other functions can be implemented in parallel relation to the tape measuring device.

CLAIMS

1. A method of measuring remaining time or elapsed time for a tape running from a supply reel to a take-up reel, comprising the steps of: approximating a plurality of straight lines to a characteristic curve indicative of a correlation between the ratio of rotational periods of said supply and take-up reels and a remaining time or elapsed time; generating clock pulse signals having a plurality of frequencies in ratios corresponding to the slopes of said plurality of straight lines; and measuring said remaining time or elapsed time by counting the product of said ratio of rotational periods and the slopes of said straight lines, using said clock pulse signals and signals generated in response to rotation of said supply and take-up reels.

2. A method as claimed in claim 1 and substantially as herein described with reference to and as shown in the accompanying drawings.

3. A tape measuring device for measuring remaining time or elapsed time for a tape running from a supply reel to a take-up reel comprising: means for approximating a plurality of straight lines to a characteristic curve indicative of a correlation between the ratio of rotational periods of said supply and take-up reels and a remaining time or elapsed time; clock means for generating clock pulse signals having a plurality of frequencies in ratios corresponding to the slopes of said plurality of straight lines; and measuring means for measuring said remaining time or elapsed time by counting the product of said ratio of rotational periods and the slopes of said straight lines, using said clock pulse signals and signals generated in response to rotation of said supply and take-up reels.

4. A tape measuring device substantially as herein described with reference to and as shown in Figure 2 of the accompanying drawings.

5. A method of measuring a tape from a supply reel to a take-up reel, comprising steps approximating a plurality of straight lines to a characteristic curve indicative of a correlation between the ratio of rotational periods of said supply and take-up reels and a remaining time or elapsed time for the tape, generating clock pulses of a first frequency and the other clock pulses having a plurality of frequencies, said first and plurality of frequencies having ratios corresponding to the slopes of said plurality of straight lines; measuring said remaining time or elapsed time for the tape by counting the product of said ratio of rotational periods and the slopes of said straight lines, using said clock pulses and signals in response to rotation of said supply and take-up reels.

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