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(54) IMPROVEMENTS IN THE GENERATION OF NON-LINEAR FUNCTIONS OF THE BUTTERFLY VALVE ANGLE IN AN INTERNAL COMBUSTION ENGINE

(71) We, ROBERT BOSCH GmbH, a German Company of Postfach 50, 7 Stuttgart 1, Federal Republic of Germany, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to the generation of a non-linear function of the butterfly valve in an internal combustion engine, e.g. for a motor vehicle.

The invention relates more particularly to a device for converting a period or frequency, which is obtained by means of an oscillator containing an inductive transducer, and which is proportional to the butterfly valve angle α into a digital output quantity (number) which, in a desired manner, is non-linearly dependent upon the amount of travel. Such a device is described in British patent specification No. 1,491,507 and uses an inductive generator of specific construction and an associated electronic circuit. The output of the inductive transducer is in the form of a frequency which digitally represents an output value which is used for producing other digital output quantities for producing the desired non-linear relationship. The inductive transducer comprises a coil mounted on a U-shaped core of ferromagnetic material, the two limbs of the U having an associated magnetic shunt which is movable along the two limbs in dependence upon the amount of travel to be measured. Since the magnetic shunt varies the total magnetic flux through the U-shaped core virtually in proportion to the travel, the inductance of the transducer coil also varies in proportion to travel. This inductance is then used as part of an electronic oscillator circuit. In the simplest case, this oscillator comprises a series combination comprising a comparator with hysteresis, the transducer coil whose inductance varies in proportion to the travel, and an integrator whose output is fed back to the input of the comparator. This oscillator supplied a saw-tooth voltage, wherein the value of the inductance determines the rise time and the decay time of the integrator voltage, so that the period of the output frequency varies in proportion to the amount of travel. This frequency may be processed further to produce for example a non-linear relationship between the butterfly valve angle and the duration of fuel injection pulses in an internal combustion engine.

Furthermore, a converter device is known which converts a butterfly valve angle into a frequency non-linearly dependent upon the butterfly valve angle. This known device uses a linear potentiometer which is actuated by the butterfly valve and which is connected to an oscillator such that the period of its output frequency varies linearly relative to the butterfly valve angle. This output frequency is fed to a counter having a device for suppressing a specific number of incoming, first counting pulses. A specific relationship then results between the oscillator frequency and the butterfly valve angle. The known circuit is very expensive and uses a mechanical potentiometer for travel/frequency conversion at the input. Furthermore, this known circuit cannot produce the desired non-linear relationship between the angle of the butterfly valve and the duration of injection pulses.

According to the present invention, a device for providing a digital output quantity which is a non-linear function of the position of the butterfly valve of an internal combustion engine, comprises an oscillator containing an inductance which varies with the butterfly valve position and producing a pulse train having a period or frequency proportional to said butterfly valve position, a backward counter to which is fed the output pulses of the oscillator, the backward counter having an associated gate for outputting the counter reading corresponding to said variable in a desired non-linear relationship after the completion of each counting operation.

Thus, the desired non-linear relationship is obtained virtually without additional expenditure on circuitry during the evaluation of the output frequency of the inductive transducer.

A shift of the zero point can be effected by setting the backward counter to an initial value.

The invention is advantageous in that no intervention in the transducer is necessary to obtain the desired non-linear relationship, that is, the output signal of the inductive generator can at the same time be used when a linear relationship is desired and necessary during evaluation. Nevertheless, a further approximation to a desired non-linear relationship is possible by influencing the contour of the transducer, for example by influencing the shape and the extent of the limbs of the U-shaped core.

The present invention is further described hereinafter, by way of example, with reference to the accompanying drawings, in which:—

Fig. 1 shows the mechanical construction of an inductive transducer having a magnetic shunt which is displaceable;

Fig. 2 is a block circuit diagram of the inductive transducer in conjunction with further electronic circuit elements for forming an oscillator;

Fig. 3 is a graph showing the frequency or the period of the transducer output signal plotted against butterfly valve angle α;

Fig. 4 is a graph of a typical performance characteristic which shows the duration of the fuel injection pulses plotted against the butterfly valve angle with the speed n of the internal combustion engine as a parameter;

Fig. 5 is a graph showing the characteristic of the reading Y of a counter fed with the output frequency of the inductive transducer, and the complementary value thereof;

Fig. 6 shows the reading Y of a backward counter upon commencement of the counting operation with a set initial value during counting-out with a minimum and maximum counting frequency; and

Fig. 7 shows an embodiment of an electronic circuit, of simple construction, for producing a non-linear relationship between the output frequency of the inductive transducer, derived from the position of the butterfly valve, and the duration of the fuel injection pulses.

The mechanical construction of the inductive position transducer is shown in Fig. 1. The transducer has a transducer coil 1 which is wound onto the base portion of a ferromagnetic core 2 having U-shaped limbs 1*a* and 1*b*. A magnetic shunt 3 is arranged so as to be displaceable along the limbs 1*a* and 1*b* in accordance with the position of the butterfly valve of an internal combustion engine and its particular position corresponding to the amounts s of its travel determines the value of the inductance L (s) of the coil 1. When a transducer so constructed is fitted into the circuit illustrated in Fig. 2, the latter forms, overall, an oscillator whose frequency is determined by the value of the inductance L of the coil 1, as described in the aforementioned British patent No. 1491507 In short, the operation of such an oscillator is that the output voltage of a comparator 5, having a hysteresis action, connected to the input of the coil 1 is raised or lowered according to the value of the inductance and thus in dependence upon the position of the magnetic shunt, the higher the voltage at the output of the coil 1, the more rapid is the integration of the transducer output voltage by an integrator 6 connected on the output side. When the comparator has attained an upper threshold value, the output voltage of the comparator jumps back to a negative value, and the output voltage of the inductive transducer 1 correspondingly changes. It will be seen that, in this manner, a proprotionality results between the period of the alternating voltage present at the output 7 of the oscillator 8 constructed in this manner and the amount of travel s or rather the angle α of the butterfly valve of the internal combustion engine. This dependence is illustrated in Fig. 3. Since the oscillator 8 oscillates permanently, a minimum period, corresponding to a maximum frequency, ensues even when the butterfly valve is in the position $\alpha = 0$. Owing to the inverse ratio between the period and the frequency, the characteristic (shown in Fig. 3) of the frequency f plotted against the butterfly valve angle α ensues in the case of an oscillator output voltage whose period is proportional to the amount of travel.

Since a non-linear relationship is required between the travel s, or rather the angle α since the information concerning the butterfly angle α is to be used as an input quantity for determining the duration of fuel injection pulses in a petrol injection system, and a possible digital final value such as a counter reading, the simplest procedure is to convert the frequency of the oscillator which is connected to the inductive transducer and whose period is proportional to the angle α of the butterfly valve, into a number in a counter by stepping this counter by the oscillator frequency within a predetermined constant time. The complement of this number is then formed as an output quantity by the number formed in the counter in each case.

A more detailed explanation will be given with reference to Fig. 4 which shows a typical performance graph of an internal combustion engine. The performance graph shows the dependence of the duration t_i of the fuel injection pulses plotted against the butterfly valve angle α, with the engine speed n as a parameter. The slope of the illustrated curve is at a maximum in the case of small angles and decreases as the angles α increase. When the angles are divided into quanta of equal size, a relatively large quantization results with small angles and also decreases as the angle increases. To ensure that this quantization error is constant over the entire range, the above-mentioned non-linear relationship must exist between the angle α and the digital output quantity produced by the circuit it being advantageous to refer to a mean curve of Fig. 4 when dimensioning the desired non-linearity. By way of example, a characteristic of a desired curve of this type is shown by a broken line in Fig. 5 and is designated I. Furthermore, curve II, shown by a solid line in Fig. 5, shows the characteristic of the counter reading Y plotted against the butterfly valve angle α in the case of a counter to which the counting frequency f of Fig. 3 is fed, including a zero point shift which has been effected. As may be seen, the complement of curve II approximately corresponds to the desired curve I. This complement $\bar{Y}$ is received by negation of the binary number Y in a counter which is triggered in each case within a predetermined constant time by the frequency f or, in a special embodiment, by means of the circuit of Fig. 7 which will be described hereinafter.

Referring to Fig. 7, the oscillator of Fig. 2 is designated 8 and supplies an output frequency f whose period is proportional to the butterfly valve angle. The output frequency is fed to the counting input 10 of a backward counter 11 by way of a stage 9 (which need not be discussed further) for strobing and standardization. A timer 13 feeds the setting input 12 of the backward counter 11 with the time signal which determines the duration of the constant time interval during which the frequency f is counted into the backward counter 11 in each case. The timer 13 may be triggered by an optional trigger pulse at 14 When one proceeds from a specific predetermined reading of the backward counter 11 at the commencement of the counting operation, the higher the frequency has been, i.e. the smaller the butterfly valve angle corresponding to Fig. 3, the smaller is the counter reading (corresponding to the number Y) at the end of each counting operation. It will be seen that the desired non-linear relationship corresponding to the curve I of Fig. 5 is obtained, wherein, for the purpose of zero point shift, it is advantageous to provide the backward counter 11 with an associated store 15 for an initial value. At the commencement of the counting operation, this initial value results in an intial counter reading which is counted out in a specific manner. To ensure that the counter reading $Y = 0$ is obtained at the maximum generator frequency, that is, when the angle α of the butterfly valve is zero, and in accordance with Fig. 6, the initial value Yo is such that the counter reading (0000) results according to the number of the stages of the counter. The minimum frequency at $\alpha = 90°$ then counts the backward counter 11 backwards from its initial value Yo to precisely an extent where it reaches its maximum reading (all the counter utputs are at "logic 1"). The backward counter 11 has an associated acceptance gate 16 which, at the commencement of a fresh counting operation or when the final counter reading has been attained after the expiry of the constant time interval, accepts the counter reading attained. This number in the acceptance gate 16 then corresponds in ech case to a specific butterfly valve angle α in the non-linear relationship of the curve 1 of Fig. 5.

If the approximation to the desired curve, made in conformity with Fig. 5, is inadequate, further precision and approximation can be obtained by slightly modifying the contour of the inductive transducer, for example by departing from the parallel configuration of the limbs of the U-shaped core. In any case, it is unnecessary to produce the desired non-linear relationship by, for example "deforming" and influencing the contour of the inductive transducer to any great extent, since this requires very accurate and thus expensive manufacture which can be realised more efficiently by the relatively simple circuit described. The measure, otherwise possible in the digital processing of input values, that is, the feeding-in of non-linearities by way of fixed value stores which are programmed in the desired sense and then interrogated, is also unnecessary, since a measure of this type is relatively expensive and complicated.

WHAT WE CLAIM IS:—

1. A device for providing a digital output quantity which is a non-linear function of the position of the butterfly valve of an internal combustion engine comprising an oscillator containing an inductance which varies with the butterfly valve position and producing a pulse train having a period or frequency proportional to said butterfly valve position, a backward counter to which is fed the output pulses of the oscillator, the backward counter having an associated gate for outputting the counter reading corresponding to said variable in a desired non-linear relationship after the completion of each counting operation.

2. A device as claimed in claim 1, further comprising a timer triggered by a trigger pulse for determining the duration of the triggering of the backward counter by the counting frequency.

3. A device as claimed in claim 1 or 2, further comprising a store containing a respective initial value and associated with the backward counter, the counter contents of the store being accepted in the backward counter for zero point shift at the commencement of each counting operation.

4. A device as claimed in claim 1, 2 or 3, in which the inductance is provided by a coil of an inductive position transducer which has a U-shaped core on whose base the coil is disposed and has a magnetic shunt displaceable along the limbs of the core in accordance

with the position of the butterfly valve.

5. A device substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.

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2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

Fig.1

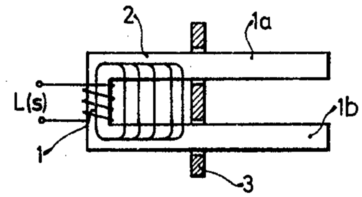

Fig.2

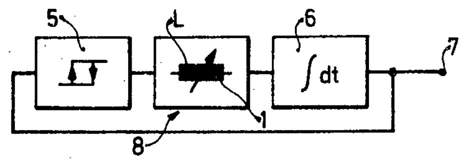

Fig.3

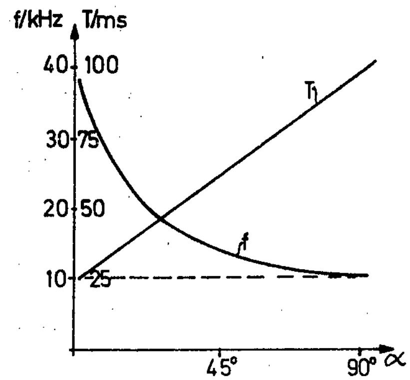

Fig.4

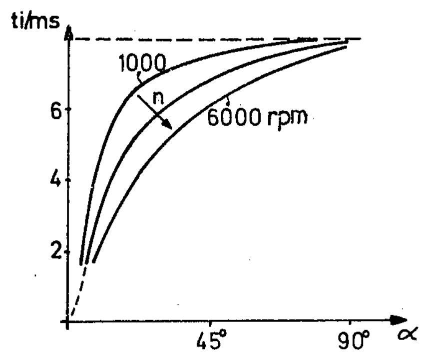

Fig.5

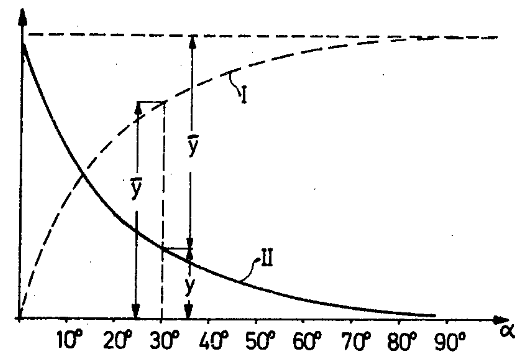

Fig.6

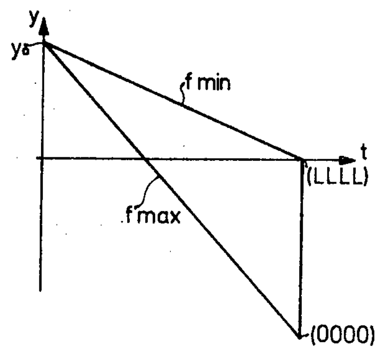

Fig.7