

SPECIFICATION

Multi-channel receiver control apparatus

5 This invention relates to control apparatus particularly, but not exclusively, for use in automatic train control systems.

A known automatic train control arrangement includes a first control system for automatic train operation, and a second control system for automatic train protection. The automatic train operation system automatically controls starting, motoring, coasting, braking and stopping of the train according to which of a number of possible alternative frequency signals is communicated to the train. From track circuits along the railway track, a further frequency command signal representing a maximum safe speed limit is transmitted to the automatic train protection system. In the event of a safe speed limit being exceeded by the train, or a fault occurring in the automatic train operating system, or in the transmission or reception of the speed limit frequency signals, the automatic train protection system over-rides any train control command to slow the train. The intention was to provide an inherently safe automatic train control system, that is, one in which no conceivable failure or combination of failures should result in a dangerous condition, such as over-speeding, and entry of a train into an occupied track section.

In the system referred to, the automatic train protection circuits comprise duplicated parallel channels each having identical narrow band-pass LC filters constructed of robust, low-failure-probability components. The speed limit signal is transmitted as a frequency encoded electric current in a track circuit and is detected on the train by inductive pick-up coils mounted on the front of the train above each rail and ahead of the leading axle. Normally, only the appropriate filter in each of the two channels corresponding to the transmitted frequency produces an output signal, these filter output signals are compared by suitable fail-safe circuitry with a signal representing the train's actual speed, for example, as derived from an axle-mounted tachometer, to determine whether or not the train is exceeding the speed limit for the particular track section occupied at that time. If the train is exceeding the maximum safe speed limit, the automatic train protection system over-rides the driving command of the automatic train operation system and applies the train's brakes to slow the train or even bring it to a halt. Also, in any other operating situation in which the outputs of the two filter channels do not agree, the train brakes are similarly applied. Such situations arise for example, if one of the filters produces no output or the track circuit or one or more of the pick-up coils fails.

In designing electrical circuits and systems of the type being referred to, and also components such as interlocking relays, a fail-safe design philosophy is adopted. Essentially this involves dividing all failure modes as either "right-side failures" or "wrong-side failures", the former mode maintains safety integrity whereas the latter results in a potentially dangerous condition. Thus, for all circuit and system configura-

tions all conceivable failures are analysed and the design arranged to ensure, as far as is possible, that any fault or failure produces a "right-side failure" state, hereinafter such circuits and systems will be referred to as safety circuits etc., and those not so designed as non-safety circuits, etc.

According to the present invention, there is provided control apparatus for preventing vehicle overspeeding comprising means for detecting a signal designating a maximum permissible vehicle speed, means for measuring actual vehicle speed, at least one safety receiving channel and at least one non-safety receiving channel operative to compare the measured speed with the designated maximum speed, a control device connected in the output of each channel adapted to occupy a first state when the measured vehicle speed is no greater than the indicated maximum speed and to occupy a second state otherwise, wherein the safety channel is also adapted to occupy the second state under fault condition, and the control devices are connected in series to control the operation of vehicle brake control means so that, in fail-safe manner, the brakes are applied except when the control devices simultaneously occupy the first state.

In order that the invention may be more clearly understood and readily put into effect, an automatic train protection system embodying the preferred form of the invention will now be described by way of example with reference to the accompanying drawings wherein:-

Figure 1a is a schematic circuit diagram of a safety A.T.P. channel;

Figure 1b is a schematic circuit diagram of a non-safety A.T.P. channel; and

Figure 2 is a schematic diagram of part of an A.T.P. system showing how the circuits of *Figures 1a* and *1b* are combined.

The part of the A.T.P. system illustrated and to be described is mounted on, and in operational configuration in a railway vehicle which may, for example, be a mass transit or rapid transit vehicle.

The safety A.T.P. channel of *Figure 1A* is basically of known type and has two signal inputs, a first of which is supplied by an inductive pick-up coil 12 mounted, as described, above the running rails of which one is shown at 10, to sense a modulated audio-frequency carrier signal in a track circuit designating a maximum safe speed for a vehicle in the corresponding track section. The sensed modulation frequency signal is passed through a carrier filter, amplifier and demodulator 14 and the detected modulation frequency is supplied to the inputs of five parallel speed-limit frequency detecting sub-channels 16, 18, 20, 22 and 24. Each of the sub-channels 16 - 24 contains a band-pass L-C filter 26 composed only of passive components. The frequency pass-bands of the filters 26 in each channel 16 - 24 are tuned to different speed limit-designating signal frequencies and have non-overlapping bandwidths. The output of each filter 26 is connected to the control winding 28 of a transducer 30 having two magnetically saturable toroidal cores 32 and 34 inductively coupled to series-connected output windings 36 and 38 respectively. (Suitable transduc-

tors are described in U.K. Patent No. 971,302.)

The five speed-limit designating code frequencies which comprise the inputs to the filters 26 in this example lie in the range of one octave e.g. 20-40

5 Hertz but wider and other ranges may be employed.

The second signal input to the circuit of Figure 1a is a vehicle speed-dependent signal derived from a tacho-generator illustrated schematically in Figure 10 1a as a toothed wheel 40 mounted on an axle 42, or driven by a wheel or other part of the traction transmission mechanism (not shown). A relatively fixed magnetic proximity sensor 44 responsive to close passage of the teeth detects rotation of the 15 wheel 40 thereby generating a signal indicative of the actual speed of the vehicle. This speed indicating signal is connected to amplifier 45 the output of which is connected in parallel to the inputs of five low pass filters, of which only the filter 46 in 20 sub-channel 16 is shown. Each filter such as 46 is tuned to cut-off at the upper band-width limit of the corresponding filter 26 and is designed and constructed to railway safety principles.

In each of the sub-channels 16-24 the output of 25 each tacho-signal filter such as 46 is connected to a respective level detector 48 the output of which is substantially zero for low amplitude inputs, but which becomes full scale when the output of filter 46 rises above a predetermined level. (Such fail-safe or 30 safety level detectors are described in U.K. Patent Nos. 1,234,096, 1,233,811, 1,246,174 and 1,406,156.

The output of the level detector 48 supplies a control winding 50 of a second transducer 52 which has two magnetically saturable cores 54 and 56 35 inductively linked with series-connected transducer output windings 58 and 60. The structural configuration of the transducer 52 is similar to that of transducer 30 except for a supplementary winding 50a capable of acting as an alternative control 40 winding connected to a zero speed unit 40a driven in the same manner as the tacho-generator and operative at zero and very low speeds to produce a correspondingly low frequency output of sufficient amplitude to energise transducer 52.

45 The output windings 36, 38, 58 and 60 of transducers 30 and 52 are connected in series with each other and with the primary winding 62 of an ordinary a.c. current transformer 64 between the poles BX and NX of a single-phase alternating current supply 50 of 10 kilohertz frequency, in this example, although other frequencies may be used in further embodiments. The secondary winding 66 of the transformer feeds a full wave rectifier comprising diodes 70 to provide a positive d.c. line 72 and has a centretap at 55 68 to provide a negative or return line supplying the coil of a relay 74. A capacitor 78 is connected between the positive and return lines in parallel with the coil of relay 74 and holds the relay on for a short period as will be described below.

60 In operation the transducers 30 and 52 act as two series-switches controlling the BX to NX current through the primary winding 62 of transformers 64. Normally a single speed designating frequency is received via coils 12, assuming this frequency is that 65 to which filter 26 in channel 16 is tuned, then filter 26

produces an output and current flows through the control winding 28 of transducer 30 switching the transducer output windings 36 and 38 to their low impedance state. Assuming also that the train is 70 travelling at less than the maximum speed-limit corresponding to the upper frequency limit of channel 16 then the tacho-generator 40-42 output amplified by amplifier 45 passes through filter 46 and produces a signal at the input of level detector 48 75 which thus occupies a "high" state. The control winding 50 of transducer 52 receives current from the output of level detector 48 and the windings 58 and 60 are switched to their low impedance condition. Current therefore passes from pole BX through 80 transformer 64 to the pole NX and relay 74 is energised. When energised relay 74 closes a pair of normally-open switch contacts 76 which are connected in a brake control circuit the function and operation of which will be described below with 85 reference to Figure 2.

If, however, the vehicle is exceeding the speed limit represented by the modulation frequency of channel 16 then there is a "low" output from 90 detector 48 and no current passes through the control winding 50 of the transducer 52, so that the windings 58 and 60 are switched to their "high" impedance state and the alternating current through primary winding 62 of transformer 64 is relatively low and the corresponding d.c. current on line 72 is 95 insufficient to maintain relay 74 in an energised condition, allowing the contacts 76 to open.

The other sub-channels 18, 20, 22 and 24 are connected in parallel with sub-channel 16 and function in like manner but at their respective 100 different frequencies thus, providing a complete channel performance characteristic covering a wide speed range in five non-overlapping steps. The sub-channel outputs are connected in parallel so that each is individually capable of energising relay 74. In 105 order that relay 74 shall not prematurely or incorrectly be released, e.g. as vehicle speed crosses from one range step to another, the relay 74 is held for a short time by the voltage on capacitor 78, the capacitance of which is therefore chosen to provide 110 a short "hold-time" sufficient for the newly activated channel to achieve substantially full output voltage.

In a conventional A.T.P. system a second complete and identical safety channel working independently of the first channel has its output connected to 115 operate a further relay, similar to relay 74, the contacts of which are connected in series with those of relay 74 to control operation of the vehicle braking system. In the A.T.P. system being described the second parallel channel is not of identical safety type 120 but is a non-safety digital channel arranged to operate in a different manner but to be responsive to the same received signal as the first channel and providing a similar relay energising output.

In the circuit of Figure 1b a coil 112 is similarly 125 mounted above one of the running rails 10 and picks-up, by electro-magnetic induction, the speed-limit-designating modulated frequency signal. This signal is fed to a carrier/filter/amplifier/demodulator 130 114 the output of which is connected to the inputs of 10 parallel band-pass filters 116-134. The first five of

these filters 116-124 are narrow band-pass filters of either passive or active type, each has its centre-frequency tuned to a different one of the five speed-limit-designating modulation frequencies.

5 The filter outputs are connected to respective level detectors 136-144, each having a binary logic output set to change logic output levels when the respective filter output passes through a predetermined amplitude level. The level detector binary outputs pass in parallel to an Exclusive-OR binary logic circuit 146
10 arranged to produce an output when only one modulation signal is present.

The second five filters 126-134 are active filters each comprising at least one operational amplifier
15 (not shown) with a resistive/capacitive feed back loop, two or more such amplifiers would be cascaded. The filters 126-134 have non-overlapping band-widths and each is tuned to a respective one of the five speed-limit-designating frequencies, so that
20 each filter 126-134 corresponds to a respective filter 26 in sub-channels 16-24 in Figure 1. The outputs 150-158 of filters 126-134 respectively are arranged to be a binary level "0" when the received frequency lies outside their respective band-widths and a
25 binary level "1" when the frequency lies within the band-width thus, normally at any one time only one of the outputs will be at binary level "1".

The actual speed of the vehicle is measured by a further tacho-generator arrangement, generally indicated at 160, which produces a pulse output on line
30 162 connected to a binary digital logic AND gate 164. A second input to AND gate 164 is connected to the output of a 1 MHz pulse generator 168 so that the output from AND gate 164 comprises bursts of 1
35 MHz pulses and the length of each burst is inversely proportional to the speed of the vehicle as measured by the tacho-generator 160. AND gate 164 is connected to serial input of a binary counter 170 which produces a parallel output on lines 172 feeding
40 parallel inputs to a binary digital store 166 the clock terminal of which is connected to line 162. The store 166 also produces a parallel output on lines 174 which in turn feed a decode logic circuit 176 which decodes the binary number appearing on lines 174
45 and produces an output on one of lines 178, 180, 182 or 186 as appropriate. In operation the output of AND gate 164 is a burst of 1 MHz pulses the length of which is inversely proportional to the speed of the vehicle, therefore during the period of one burst the
50 digital number accumulated in counter 170 is also inversely proportional to the vehicle's speed. This accumulated number appears on lines 172 and, for example at the commencement of the next burst, is loaded into store 166 where it is temporarily held
55 until the next clock pulse occurs on line 162. This digital number also appears on lines 174 and is decoded by logic circuit 176.

If the output of tacho-generator 160 can vary between 0 and 5 KHz then the minimum number of
60 pulses counted by counter 170 is 200 in one burst, corresponding to the vehicle's highest permitted speed. A progressively larger number of pulses will be counted in each burst at progressively slower vehicle speeds. Decode logic circuit 176 is arranged
65 to produce outputs on its five output lines according

to within which of the five speed ranges the speed represented by the counted binary number lies.

Each of the five outputs from decode logic circuit 176 is connected to an input of one of five 3-input
70 AND gates 188, 190, 192, 194 or 196. A second input on each of these AND gates is connected to the output 148 of Exclusive-OR gate 146, and the third input of each gate is connected to the respective output 150 - 158 from filters 126 - 134 corresponding
75 to the appropriate speed range. The outputs from the AND gates 188 - 196 are connected to the inputs of a 5-input OR gate 198 the output of which is in turn connected to energise a relay 200. Relay 200 has a pair of normally open contacts 202 which are closed
80 when relay 200 is energised, these contacts 202 are connected as will be described below with reference to Figure 2.

In operation of the non-safety A.T.P. channel of Figure 1b a maximum speed-indicating signal is
85 detected and fed to filters 116 - 134, Exclusive-OR circuit 146 indicates that only one such signal has been received, filters 126 - 134 indicate the designated maximum speed limit and the outputs 178 - 186 indicate which maximum speed limits are
90 exceeded and which are not exceeded. If the measured speed of the vehicle is less than the maximum speed limit and there is no mixed modulation then one of the AND gates 188 - 196 will produce an output and OR gate 198 will energise
95 relay 200. In order that relay 200 will not be prematurely or incorrectly released, e.g. as vehicle speed crosses from one range step to another, a capacitor 204 is connected between relay energising terminal and earth in order to "hold-on" the relay
100 energising voltage.

Figure 2 shows in schematic form the manner in which the channel circuit of Figures 1a and 1b are combined in a vehicle installation. The contacts 76 and 202, of relays 74 and 200 respectively, are
105 connected in series between a terminal 80, to which the positive terminal B of a power supply (not shown) is connected, and a terminal 206 which is connected to the negative terminal N of the power supply through the armature coil of a relay 310.
110 Relay 310 controls an electrically operated pneumatic valve 312 connected in the compressed air supply line of a vehicle braking system. Valve 312 is normally open when relay 310 is not energised but is closed by energisation of relay 310. The valve 312 is connected in the output line of a compressed air
115 reservoir 314, which is charged from a compressed air line 316, and controls the supply of compressed air to a brake actuator cylinder 318. The brake actuator has a piston 320 slidably disposed within the cylinder 318 and connected by means of a
120 connecting rod 322 to a brake block or pad 324 mounted by means schematically shown in the drawing as a pivot 326 for acting against the friction braking surface 328 of a vehicle wheel. The braking system shown is intended only to be a diagrammatic illustration of any known braking system.

In operation of the system each of the channels of Figure 1a and Figure 1b independently assesses the vehicles's speed relative to the maximum permitted speed and providing the maximum speed is not
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exceeded the relay contacts 76 and 202 remain closed energising relay 310 which maintains pneumatic valve 312 in a closed position preventing operation of the emergency braking system, it will of course be appreciated that some other means of operating the emergency braking system may be connected in parallel with the A.T.P. system being described. If some form of fault occurs in either of the channels or in the track circuit carrying the speed indicating modulated frequency signal then one or other, or both, the relay contacts 76 and 202 will open de-energising relay 310, opening valve 312 and operating the emergency braking system. Similarly, if the vehicle exceeds the indicated maximum speed limit, then, again, the relay contacts 76 and 202 will open and cause operation of the emergency braking system.

It has already been mentioned above that in a conventional A.T.P. system both channels would be of conventional safety type and probably of identical construction. According to the invention, the channels are not of identical construction and only one is of the conventional safety type while the other is of the non-safety type. The conventional dual parallel safety channel system cannot be arranged to reliably detect mixed modulation frequencies present in a track circuit. In the present system, the non-safety channel includes a mixed modulation detector comprising filters 116-124, level detectors 136-144 and Exclusive-OR gate 146 wherein, as described above, gate 146 only produces an output when a single modulation frequency is detected. Furthermore, the active channel enables more compact electronic circuits to be employed, therefore contributing to a reduction in size, lightness and cost. The combination of a non-safety channel with a safety channel also has another advantage in that the possibility of the occurrence of a common-mode failure is substantially reduced, or even completely eliminated.

Under fault conditions, several speed-limit-indicating frequencies may be present in one track section due to e.g. cross-talk between adjacent tracks and at sufficient amplitude to cause activation of two or more sub-channel filters in the safety channel circuit of Figure 1a. At least one of these wrongly activated filters may correspond to a maximum permitted speed higher than the genuine maximum permitted speed. This can lead to the situation where providing that the measured speed of the vehicle lies within one of the speed ranges corresponding to an activated filter the safety relay 74 remains energised allowing the train to achieve a speed higher than the genuine maximum permitted speed. In a non-safety channel, such as is shown in Figure 1b, this situation cannot arise since if two or more of the filters 126-134 are activated, which would allow the above situation, then the corresponding filters 116-124 in the mixed modulation detector would also be activated so that the Exclusive-OR circuit 146 would not produce an output and the AND gates 188-196 would be inhibited and so would not produce an output to maintain relay 200 in an energised condition. Thus, the contacts 202 must open and cause the emergency braking system to be applied.

CLAIMS

1. Control apparatus for preventing vehicle overspeeding comprising means for detecting a signal designating a maximum permissible vehicle speed, means for measuring actual vehicle speed, at least one safety receiving channel and at least one non-safety receiving channel operative to compare the measured speed with the designated maximum speed, a control device connected in the output of each channel adapted to occupy a first state when the measured vehicle speed is no greater than the indicated maximum speed and to occupy a second state otherwise, wherein the safety channel is also adapted to occupy the second state under fault condition, and the control devices are connected in series to control the operation of vehicle brake control means so that, in fail-safe manner, the brakes are applied except when the control devices simultaneously occupy the first state.

2. A control apparatus according to Claim 1 wherein the receiving channels are arranged to be responsive to a transmitted carrier signal modulated by one of a number of alternative modulation frequencies each of which designates a maximum speed limit.

3. A control apparatus according to Claim 2 wherein the non-safety receiving channel includes a plurality of sub-channels each responsive to a respective modulation frequency, mixed modulation detecting means responsive to the presence of more than one modulation frequency to cause the respective control device to occupy the second state.

4. A control apparatus according to Claim 3 wherein the mixed modulation detecting means comprises a plurality of filter means, each responsive to a respective modulation frequency, and Exclusive-OR gating means connected to receive the outputs of the filter means and to produce an output in the first state in response to an output from any one of the filters and to produce an output in the second state in response to any other combination of filter outputs.

5. A control apparatus according to Claim 4 wherein the non-safety receiving channel includes a plurality of sub-channel filter means, each responsive to a respective modulation frequency and the outputs of which are connected to sub-channel output gating means arranged to be inhibited by an output in the second state from the mixed modulation detecting means.

6. A control apparatus according to Claim 5 wherein the sub-channel output gating means comprises AND gating means connected between each sub-channel output and the control device and also connected to the mixed modulation means whereby the channel output is inhibited when more than one modulation frequency is detected so that the control device is caused to occupy its second state.

7. A control apparatus according to any of Claims 3 to 6 wherein, in the non-safety channel, the vehicle speed measuring means comprises a pulse generator the frequency of which is proportional to vehicle speed, the pulse generator output gates the



exceeded the relay contacts 76 and 202 remain closed energising relay 310 which maintains pneumatic valve 312 in a closed position preventing operation of the emergency braking system, it will of course be appreciated that some other means of operating the emergency braking system may be connected in parallel with the A.T.P. system being described. If some form of fault occurs in either of the channels or in the track circuit carrying the speed indicating modulated frequency signal then one or other, or both, the relay contacts 76 and 202 will open de-energising relay 310, opening valve 312 and operating the emergency braking system. Similarly, if the vehicle exceeds the indicated maximum speed limit, then, again, the relay contacts 76 and 202 will open and cause operation of the emergency braking system.

It has already been mentioned above that in a conventional A.T.P. system both channels would be of conventional safety type and probably of identical construction. According to the invention, the channels are not of identical construction and only one is of the conventional safety type while the other is of the non-safety type. The conventional dual parallel safety channel system cannot be arranged to reliably detect mixed modulation frequencies present in a track circuit. In the present system, the non-safety channel includes a mixed modulation detector comprising filters 116-124, level detectors 136-144 and Exclusive-OR gate 146 wherein, as described above, gate 146 only produces an output when a single modulation frequency is detected. Furthermore, the active channel enables more compact electronic circuits to be employed, therefore contributing to a reduction in size, lightness and cost. The combination of a non-safety channel with a safety channel also has another advantage in that the possibility of the occurrence of a common-mode failure is substantially reduced, or even completely eliminated.

Under fault conditions, several speed-limit-indicating frequencies may be present in one track section due to e.g. cross-talk between adjacent tracks and at sufficient amplitude to cause activation of two or more sub-channel filters in the safety channel circuit of Figure 1a. At least one of these wrongly activated filters may correspond to a maximum permitted speed higher than the genuine maximum permitted speed. This can lead to the situation where providing that the measured speed of the vehicle lies within one of the speed ranges corresponding to an activated filter the safety relay 74 remains energised allowing the train to achieve a speed higher than the genuine maximum permitted speed. In a non-safety channel, such as is shown in Figure 1b, this situation cannot arise since if two or more of the filters 126-134 are activated, which would allow the above situation, then the corresponding filters 116-124 in the mixed modulation detector would also be activated so that the Exclusive-OR circuit 146 would not produce an output and the AND gates 188-196 would be inhibited and so would not produce an output to maintain relay 200 in an energised condition. Thus, the contacts 202 must open and cause the emergency braking system to be applied.

CLAIMS

1. Control apparatus for preventing vehicle overspeeding comprising means for detecting a signal designating a maximum permissible vehicle speed, means for measuring actual vehicle speed, at least one safety receiving channel and at least one non-safety receiving channel operative to compare the measured speed with the designated maximum speed, a control device connected in the output of each channel adapted to occupy a first state when the measured vehicle speed is no greater than the indicated maximum speed and to occupy a second state otherwise, wherein the safety channel is also adapted to occupy the second state under fault condition, and the control devices are connected in series to control the operation of vehicle brake control means so that, in fail-safe manner, the brakes are applied except when the control devices simultaneously occupy the first state.

2. A control apparatus according to Claim 1 wherein the receiving channels are arranged to be responsive to a transmitted carrier signal modulated by one of a number of alternative modulation frequencies each of which designates a maximum speed limit.

3. A control apparatus according to Claim 2 wherein the non-safety-receiving channel includes a plurality of sub-channels each responsive to a respective modulation frequency, mixed modulation detecting means responsive to the presence of more than one modulation frequency to cause the respective control device to occupy the second state.

4. A control apparatus according to Claim 3 wherein the mixed modulation detecting means comprises a plurality of filter means, each responsive to a respective modulation frequency, and Exclusive-OR gating means connected to receive the outputs of the filter means and to produce an output in the first state in response to an output from any one of the filters and to produce an output in the second state in response to any other combination of filter outputs.

5. A control apparatus according to Claim 4 wherein the non-safety receiving channel includes a plurality of sub-channel filter means each responsive to a respective modulation frequency and the outputs of which are connected to sub-channel output gating means arranged to be inhibited by an output in the second state from the mixed modulation detecting means.

6. A control apparatus according to Claim 5 wherein the sub-channel output gating means comprises AND gating means connected between each sub-channel output and the control device and also connected to the mixed modulation means whereby the channel output is inhibited when more than one modulation frequency is detected so that the control device is caused to occupy its second state.

7. A control apparatus according to any of Claims 3 to 6 wherein, in the non-safety channel, the vehicle speed measuring means comprises a pulse generator the frequency of which is proportional to vehicle speed, the pulse generator output gates the



- 5 output of a further relatively higher frequency pulse generator to produce bursts of pulses the number of which is inversely proportional to speed, pulse counting means adapted to produce an output
- 5 according to the number of pulses counted on one of several alternative lines which correspond to the maximum speed limits and wherein the sub-channel outputs and pulse count lines corresponding to the same maximum speeds are connected to AND
- 10 gating means to compare the vehicle speed with the designated speed limits.
8. A control apparatus according to Claim 7 dependent on Claim 6 wherein the sub-channel outputs, the pulse count lines and the output from
- 15 the mixed modulation detecting means are connected to the same AND gating means.
9. A control apparatus including a non-safety channel substantially as described herein with reference to Figure 1b.
- 20 10. A vehicle control system including multi-channel receiver control apparatus according to any preceding claim.
11. A vehicle control system substantially as described herein with reference to the
- 25 accompanying drawings.