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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 5 :
H04L 27/14, H03D 3/02, H03H 7/19

A1

(11) International Publication Number: WO 94/13084

(43) International Publication Date: 9 June 1994 (09.06.94)

(21) International Application Number: PCT/GB93/02202

(22) International Filing Date: 25 October 1993 (25.10.93)

(30) Priority Data:
980,071 23 November 1992 (23.11.92) US

(71) Applicant: FORD MOTOR COMPANY [US/US]; County of Wayne, Dearborn, MI 48126 (US).

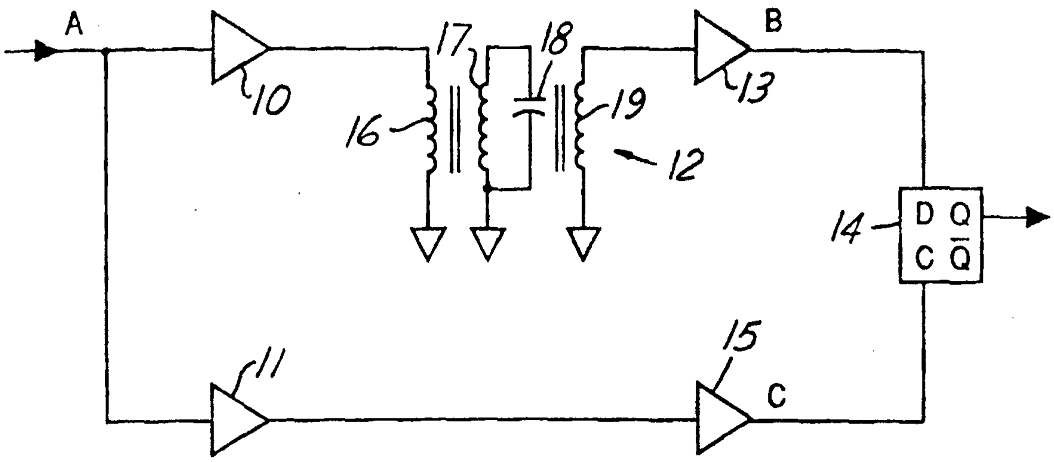
(72) Inventors: KENNEDY, John, Francis; 30453 Sheridan, Garden City, MI 48135 (US). PLOWDREY, Robert, Donald; 33725 East Eight Mile Road, Livonia, MI 48152 (US).

(74) Agent: MESSULAM, Alec, Moses; A. Messulam & Co., 24 Broadway, Leigh on Sea, Essex SS9 1BN (GB).

(81) Designated States: JP, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published
With international search report.

(54) Title: HIGH SPEED FSK DEMODULATOR



(57) Abstract

In an FSK demodulator, the received, modulated signal (A) is divided between two paths. In one path, the signal (A) undergoes non-linear amplification (11, 15), providing an amplitude limited output (C). In the other path, the signal (A) also undergoes non-linear amplification (10, 13), but, in addition, is subjected to a phase shift (12). The phase shift is positive at the frequency representing binary ones, and negative at the frequency representing binary zeros (or vice versa). Thus, the signal (B) from this second branch, is a phase shifted version of the signal (C) from the first. A phase detector (14), comprising a D type flip flop, provides the demodulated output.

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High Speed FSK Demodulator

The present invention relates in general to decoding frequency-shift keying (FSK) signals, and more specifically to an FSK decoding scheme having a fast response time by avoiding integration in the decoder.

Frequency-shift keying is a well-known method for representing binary data using a first frequency to represent a binary zero and a second frequency to represent a binary one. When the binary digit to be represented changes, the frequency of the FSK signal shifts from one frequency to the other. Although the frequency shifts abruptly, FSK systems typically employ a continuous phase, i.e., there is no phase discontinuity when the frequency shifts.

Frequency-shift keying is a type of frequency modulation and can be used to transmit digital information by radio waves. FSK modulation is also used in transmitting binary information over phone lines using modems.

Demodulation of FSK signals typically employs FM detection techniques which include filtering with long time constants or other integration of the FSK signal. For example, the FSK signal to be demodulated is applied to the inputs of a pair of bandpass filters having respective centre frequencies corresponding to the two frequencies of the FSK signal. The filter outputs are coupled to the inputs of a differential amplifier which recreates the digital signal. However, the integration time constants of the filters introduce a time delay slowing down the response time of the FSK demodulator.

Other demodulation techniques rely on the use of quadrature mixing signals to generate quadrature and in-phase FSK components for detection, resulting in high part count and high cost.

The invention has the object and advantage of decoding FSK signals at high speed with a low part count and a low cost.

Specifically, the invention decodes an FSK signal which modulates between a first frequency f_1 and a second frequency f_2 to encode digital information. Wave-shaping means shape the FSK signal to generate substantially identical first and second wave-shaped signals. Phase-altering means receives the first wave-shaped signal for generating a phase-altered signal. The phase-altering means has a frequency response at frequency f_1 different from its frequency response at frequency f_2. Sampling means samples one of the phase-altered signal or the second wave-shaped signal in response to a transition in the other one of the phase-altered signal or the second wave-shaped signal to generate a decoded signal. In a preferred embodiment, the phase-altering means is comprised of a resonant circuit having a resonant frequency f_0 substantially halfway between f_1 and f_2. The sampling means is preferably comprised of a D-type flip-flop.

The invention will now be described further, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a schematic diagram showing a decoder according to the present invention.

Figure 2 is a frequency response curve provided by the tank circuit of Figure 1.

Figures 3-6 show waveform diagrams at respective points in the circuit of Figure 1 during operation.

As shown in Figure 1, an input FSK signal A obtained from an antenna, phone line, or other source (not shown) is coupled to the input of an amplifier 10 and the input of an amplifier 11. The output of amplifier 10 is connected to the input of a resonant circuit 12. The output of resonant circuit 12 is connected to the input of an amplifier 13. An output signal B from amplifier 13 is connected to the D input of a D-type flip-flop 14. The output of amplifier 11 is connected to the input of an amplifier 15 which produces a C output signal coupled to the C input of D flip-flop 14.

Resonant circuit 12 includes an inductor 16 inductively coupled to an inductor 17. A capacitor 18 is connected in parallel with inductor 17. An inductor 19 is magnetically coupled to inductor 17 and provides the output of the resonant circuit 12. In this preferred embodiment, resonant circuit 12 takes the form of a tank circuit which is a parallel resonant circuit having a resonant frequency f_0 at a frequency between the frequencies f_1 and f_2 used by the FSK signal to encode binary digits. Resonant circuit 12 has a high Q factor (by virtue of a low effective series resistance) in order to insure very low integration of the FSK signal. Consequently, resonant circuit 12 alters the phase of the FSK signal but introduces very little time delay, thus enabling fast decoding of the FSK signal.

As shown in Figure 2, resonant circuit 12 provides a relative phase change according to the frequency of its input signal. At frequency f_1, the resonant circuit introduces a phase lag. At frequency f_2, a phase lead is introduced. Although phase shifts of about 45 provide the best accuracy of detection, much smaller relative phase shifts can be employed using the decoder of the present invention.

Amplifiers 10, 11, 13, and 15 are comprised of very high gain amplifiers yielding nonlinear amplification to produce square-wave signals which indicate transitions in the respective input signals. Other forms of square-waved generators can alternatively be employed, such as zero crossing detectors.

The input FSK signal A is shown in Figure 3 which shifts from frequency f_1 to frequency f_2 at a time t_1. FSK signal A is amplified and limited in amplifiers 10 and 11 to produce wave-shaped (i.e., square-wave) signals indicating zero crossings of FSK signal A. Prior to time t_1 while FSK signal A has a frequency f_1, resonant circuit 12 introduces a phase lag resulting in output signal B relative to FSK signal A as shown in Figure 4.

Amplifiers 11 and 15 provide an output signal C, shown in Figure 5, which is identical to the output signal produced at B except for the phase alteration introduced by resonant circuit 12.

Flip-flop 14 receives output signal C at its clock input C so that output signal B is sampled at each positive transition in output signal C. Output signal B applied to the D input of flip-flop 14 is shifted in phase relative to output signal C depending upon whether the FSK signal is transmitted at f_1 or f_2. Due to the phase shift, flip-flop 14 will provide an output signal Q according to the phase difference. As shown in Figure 6, output signal Q switches to a high output signal after a short time delay following time t_1. This delay is due to residual stored energy in the tank circuit.

In the preferred embodiment of Figure 1, amplifiers- fiers 10, 11, 13 and 15 have a slew rate and a bandwidth product at least ten times greater than frequency f_2. Providing a Q factor for resonant circuit 12 of about 300, the present invention was able to detect a shift in the FSK frequency within three cycles of the FSK signal. Even faster detection can be obtained if desired using a resonant circuit with a higher Q factor.

It will be apparent to those skilled in the art that other types of resonant phase-altering devices can be employed other than the tank circuit, such as a ceramic filter, a crystal or a SAW filter. In addition, nonresonant circuits can be employed to introduce the necessary phase difference, such as high-pass or low-pass RC filters.

Flip-flop 14 could be replaced with other known sample-and-hold devices. Furthermore, the inputs to flip-flop 14 could be reversed, resulting in the inversion of the decoded output signal.

CLAIMS

1. Apparatus for decoding a frequency-shift keying (FSK) signal which modulates between a first frequency f_1 and a second frequency f_2 to encode digital information, comprising:

wave-shaping means (10,17) for shaping said FSK signal to generate substantially identical first and second wave-shaped signals;

phase-altering means (12) receiving said first wave-shaped signal for generating a phase-altered signal, said phase-altering means having a frequency response at frequency f_1 different from its frequency response at frequency f_2; and

sampling means (14) for sampling one of said phase-altered signal or said second wave-shaped signal in response to a transition in said other one of said phase-altered signal or said second wave-shaped signal to generate a decoded signal.

2. An apparatus as claimed in claim 1 wherein said wave-shaping means includes means for generating a square-wave signal having transitions in response to zero crossings of said FSK signal.

3. An apparatus as claimed in claim 1 wherein said wave-shaping means is comprised of a nonlinear amplifier.

4. An apparatus as claimed in claim 1 wherein said phase-altering means is comprised of a resonant circuit having a resonant frequency f_0 between said first frequency f_1 and said second frequency f_2.

5. An apparatus as claimed in claim 4 wherein said resonant frequency f_0 is substantially halfway between said first frequency f_1 and said second frequency f_2.

6. An apparatus as claimed in claim 4 wherein said resonant circuit is comprised of a tank circuit with substantially no integration.

7. An apparatus as claimed in any one of the preceding claims, wherein said sampling means is comprised of a D-type flip-flop having one of said phase-altered signal or said second wave-shaped signal coupled to its D input and having the other one of said phase-altered signal or said second wave-shaped signal coupled to its clock input.

8. A method for decoding a frequency-shift keying (FSK) signal which modulates between a first frequency f_1 and a second frequency f_2 to encode digital information, comprising the steps of:

generating substantially identical first and second wave-shaped signals in response to said FSK signal;

phase-altering said first wave-shaped signal to generate a phase-altered signal either leading or lagging said second wave-shaped signal depending on whether said first wave-shaped signal exhibits said frequency f_1 or said frequency f_2; and

sampling one of said phase-altered signal or said second wave-shaped signal in response to a transition in said other one of said phase-altered signal or said second wave-shaped signal to generate a decoded signal.

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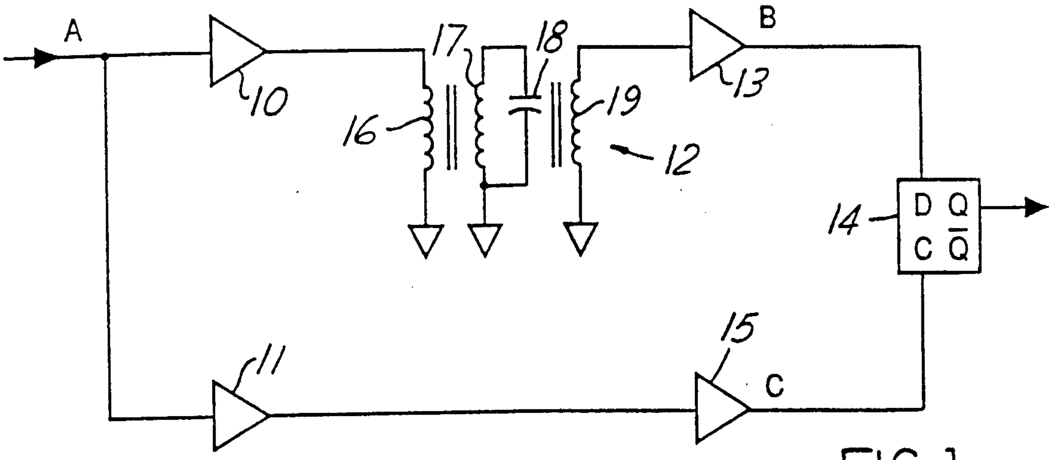

FIG.1

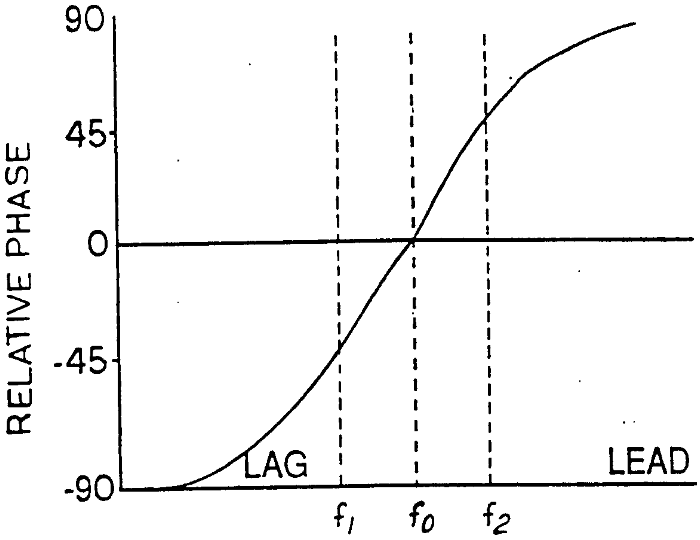

FIG.2

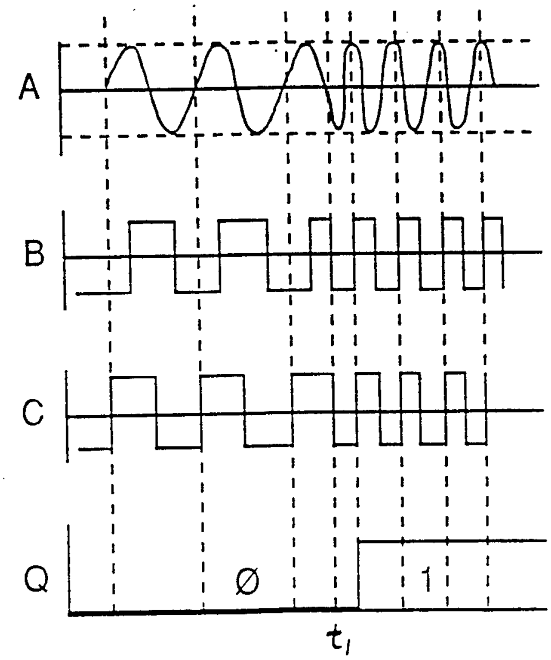

FIG.3

FIG.4

FIG.5

FIG.6

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 93/02202

A. CLASSIFICATION OF SUBJECT MATTER
IPC 5 H04L27/14 H03D3/02 H03H7/19

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 5 H04L H03D H03H

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US,A,3 739 288 (COCCAGNA) 12 June 1973 see abstract; figures 1,2 see column 1, line 26 - line 45 see column 2, line 36 - line 43	1-5,7,8
Y		6

X	DE,B,25 16 679 (SIEMENS) 8 July 1976 see figures 2,3 see column 2, line 1 - line 8 see column 3, line 4 - line 8 see column 5, line 10 - line 25	1-5,7,8
Y		6

X	US,A,3 569 845 (STEINBERG) 9 March 1971 see abstract; figures 1,3 see column 1, line 43 - line 53 see column 1, line 69 - column 2, line 22	1-5,7,8
Y		6

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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28 January 1994	18.02.94

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	PATENT ABSTRACTS OF JAPAN vol. 6, no. 37 (E-97)(915) 6 March 1982 & JP,A,56 156 012 (NIPPON DENKI K. K.) see abstract ---	6
A	GB,A,2 032 737 (STANDARD TELEPHONES AND CABLES LIMITED) 8 May 1980 see figure 1 -----	1,7,8

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Information on patent family members

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PCT/GB 93/02202

Patent document cited in search report	Publication date	Patent family member(s)		Publication date
US-A-3739288	12-06-73	NONE		
DE-B-2516679	08-07-76	NONE		
US-A-3569845	09-03-71	NONE		
GB-A-2032737	08-05-80	DE-A-	2942512	08-05-80
		FR-A,B	2440124	23-05-80
		NL-A-	7907712	28-04-80
		US-A-	4254503	03-03-81