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Elliott

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[54] **DIGITAL VELOCITY CONTROL FOR A DISK DRIVE SERVO SYSTEM**

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[51] **Int. Cl.**[4] **G11B 5/55**

[52] **U.S. Cl.** **360/78**

[58] **Field of Search** 360/78

[56] **References Cited**

U.S. PATENT DOCUMENTS

4,172,267 10/1979 Sidman 360/78

4,288,731 9/1981 Lee 360/78

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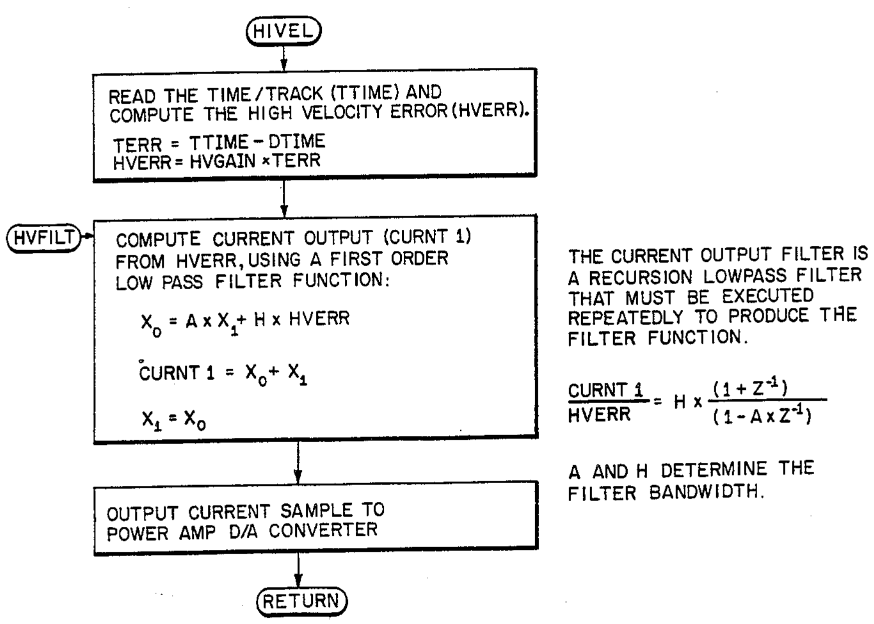
[57] **ABSTRACT**

A high velocity seek deceleration technique is disclosed for seek operations of disk drives wherein measured time per track is compared to a predetermined time per track in a memory as indexed by number of tracks to end of seek determines an error value which adjusts a deceleration amplifier. The gain of digital output to the amplifier is adjusted depending on the number of tracks to end of seek, the higher the number, the higher the gain. Further, a variable bandwidth filter is employed to increase bandwidth as velocity decreases.

3 Claims, 3 Drawing Figures



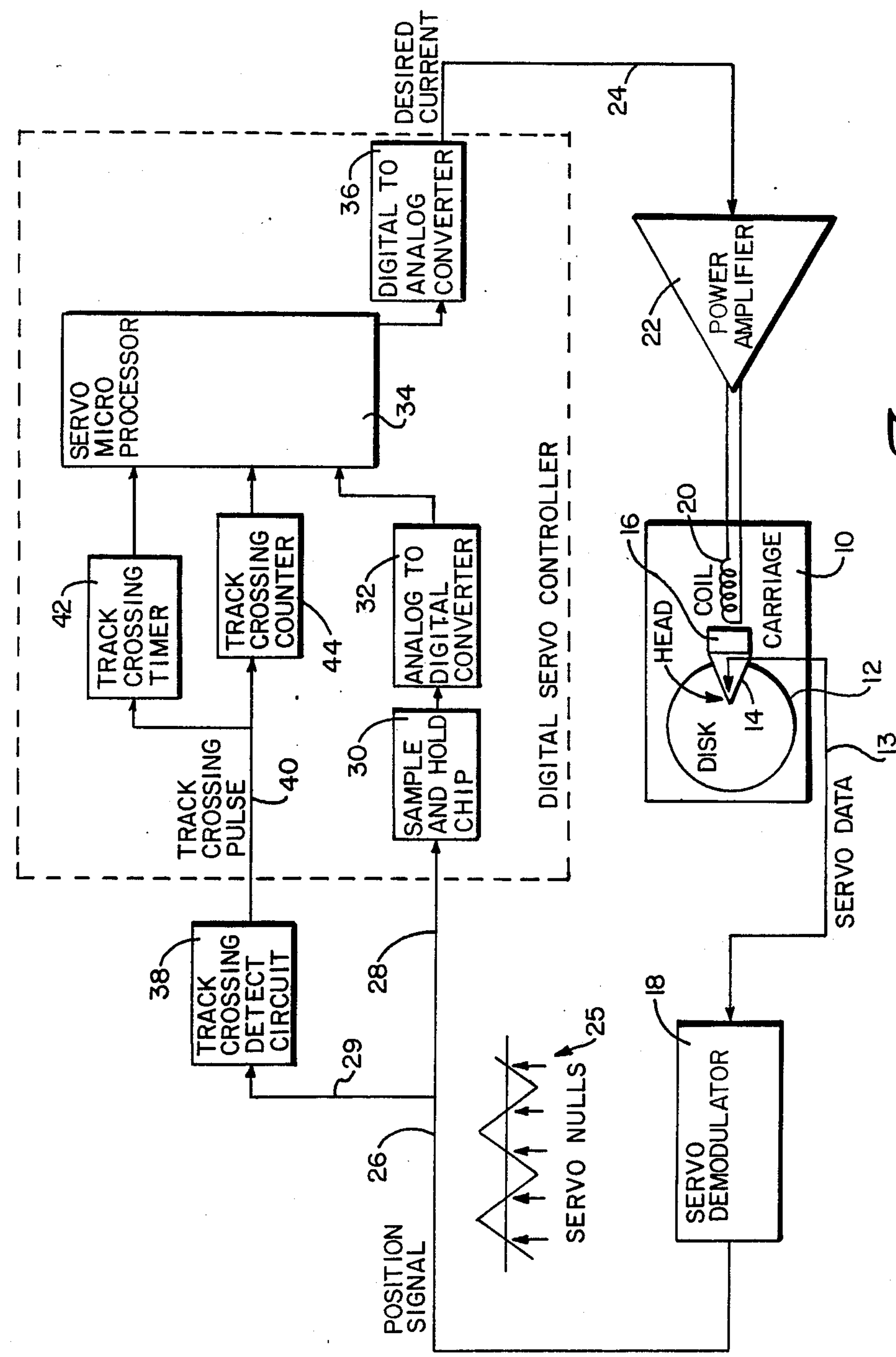

DESIRED CURRENT
24
36
DIGITAL TO ANALOG CONVERTER
SERVO MICRO PROCESSOR
34
POWER AMPLIFIER
22
DIGITAL SERVO CONTROLLER
42
TRACK CROSSING TIMER
TRACK CROSSING COUNTER
44
32
ANALOG TO DIGITAL CONVERTER
TRACK CROSSING PULSE
40
30
SAMPLE AND HOLD CHIP
16
20
HEAD
COIL
CARRIAGE
10
DISK
14
12
13
SERVO DATA
38
TRACK CROSSING DETECT CIRCUIT
28
29
18
SERVO DEMODULATOR
25
SERVO NULLS
26
POSITION SIGNAL

Fig. 1

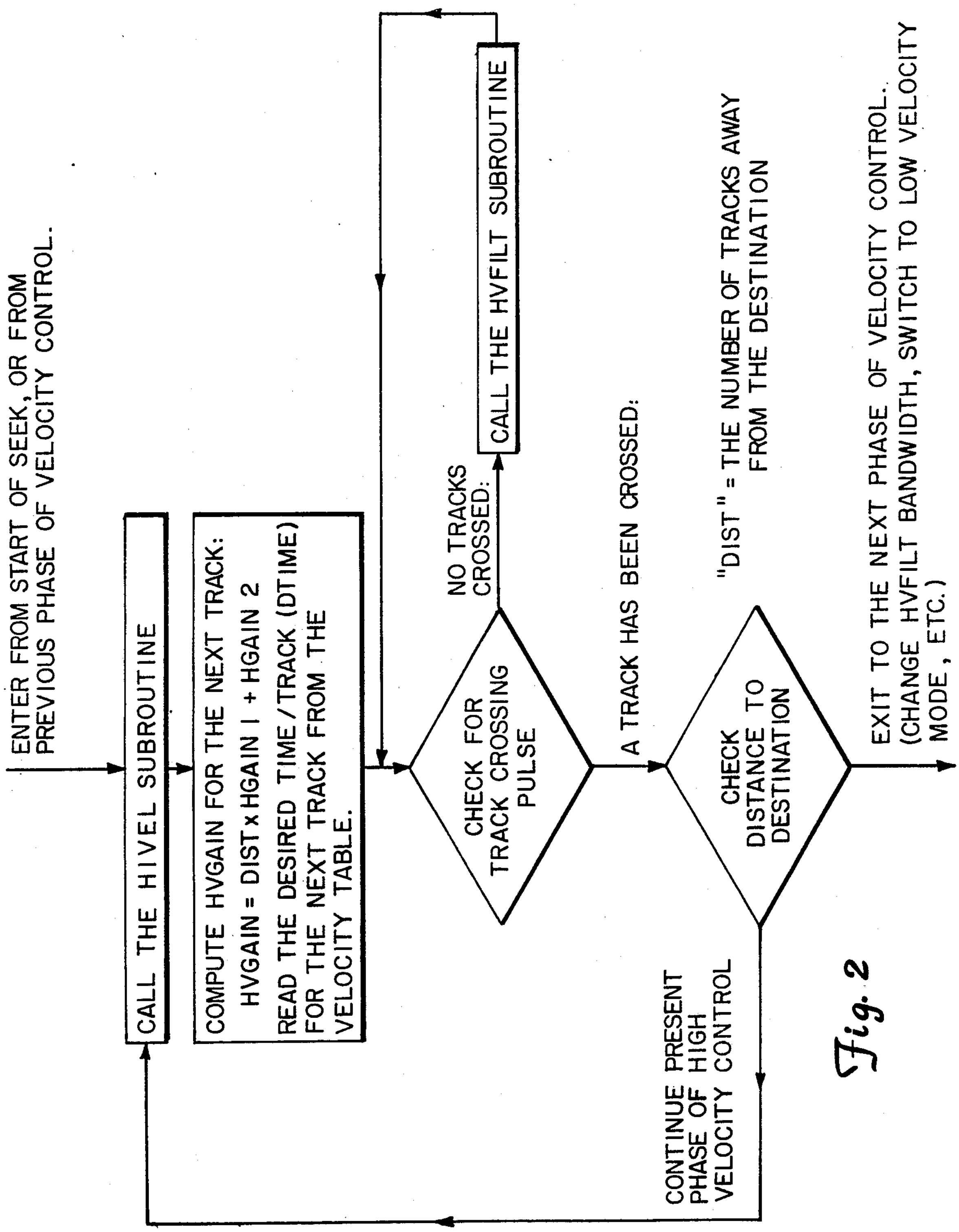

ENTER FROM START OF SEEK, OR FROM PREVIOUS PHASE OF VELOCITY CONTROL.
CALL THE HIVEL SUBROUTINE
COMPUTE HVGAIN FOR THE NEXT TRACK:
HVGAIN = DIST x HGAIN 1 + HGAIN 2
READ THE DESIRED TIME/TRACK (DTIME) FOR THE NEXT TRACK FROM THE VELOCITY TABLE.
CHECK FOR TRACK CROSSING PULSE
NO TRACKS CROSSED:
CALL THE HVFILT SUBROUTINE
A TRACK HAS BEEN CROSSED:
CHECK DISTANCE TO DESTINATION
"DIST" = THE NUMBER OF TRACKS AWAY FROM THE DESTINATION
CONTINUE PRESENT PHASE OF HIGH VELOCITY CONTROL
EXIT TO THE NEXT PHASE OF VELOCITY CONTROL. (CHANGE HVFILT BANDWIDTH, SWITCH TO LOW VELOCITY MODE, ETC.)

Fig. 2

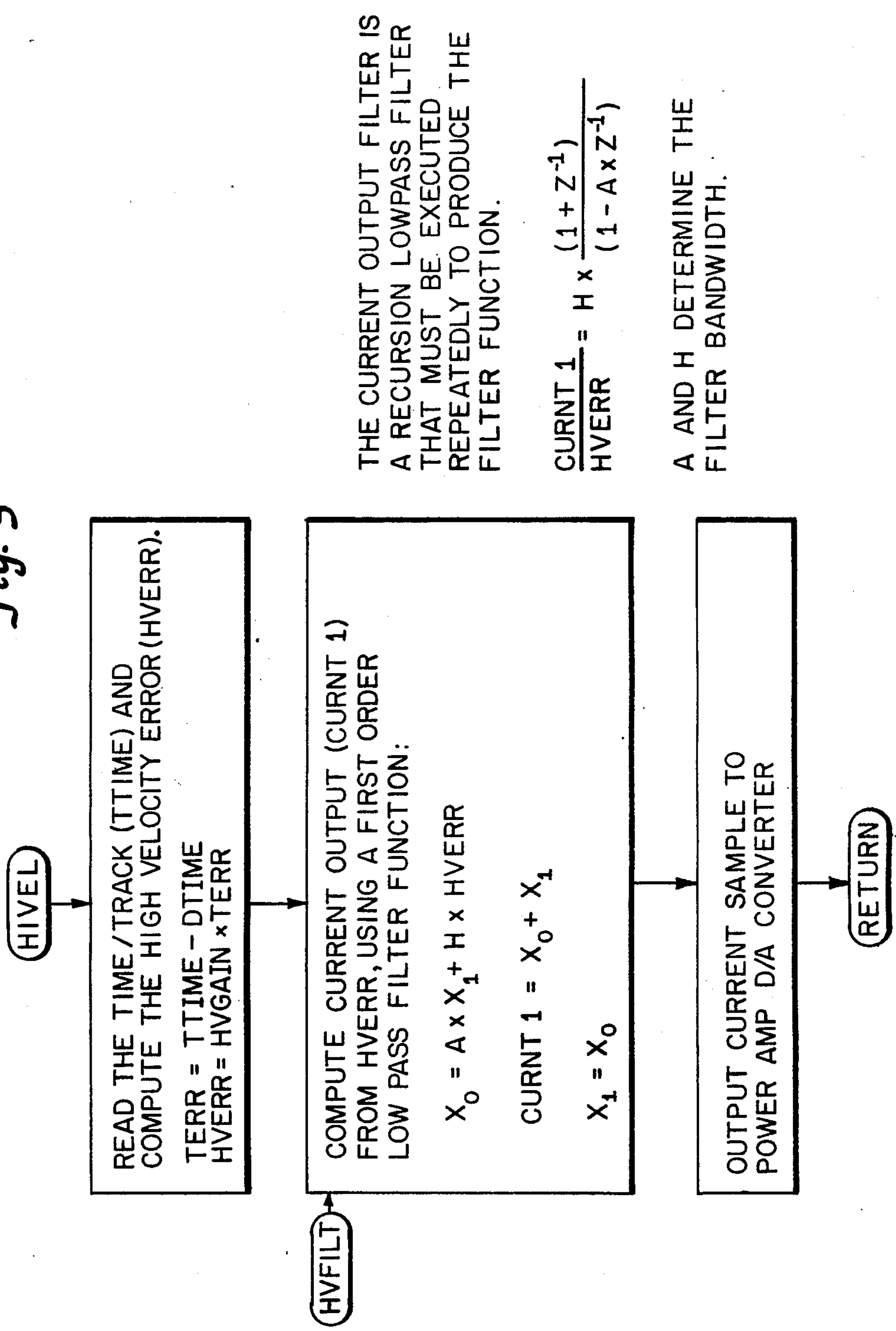

HIVEL
READ THE TIME/TRACK (TTIME) AND COMPUTE THE HIGH VELOCITY ERROR (HVERR).
TERR = TTIME - DTIME
HVERR = HVGAIN × TERR
HVFILT
COMPUTE CURRENT OUTPUT (CURNT 1) FROM HVERR, USING A FIRST ORDER LOW PASS FILTER FUNCTION:
$X_0 = A \times X_1 + H \times HVERR$
$CURNT\ 1 = X_0 + X_1$
$X_1 = X_0$
THE CURRENT OUTPUT FILTER IS A RECURSION LOWPASS FILTER THAT MUST BE EXECUTED REPEATEDLY TO PRODUCE THE FILTER FUNCTION.
$\frac{CURNT\ 1}{HVERR} = H \times \frac{(1 + Z^{-1})}{(1 - A \times Z^{-1})}$
A AND H DETERMINE THE FILTER BANDWIDTH.
OUTPUT CURRENT SAMPLE TO POWER AMP D/A CONVERTER
RETURN

Fig. 3

DIGITAL VELOCITY CONTROL FOR A DISK DRIVE SERVO SYSTEM

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates generally to disk drive servo systems and more particularly to methods and means for controlling the deceleration curves during high velocity seeks.

2. Brief Description of the Prior Art

Disk drive servo seek systems typically drive the head to a high velocity and control the velocity on deceleration so that the head can settled over a track in as short a time as possible. The servo systems obtain input from the servo tracks or other information on the disk which provides position information. Most prior systems differentiated this servo position signal to obtain velocity and adjusted the deceleration amplifier depending on how the the measured velocity varied from a desired velocity. Some systems used the time per track from servo position outputs to compute velocity of the head. See e.g., U.S. Pat. No. 4,329,721. Other systems have employed the time per track measured directly to compare to a desired time per track, and depending upon the difference, either turn on the deceleration amplifier or turned it off.

An advantage of systems employing velocity in the feedback loop is that it uses a measure of velocity to control velocity, a linear relationship. Correspondingly, systems employing time per track to control velocity have the disadvantage in that time per track is inversely proportional to velocity and a loop controlling velocity is non linear. This non linear relationship degrades velocity control accuracy.

However, computing velocity (differentiating or dividing distance by time per track) has the disadvantage in high speed systems in that if analog circuits are employed, a time lag is introduced into the feedback loop, and if digital techniques are employed, processor time to calculate velocity is high (division takes a lot of processor time). Therefore, velocity systems are inherently slower and therefore less accuracy is available. Seek speeds are thereby limited.

SUMMARY OF THE INVENTION

The invention employs a time per track technique further including a variable gain on the output to linearize the relationship between time per track and velocity to decrease instability. Gain is made proportional to distance from destination. A variable bandwidth filter is employed with a narrow bandpass at high velocities to control noise instability introduced by the high gain.

DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. **1** shows the apparatus employed in the preferred embodiment. A disk drive **10** includes a disk **12** on which are recorded servo track which are read by head **14** during seek operations. The servo data read by head **14** is provided on line **13** to a servo demodulator **18** which provides a position signal output on line **26**. The signal looks like the sawtooth pattern **25**, with each null representing a track center. One branch of the signal **28** is provided to a sample and hold **30**, the output of which is converted to an analog to digital converter **32**, which provides a digital representation of the signal to a microprocessor **34**. This digital value is differentiated to yield velocity as is conventional, but is only used when seek velocities are low (e.g., within 3 tracks of the desired track).

Another branch of the position signal **29** is provided to a track crossing detect circuit **38**, which preferably detects track crossing by the presence of the servo nulls. This circuit **38** outputs on line **40** a track crossing pulse which is input to a track crossing timer (which may be of conventional design employing counters clocked by a reference oscillator which are set or reset by the track crossing pulse) and a track crossing counter. The outputs of these two devices are input to microprocessor **34**, which in the preferred embodiment is a Texas Instruments TM32010.

The micro **34** uses the track crossing counter to determine the number of tracks left in a seek. This number indexes a memory to recall a predetermined desired time per track which a compared to the measured time per track from timer **42** to yield a time error value. The number is also used to adjust the gain of a variable gain value. The time error value and gain value are multiplied together and provided to a variable bandwidth digital filter (in the preferred embodiment a conventional low pass IIR digital filter) the output of which is provided by the micro **34** to a digital to analog converter (DAC) **36** whose analog current output is provided on line **24** to a power amplifier **22** to control the current in a coil **20** mounted on a carriage **16**. Current in the coil causes acceleration or deceleration depending upon the direction of the current. The number (from counter **44**) is also used to vary the bandwidth of the digital filter.

FIGS. **2** and **3** show the preferred algorithms for computing the output to the DAC **36** from the inputs from devices **42** and **44** during high velocity seek. FIG. **2** shows overall routine, and FIG. **3** shows two of the subroutines.

The FIG. **2** routing is structured as a series of loops that are used for various phases of the seek operation. These are determined by the distance remaining to reach the destination track. Each loop monitors the progress of the move, computes the forward gain variable (HVGAIN) needed by the control loop, and reads the Desired Time per Track (DTIME) from a velocity lookup table residing in the micro's memory. Velocity control feedback computations are handled by a HIVEL subroutine (FIG. 3). After each track is crossed, the high velocity control loop checks the distance remaining (number of tracks) to the destination and determines if it should remain in the present control loop or branch to the next succeeding loop.

FIG. 3 shows the High Velocity subroutine (HIVEL) and the High Velocity Filter subroutine (HVFILT). Immediately after track crossings, HIVEL is entered to read the time per track counter **42** (TTIME), compute the time per track error (TERR) by subtracting DTIME from the lookup table, and multiply the error by the high velocity gain variable (HVGAIN from FIG. 2) to obtain an error variable HVERR. This value of HVERR is used until the next track is crossed.

HVERR is provided to the HVFILT subroutine to perform a filter computation. The filter computation is a recursive function that must be executed repeatedly at a constant rate. A and H in the formula shown are filter coefficients. These are changed to vary the bandwidth of the filter. The filter coefficients in the preferred embodiment have three phases, that before **64** tracks until destination where the bandwidth is very narrow, between **64** and **3**, the bandwidth is widened, and at **3** the bandwidth is widened again (here the low speed routine, not part of the present invention takes over from the high velocity routine). **X0** and **X1** are state variables used to pass information from one execution to the next. And **CURNT1** is the filter output provided to the DAC **36**.

Referring to FIG. **2**, HVGAIN is made porportional to velocity by relating it to the distance from destination. Thus

*HVGAIN=DIST*HVGAIN1+HVGAIN2*

where DIST is the number of tracks from destination, and HVGAIN1 and HVGAIN2 are constants which are dependent upon the current to deceleration profile of each particular apparatus and must be determined experimentally.

Once the constants HVGAIN1 and HVGAIN2 are determined, HVGAIN is calculable, and DTIME is determinable. The desired velocity profile (from the prior art) is converted into a time per track profile at each track. Thus DTIME is a function of distance to destination and rate of deceleration. Do to the non linearity of the feedback loop, a strict conversion of velocity profile to time per track profile will result in an inherent error. This error is

Time Error=Deceleration Current/(HVGAIN*KFWD),

where Deceleration Current is the desired current to produce the required deceleration, and KFWD is a forward gain factor related to coil current and is a constant determined by the DAC **36** and power amplifier **2** circuits.

Table 1 is an example of time per track and DTIME information related to tracks. Tracks **8** to **225** represent high velocity values and tracks **1** to **7** represent low velocity values. In the table N is the number of tracks to destination; VEL is the velocity in inches per second; TIME is time to reach track zero in milliseconds; TIME/TRACK is time difference between tracks from previous track in microseconds; DVEL is the desired velocity in inches per second used in the low velocity system (not part of the present invention) and represents the a difference from actual velocity sufficient to maintain desired deceleration current; LOWVEL is a hex value of DVEL scaled according to a low velocity sense gain (not used by the present invention); LOWTAB is a value input to the microprocessor for LOWVEL (not used in the present invention), DTIME is the desired time used by the present invention and represents the actual TIME/T plus the time error that is required to maintain desired deceleration current; HITAB is the high velocity table entry for DTIME (tracks 0-7 HITAB=LOWTAB) scaled by the cylinder time clock period of track crossing timer **42** and converted to four-digit hex, and HVGAIN is the value computed from the formula given above for the given track. Also, in this example, track are space 1042 micro-inches apart, the acceleration constant for the coil is 238.7 ((meters/second)/second)/amp, the friction of the carriage is 0.001 amps/(m/s) and the power amp gain is 1 amp/B where B is the maximum value input to the DAC **36**.

TABLE 1

N	VEL (IPS)	TIME (MS)	TIME/T (US)	DVEL (IPS)	LOWVEL (HEX)	LOWTAB (HEX)	DTIME (US)	HITAB (HEX)	HVGAIN (AMPS/IPS)
1	1.979	1.05	385.4	1.44	10F1	10F1	312.6	10F1	−.7307
2	3.428	1.44	265.4	2.34	1BA1	1BA7	920.7	1BA7	.0541
3	4.425	1.70	207.9	3.34	2765	2768	308.7	2768	.2111
4	5.598	1.91	171.4	3.97	2ED2	2ED5	253.3	2ED5	.2436
5	6.564	2.08	149.2	4.94	3A37	3A37	205.4	3A37	.2583
6	7.405	2.23	133.9	5.78	4423	4426	176.6	4426	.2667
7	8.160	2.37	122.5	6.53	4D0A	4D16	157.0	4D16	.2722
8	8.851	2.49	112.3	7.22	5530	5535	141.2	0311	.2760
9	9.713	2.60	103.1	7.50	5869	5872	137.0	02C2	.2663
10	10.504	2.70	95.8	8.29	61BE	61C6	125.6	02AD	.2594
11	11.240	2.80	89.9	9.02	6A6C	6A76	116.4	0274	.2542
12	11.931	2.89	85.0	9.71	7291	6A70	108.9	0246	.2502
13	12.583	2.97	80.8	10.37	7A43	6A70	102.6	0221	.2470
14	13.204	3.06	77.2	10.99	7FFF	6A70	97.2	0201	.2444
15	13.796	3.13	74.0	11.58	7FFF	6A70	92.5	01E6	.2422
16	13.365	3.21	71.2	12.15	7FFF	6A70	88.3	01CE	.2404
17	14.911	3.28	68.7	12.69	7FFF	6A70	84.7	01BA	.2388
18	14.438	3.35	66.4	13.22	7FFF	6A70	81.4	01A7	.2375
19	15.948	3.41	64.3	13.73	7FFF	6A70	78.5	0197	.2363
20	16.442	3.48	62.5	14.23	7FFF	6A70	75.8	0189	.2352
21	16.922	3.54	60.7	14.71	7FFF	6A70	73.4	017B	.2343
22	17.388	3.60	59.2	15.17	7FFF	6A70	71.2	016F	.2335
23	17.842	3.66	57.7	15.63	7FFF	6A70	69.2	0164	.2327
24	18.285	3.72	56.3	16.07	7FFF	6A70	67.3	015A	.2321
25	18.718	3.77	55.0	16.50	7FFF	6A70	65.5	0150	.2314
26	19.140	3.83	53.9	16.92	7FFF	6A70	63.9	0148	.2309
27	19.554	3.88	52.7	17.34	7FFF	6A70	62.4	0140	.2304
28	19.959	3.94	51.7	17.74	7FFF	6A70	61.0	0138	.2299
29	20.356	3.99	50.7	18.14	7FFF	6A70	59.7	0131	.2295
30	20.745	4.04	49.8	18.53	7FFF	6A70	58.4	012A	.2291
31	21.127	4.09	48.9	18.91	7FFF	6A70	57.2	0124	.2287
32	21.502	4.14	48.0	19.29	7FFF	6A70	56.1	011E	.2283
33	21.871	4.18	47.3	19.65	7FFF	6A70	55.1	0119	.2280
34	22.234	4.23	46.5	20.02	7FFF	6A70	54.1	0113	.2277
35	22.591	4.28	45.8	20.37	7FFF	6A70	53.1	010E	.2274
36	22.942	4.32	45.1	20.73	7FFF	6A70	52.2	010A	.2272
37	23.591	4.37	44.4	21.07	7FFF	6A70	51.3	0105	.2269
38	23.630	4.41	43.8	21.41	7FFF	6A70	50.5	0101	.2267

TABLE 1-continued

N	VEL (IPS)	TIME (MS)	TIME/T (US)	DVEL (IPS)	LOWVEL (HEX)	LOWTAB (HEX)	DTIME (US)	HITAB (HEX)	HVGAIN (AMPS/IPS)
39	23.966	4.46	43.2	21.75	7FFF	6A70	49.7	00FD	.2264
40	24.297	4.50	42.6	22.08	7FFF	6A70	49.0	00F9	.2262
41	24.624	4.54	42.0	22.41	7FFF	6A70	48.3	00F5	.2260
42	24.947	4.59	41.5	22.73	7FFF	6A70	47.6	00F1	.2258
43	25.266	4.63	41.0	23.05	7FFF	6A70	46.9	00EE	.2257
44	25.580	4.67	40.5	23.36	7FFF	6A70	46.3	00EA	.2255
45	25.891	4.71	40.0	23.67	7FFF	6A70	45.6	00E7	.2253
46	26.199	4.75	39.5	23.98	7FFF	6A70	45.1	00E4	.2252
47	26.502	4.79	39.1	24.29	7FFF	6A70	44.5	00E1	.2250
48	26.802	4.83	38.7	24.59	7FFF	6A70	43.9	00DE	.2249
49	27.099	4.87	38.2	24.88	7FFF	6A70	43.4	00DC	.2247
50	27.393	4.90	37.8	25.18	7FFF	6A70	42.9	00D9	.2246
51	27.683	4.94	37.4	25.47	7FFF	6A70	42.4	00D6	.2245
52	27.971	4.98	37.1	25.75	7FFF	6A70	41.9	00D4	.2244
53	28.255	5.02	36.7	26.04	7FFF	6A70	41.5	00D2	.2242
54	28.537	5.05	36.3	26.32	7FFF	6A70	41.0	00CF	.2241
55	28.816	5.09	36.0	26.60	7FFF	6A70	40.6	00CD	.2240
56	29.092	5.12	35.6	26.88	7FFF	6A70	40.1	00CB	.2239
57	29.366	5.16	35.3	27.15	7FFF	6A70	39.7	00C9	.2238
58	29.637	5.20	35.0	27.42	7FFF	6A70	39.3	00C7	.2237
59	29.906	5.23	34.7	27.69	7FFF	6A70	38.9	00C5	.2236
60	30.172	5.27	34.4	27.96	7FFF	6A70	38.6	00C3	.2236
61	30.436	5.30	34.1	28.22	7FFF	6A70	38.2	00C1	.2235
62	30.698	5.33	33.8	28.48	7FFF	6A70	37.8	00BF	.2234
63	30.958	5.37	33.5	28.74	7FFF	6A70	37.5	00BD	.2233
64	31.215	5.40	33.2	29.00	7FFF	6A70	37.2	00BB	.2232
65	31.470	5.43	33.0	29.25	7FFF	6A70	36.8	00BA	.2232
66	31.723	5.47	32.7	29.51	7FFF	6A70	36.5	00B8	.2231
67	31.975	5.50	32.5	29.76	7FFF	6A70	36.2	00B7	.2230
68	32.224	5.53	32.2	30.01	7FFF	6A70	35.9	00B5	.2229
69	32.471	5.57	32.0	30.25	7FFF	6A70	35.6	00B3	.2229
70	32.717	5.60	31.7	30.50	7FFF	6A70	35.3	00B2	.2228
71	32.960	5.63	31.5	30.74	7FFF	6A70	35.0	00B1	.2228
72	33.202	5.66	31.3	30.99	7FFF	6A70	34.7	00AF	.2227
73	33.442	5.69	31.0	31.23	7FFF	6A70	34.5	00AE	.2226
74	33.681	5.72	30.8	31.46	7FFF	6A70	34.2	00AC	.2226
75	33.917	5.75	30.6	31.70	7FFF	6A70	33.9	00AB	.2225
76	34.152	5.78	30.4	31.94	7FFF	6A70	33.7	00AA	.2225
77	34.386	5.81	30.2	32.17	7FFF	6A70	33.4	00A8	.2224
78	34.618	5.84	30.0	32.40	7FFF	6A70	33.2	00A7	.2224
79	34.848	5.87	29.8	32.63	7FFF	6A70	33.0	00A6	.2223
80	35.077	5.90	29.6	32.86	7FFF	6A70	32.7	00A5	.2223
81	35.304	5.93	29.4	33.09	7FFF	6A70	32.5	00A4	.2222
82	35.530	5.96	29.2	33.31	7FFF	6A70	32.3	00A2	.2222
83	35.755	5.99	29.1	33.54	7FFF	6A70	32.1	00A1	.2221
84	35.978	6.02	28.9	33.76	7FFF	6A70	31.8	00A0	.2221
85	36.199	6.05	28.7	33.98	7FFF	6A70	31.6	009F	.2220
86	36.420	6.08	28.5	34.20	7FFF	6A70	31.4	009E	.2220
87	36.639	6.11	28.4	34.42	7FFF	6A70	31.2	009D	.2220
88	36.856	6.14	28.2	34.64	7FFF	6A70	31.0	009C	.2219
89	37.073	6.16	28.0	34.86	7FFF	6A70	30.8	009B	.2219
90	37.288	6.19	27.9	35.07	7FFF	6A70	30.6	009A	.2218
91	37.502	6.22	27.7	35.29	7FFF	6A70	30.4	0099	.2218
92	37.715	6.25	27.6	35.50	7FFF	6A70	30.3	0098	.2218
93	37.926	6.28	27.4	35.71	7FFF	6A70	30.1	0097	.2217
94	38.137	6.30	27.2	35.92	7FFF	6A70	29.9	0096	.2217
95	38.346	6.33	27.1	36.13	7FFF	6A70	29.7	0095	.2217
96	38.554	6.36	27.0	36.34	7FFF	6A70	29.5	0095	.2216
97	38.761	6.38	26.8	36.54	7FFF	6A70	29.4	0094	.2216
98	38.967	6.41	26.7	36.75	7FFF	6A70	29.2	0093	.2216
99	39.171	6.44	26.5	36.95	7FFF	6A70	29.0	0092	.2215
100	39.375	6.46	26.4	37.16	7FFF	6A70	28.9	0091	.2215
101	39.578	6.49	26.3	37.36	7FFF	6A70	28.7	0090	.2215
102	39.779	6.52	26.1	37.56	7FFF	6A70	28.6	0090	.2215
103	39.980	6.54	26.0	37.76	7FFF	6A70	28.4	008F	.2214
104	40.180	6.57	25.9	37.96	7FFF	6A70	28.3	008E	.2214
105	40.378	6.59	25.7	38.16	7FFF	6A70	28.1	008D	.2214
106	40.576	6.62	25.6	38.36	7FFF	6A70	28.0	008D	.2213
107	40.773	6.65	25.5	38.56	7FFF	6A70	27.8	008C	.2213
108	40.968	6.67	25.4	38.75	7FFF	6A70	27.7	008B	.2213
109	41.163	6.70	25.3	38.95	7FFF	6A70	27.5	008A	.2213
110	41.357	6.72	25.1	39.14	7FFF	6A70	27.4	008A	.2212
111	41.550	6.75	25.0	39.33	7FFF	6A70	27.2	0089	.2212
112	41.742	6.77	24.9	39.53	7FFF	6A70	27.1	0088	.2212
113	41.933	6.80	24.8	39.72	7FFF	6A70	27.0	0088	.2212
114	42.124	6.82	24.7	39.91	7FFF	6A70	26.9	0087	.2211
115	42.313	6.85	24.6	40.10	7FFF	6A70	26.7	0086	.2211
116	42.502	6.87	24.5	40.29	7FFF	6A70	26.6	0086	.2211
117	42.690	6.90	24.4	40.47	7FFF	6A70	26.5	0085	.2211
118	42.877	6.92	24.2	40.66	7FFF	6A70	26.3	0084	.2211

TABLE 1-continued

N	VEL (IPS)	TIME (MS)	TIME/T (US)	DVEL (IPS)	LOWVEL (HEX)	LOWTAB (HEX)	DTIME (US)	HITAB (HEX)	HVGAIN (AMPS/IPS)
119	43.063	6.94	24.1	40.85	7FFF	6A70	26.2	0084	.2210
120	43.248	6.97	24.0	41.03	7FFF	6A70	26.1	0083	.2210
121	43.433	6.99	23.9	41.22	7FFF	6A70	26.0	0083	.2210
122	43.617	7.02	23.8	41.40	7FFF	6A70	25.9	0082	.2210
123	43.800	7.04	23.7	41.58	7FFF	6A70	25.7	0081	.2210
124	43.982	7.06	23.6	41.77	7FFF	6A70	25.6	0081	.2209
125	44.163	7.09	23.5	41.95	7FFF	6A70	25.5	0080	.2209
126	44.344	7.11	23.5	42.13	7FFF	6A70	25.4	0080	.2209
127	44.524	7.13	23.4	42.31	7FFF	6A70	25.3	007F	.2209
128	44.704	7.16	23.3	42.49	7FFF	6A70	25.2	007F	.2209
129	44.882	7.18	23.2	42.67	7FFF	6A70	25.1	007E	.2208
130	45.060	7.20	23.1	42.84	7FFF	6A70	25.0	007D	.2208
131	45.237	7.23	23.0	43.02	7FFF	6A70	24.9	007D	.2208
132	45.414	7.25	22.9	43.20	7FFF	6A70	24.8	007C	.2208
133	45.590	7.27	22.8	43.37	7FFF	6A70	24.7	007C	.2208
134	45.765	7.30	22.7	43.55	7FFF	6A70	24.6	007B	.2208
135	45.939	7.32	22.6	43.72	7FFF	6A70	24.5	007B	.2207
136	46.113	7.34	22.6	43.90	7FFF	6A70	24.4	007A	.2207
137	46.286	7.36	22.5	44.07	7FFF	6A70	24.3	007A	.2207
138	46.459	7.39	22.4	44.24	7FFF	6A70	24.2	0079	.2207
139	46.631	7.41	22.3	44.41	7FFF	6A70	24.1	0079	.2207
140	46.802	7.43	22.2	44.59	7FFF	6A70	24.0	0078	.2207
141	46.973	7.45	22.1	44.76	7FFF	6A70	23.9	0079	.2206
142	47.143	7.48	22.1	44.93	7FFF	6A70	23.8	0077	.2206
143	47.312	7.50	22.0	45.10	7FFF	6A70	23.7	0077	.2206
144	47.381	7.52	21.9	45.26	7FFF	6A70	23.6	0077	.2206
145	47.649	7.54	21.8	45.43	7FFF	6A70	23.5	0076	.2206
146	47.817	7.56	21.8	45.60	7FFF	6A70	23.4	0076	.2206
147	47.984	7.59	21.7	45.77	7FFF	6A70	23.4	0075	.2206
148	48.150	7.61	21.6	45.93	7FFF	6A70	23.3	0075	.2206
149	48.316	7.63	21.5	46.10	7FFF	6A70	23.2	0074	.2205
150	48.481	7.65	21.5	46.26	7FFF	6A70	23.1	0074	.2205
151	48.646	7.67	21.4	46.43	7FFF	6A70	23.0	0073	.2205
152	48.810	7.69	21.3	46.59	7FFF	6A70	22.9	0073	.2205
153	48.974	7.71	21.2	46.76	7FFF	6A70	22.9	0073	.2205
154	48.137	7.74	21.2	46.92	7FFF	6A70	22.8	0072	.2205
155	49.299	7.76	21.1	47.08	7FFF	6A70	22.7	0072	.2205
156	49.461	7.78	21.0	47.24	7FFF	6A70	22.6	0071	.2204
157	49.623	7.80	21.0	47.41	7FFF	6A70	22.5	0071	.2204
158	49.784	7.82	20.9	47.57	7FFF	6A70	22.5	0071	.2204
159	49.944	7.84	20.8	47.73	7FFF	6A70	22.4	0070	.2204
160	50.104	7.86	20.8	47.89	7FFF	6A70	22.3	0070	.2204
161	50.264	7.88	20.7	48.05	7FFF	6A70	22.2	0070	.2204
162	50.423	7.90	20.6	48.21	7FFF	6A70	22.2	006F	.2204
163	50.581	7.92	20.6	48.36	7FFF	6A70	22.1	006F	.2204
164	50.739	7.94	20.5	48.52	7FFF	6A70	22.0	006E	.2204
165	50.896	7.96	20.4	48.68	7FFF	6A70	21.9	006E	.2203
166	50.053	7.99	20.4	48.84	7FFF	6A70	21.9	006E	.2203
167	50.210	8.01	20.3	48.99	7FFF	6A70	21.8	006D	.2203
168	51.366	8.03	20.3	49.15	7FFF	6A70	21.7	006D	.2203
169	51.521	8.05	20.2	49.30	7FFF	6A70	21.7	006D	.2203
170	51.676	8.07	20.1	49.46	7FFF	6A70	21.6	006C	.2203
171	51.831	8.09	20.1	49.61	7FFF	6A70	21.5	006C	.2203
172	51.985	8.11	20.0	49.77	7FFF	6A70	21.4	006C	.2203
173	52.139	8.13	20.0	49.92	7FFF	6A70	21.4	006B	.2203
174	52.292	8.15	19.9	50.08	7FFF	6A70	21.3	006B	.2203
175	52.445	8.17	19.8	50.23	7FFF	6A70	21.2	006B	.2202
176	52.597	8.19	19.8	50.38	7FFF	6A70	21.2	006A	.2202
177	52.749	8.21	19.7	50.53	7FFF	6A70	21.1	006A	.2202
178	52.900	8.23	19.7	50.68	7FFF	6A70	21.1	006A	.2202
179	53.051	8.25	19.6	50.83	7FFF	6A70	21.0	0069	.2202
180	53.202	8.27	19.6	50.99	7FFF	6A70	20.9	0069	.2202
181	53.352	8.28	19.5	51.14	7FFF	6A70	20.9	0069	.2202
182	53.502	8.30	19.4	51.29	7FFF	6A70	20.8	0068	.2202
183	53.651	8.32	19.4	51.43	7FFF	6A70	20.7	0068	.2202
184	53.800	8.34	19.3	51.58	7FFF	6A70	20.7	0068	.2202
185	53.949	8.36	19.3	51.73	7FFF	6A70	20.6	0067	.2202
186	54.097	8.38	19.2	51.88	7FFF	6A70	20.6	0067	.2201
187	54.244	8.40	19.2	52.03	7FFF	6A70	20.5	0067	.2201
188	54.392	8.42	19.1	52.17	7FFF	6A70	20.4	0066	.2201
189	54.539	8.44	19.1	52.32	7FFF	6A70	20.4	0066	.2201
190	54.685	8.46	19.0	52.47	7FFF	6A70	20.3	0066	.2201
191	54.831	8.48	19.0	52.61	7FFF	6A70	20.3	0066	.2201
192	54.977	8.50	18.9	52.76	7FFF	6A70	20.2	0065	.2201
193	54.122	8.52	18.9	52.91	7FFF	6A70	20.2	0065	.2201
194	54.267	8.53	18.8	53.05	7FFF	6A70	20.1	0065	.2201
195	54.412	8.55	18.8	53.19	7FFF	6A70	20.0	0064	.2201
196	54.556	8.57	18.7	53.34	7FFF	6A70	20.0	0064	.2201
197	55.700	8.59	18.7	53.48	7FFF	6A70	19.9	0064	.2201
198	55.843	8.61	18.6	53.63	7FFF	6A70	19.9	0064	.2201

TABLE 1-continued

N	VEL (IPS)	TIME (MS)	TIME/T (US)	DVEL (IPS)	LOWVEL (HEX)	LOWTAB (HEX)	DTIME (US)	HITAB (HEX)	HVGAIN (AMPS/IPS)
199	55.986	8.63	18.6	53.77	7FFF	6A70	19.8	0063	.2200
200	56.129	8.65	18.5	53.91	7FFF	6A70	19.8	0063	.2200
201	56.271	8.66	18.5	54.05	7FFF	6A70	19.7	0063	.2200
202	56.413	8.68	18.4	54.20	7FFF	6A70	19.7	0063	.2200
203	56.555	8.70	18.4	54.34	7FFF	6A70	19.6	0062	.2200
204	56.696	8.72	18.4	54.48	7FFF	6A70	19.6	0062	.2200
205	56.837	8.74	18.3	54.62	7FFF	6A70	19.5	0062	.2200
206	56.978	8.76	18.3	54.73	7FFF	6A70	19.5	0062	.2200
207	57.118	8.78	18.2	54.90	7FFF	6A70	19.4	0061	.2200
208	57.258	8.79	18.2	55.04	7FFF	6A70	19.4	0061	.2200
209	57.397	8.81	18.1	55.18	7FFF	6A70	19.3	0061	.2200
210	57.537	8.83	18.1	55.32	7FFF	6A70	19.3	0061	.2200
211	57.676	8.85	18.0	55.46	7FFF	6A70	19.2	0060	.2200
212	57.814	8.87	18.0	55.60	7FFF	6A70	19.2	0060	.2200
213	57.952	8.88	18.0	55.74	7FFF	6A70	19.1	0060	.2200
214	58.090	8.90	17.9	55.87	7FFF	6A70	19.1	0060	.2199
215	58.228	8.92	17.9	56.01	7FFF	6A70	19.0	005F	.2199
216	58.365	8.94	17.8	56.15	7FFF	6A70	19.0	005F	.2199
217	58.502	8.96	17.8	56.29	7FFF	6A70	18.9	005F	.2199
218	58.639	8.97	17.7	• 56.42	7FFF	6A70	18.9	005F	.2199
219	58.775	8.99	17.7	56.56	7FFF	6A70	18.8	005E	.2199
220	58.911	9.01	17.7	56.69	7FFF	6A70	18.8	005E	.2199
221	59.046	9.03	17.6	56.83	7FFF	6A70	18.7	005E	.2199
222	59.182	9.04	17.6	56.96	7FFF	6A70	18.7	005E	.2199
223	59.317	9.06	17.5	57.10	7FFF	6A70	18.6	005D	.2199
224	59.451	9.08	17.5	57.23	7FFF	6A70	18.6	005D	.2199
225	59.586	9.10	17.5	57.37	7FFF	6A70	18.6	005D	.2199
226	59.720	9.11	17.4	57.50	7FFF	6A70	18.5	005D	.2199
227	59.854	9.13	17.4	57.64	7FFF	6A70	18.5	005D	.2199
228	59.987	9.15	17.4	57.77	7FFF	6A70	18.4	005C	.2199
229	60.121	9.17	17.3	57.90	7FFF	6A70	18.4	005C	.2199
230	60.253	9.18	17.3	58.04	7FFF	6A70	18.3	005C	.2199
231	60.386	9.20	17.2	58.17	7FFF	6A70	18.3	005C	.2198
232	60.518	9.22	17.2	58.30	7FFF	6A70	18.3	005B	.2198
233	60.651	9.24	17.2	58.43	7FFF	6A70	18.2	005B	.2198
234	60.782	9.25	17.1	58.57	7FFF	6A70	18.2	005B	.2198
235	60.914	9.27	17.1	58.70	7FFF	6A70	18.1	005B	.2198
236	61.045	9.29	17.1	58.83	7FFF	6A70	18.1	005B	.2198
237	61.176	9.30	17.0	58.96	7FFF	6A70	18.0	0058	.2198
238	61.307	9.32	17.0	59.09	7FFF	6A70	18.0	005A	.2198
239	61.437	9.34	16.9	59.22	7FFF	6A70	18.0	005A	.2198
240	61.567	9.35	16.9	59.35	7FFF	6A70	17.9	005A	.2198
241	61.697	9.37	16.9	59.48	7FFF	6A70	17.9	005A	.2198
242	61.826	9.39	16.8	59.61	7FFF	6A70	17.8	0059	.2198
243	61.956	9.41	16.8	59.74	7FFF	6A70	17.8	0059	.2198
244	62.085	9.42	16.8	59.87	7FFF	6A70	17.8	0059	.2198
245	62.213	9.44	16.7	60.00	7FFF	6A70	17.7	0059	.2198
246	62.342	9.46	16.7	60.13	7FFF	6A70	17.7	0059	.2198
247	62.470	9.47	16.7	60.25	7FFF	6A70	17.7	0059	.2198
248	62.598	9.49	16.6	60.38	7FFF	6A70	17.6	0058	.2198
249	62.726	9.51	16.6	60.51	7FFF	6A70	17.6	0058	.2198
250	62.853	9.52	16.6	60.64	7FFF	6A70	17.5	0058	.2197
251	62.980	9.54	16.5	60.76	7FFF	6A70	17.5	0058	.2197
252	63.107	9.56	16.5	60.89	7FFF	6A70	17.5	0058	.2197
253	63.234	9.57	16.5	61.02	7FFF	6A70	17.4	0057	.2197
254	63.360	9.59	16.4	61.14	7FFF	6A70	17.4	0057	.2197
255	63.486	9.60	16.4	61.27	7FFF	6A70	17.4	0057	.2197

I claim:

1. A high velocity seek apparatus comprising;

timer means for determining a TTIME time per track of a disk drive head crossing tracks during a high velocity seek;

counter means for determining the number of tracks to destination;

means responsive to the number for indexing a lookup table to determine a DTIME desired time per track value;

means for determining a TERR difference between TTIME and DTIME;

means responsive to the number for adjusting a gain variable HVGAIN according to the formula

$$HVGAIN = \text{number}*HVGAIN1 + HVGAIN2$$

where HVGAIN1 and HVGAIN2 are constants;

means for determining a HVERR scaled error value according to the formula

$$HVERR = HVGAIN*TERR$$

means for filtering HVERR to produce a CURNT1 filtered value;

means for converting CURNT1 into a current; and

means for inputting the current into a coil mounted on the head carriage of a disk drive to produce deceleration of the head.

2. The apparatus of claim 1 wherein said means for filtering comprises a variable bandwidth filter and further including means for providing a narrower bandwidth at high track numbers to destination and a wider bandwidth at lower track numbers to destination.

3. The apparatus of claim 1 wherein said DTIME values are calculated from a desired velocity profile plus a time error value computed by dividing a desired deceleration current value by the HVGAIN value at each track and further divided by the forward current gain of said means for converting said CURNT1 value to a current.

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