Copy Protection vs. Emulators:
The battle rages on

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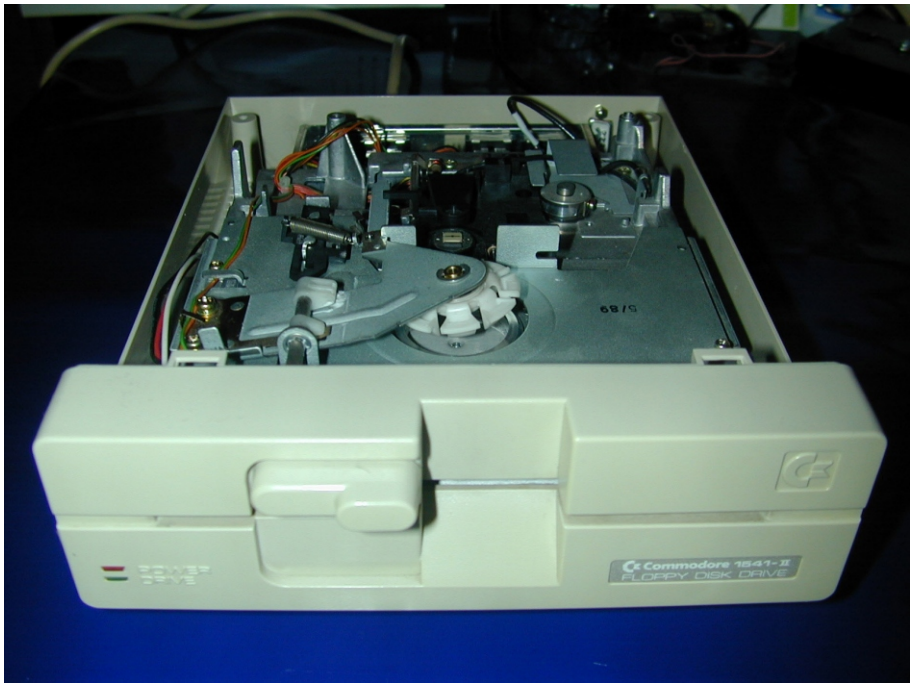
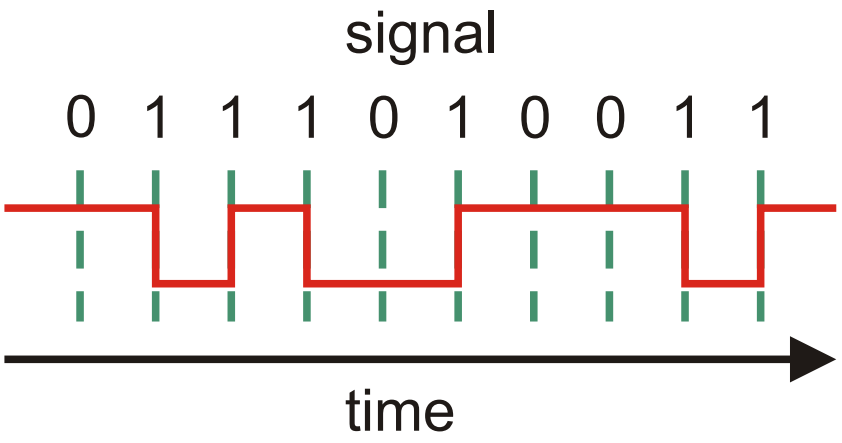
Floppy Disks

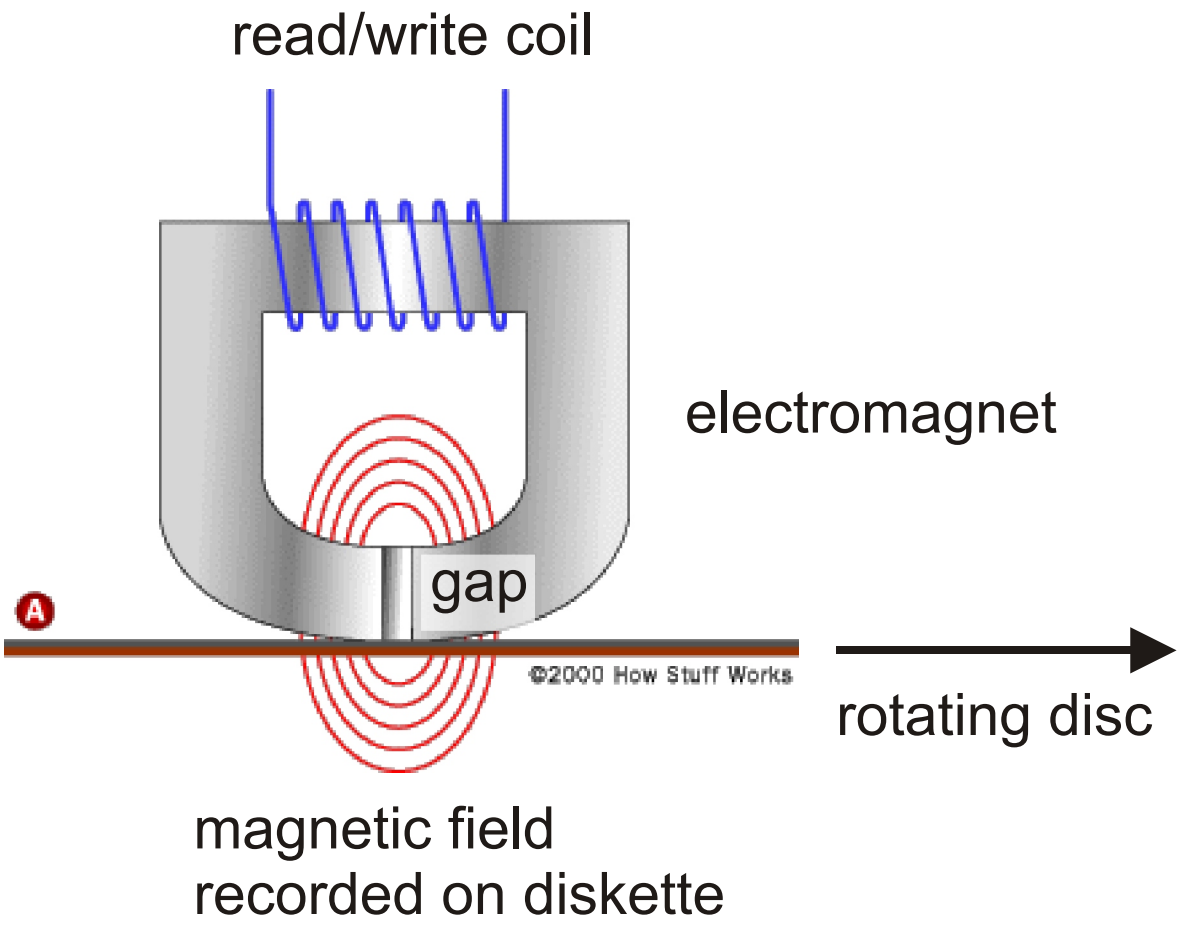
5.25“ floppy disks

Commodore 1541-II disk drive

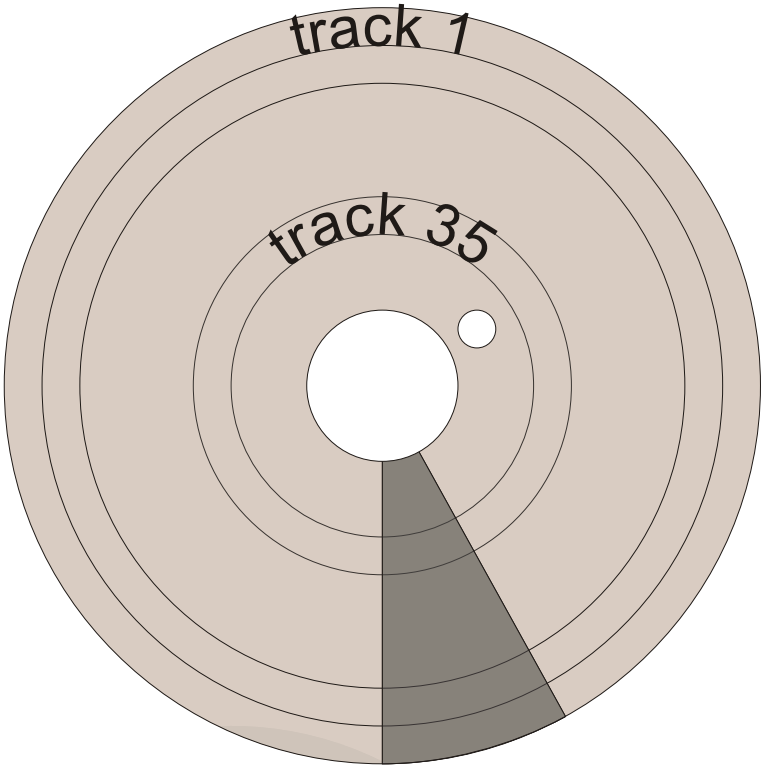


Read/Write Head



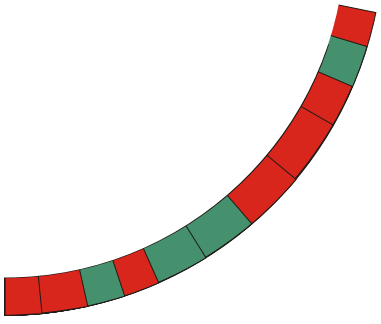


Commodore Disks - logical



one sector

magnetic recording of data



field:	N	N	S	N	S	S	N	N	N	S	N
data:	0	1	1	1	0	1	0	0	1	0	

GCR encoding

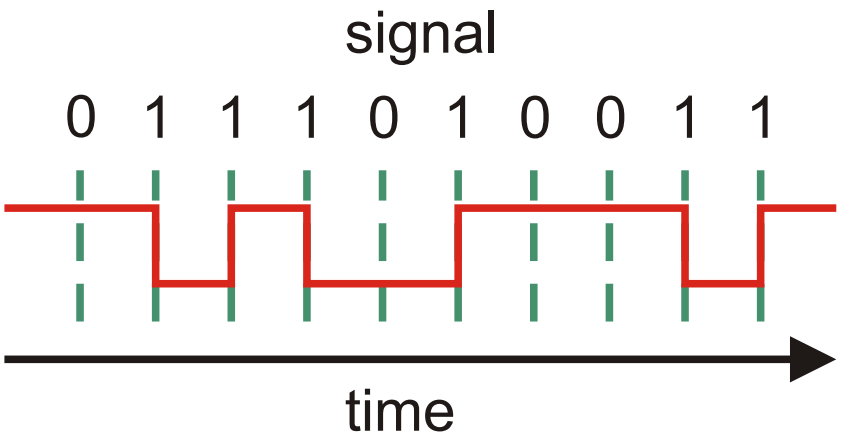
no more than two ‘0’ Bits
no more than eight ‘1’ Bits

-> GCR encoding

Nibble	GCR
$0	01010
$1	01011
$2	10010
$3	10011
$4	01110
$5	01111
$6	10110
$7	10111
$8	01001
$9	11001
$a	11010
$b	11011
$c	01101
$d	11101
$e	11110
$f	10101

Sync = twelve ‘1’ bits in a row

Example



N N S N S S N N N S N

0 1 1 1 0 1 0 0 1 0

GCR: 01110 10010

Nibble: $4 $3

Byte: $43

ASCII: ‘C’

Nibble	GCR
$0	01010
$1	01011
$2	10010
$3	10011
$4	01110
$5	01111
$6	10110
$7	10111
$8	01001
$9	11001
$a	11010
$b	11011
$c	01101
$d	11101
$e	11110
$f	10101

Read Errors

CODE	MEANING	DOS ERROR MESSAGE
01	Everything OK	00, OK
02	Header block not found	20, READ ERROR
03	SYNC not found	21, READ ERROR
04	Data block not found	22, READ ERROR
05	Checksum error in data block	23, READ ERROR
07	Verify error	25, WRITE ERROR
08	Disk write protected	26, WRITE PROTECT ON
09	Checksum error in header block	27, READ ERROR
0B	Id mismatch	29, DISK ID MISMATCH

```
7000 OPEN 15,8,15:OPEN 5,8,5,"#"
7010 PRINT#15,"U1:";5;0;33;5
7020 INPUT#15,S
7030 IF S<>23 then 7030
7040 CLOSE 15:CLOSE 5
```

Tracks 36-40

The 1541 uses a standard 80 track drive mech with a Single Density read/write head.

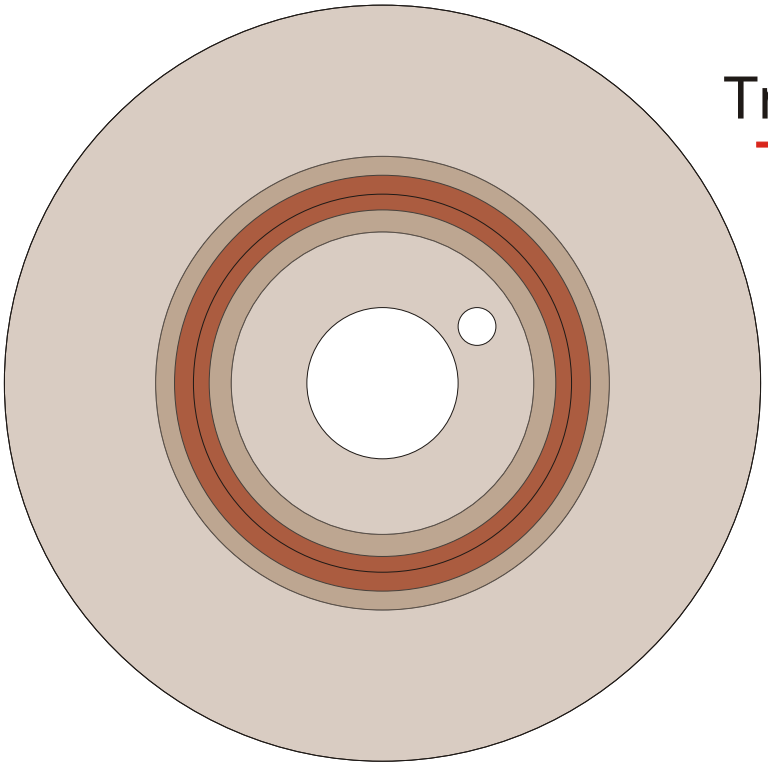
For safety reasons, standard disks only use the outer 35 tracks.

Copy protections are free to use all 40 tracks.

Halftracks

As a double density drive mech is used with a single density read/write head, each track increment needs two motor steps.

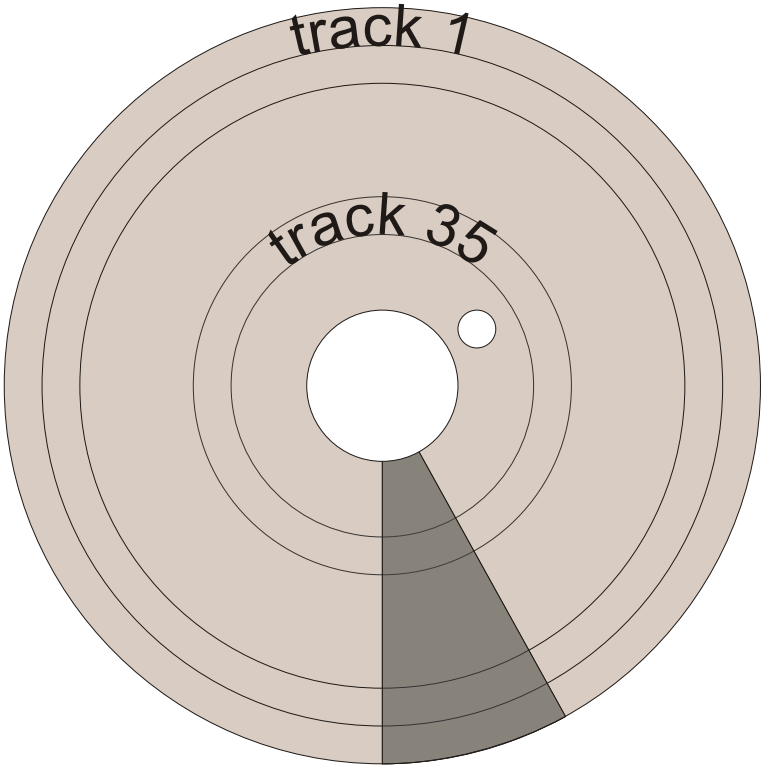
By stepping only once, a halftrack is selected.



Wide Track Protection:

An extra wide write head is used for recording two tracks at once (tracks 35 and 36). The copy protection tries to read the same data from track 35, 35.5 and 36.

Sector Synchronization



sector 0

1541 disks are *soft sectored*, as the drive doesn’t use the index hole.

Sector boundaries are determined by Sync mark position during formatting. Usually Sectors don’t match up exactly.

For copy protection reasons, Sync marks and sectors may be aligned by using a drive with an index-hole sensor.

Long Tracks

The 1541 is a smart drive, but only has 2kB of memory.

A whole track holds about 8kB of GCR data.

Copy protections either check for a specific extra-long pattern or use custom GCR encoding:

byte = (GCR1 AND 0xaa) OR (GCR2 AND 0x55)

Sectors encoded this way may be decoded and sent to the C64 on-the-fly (fast loaders)

Nonstandard Bit-Rates

When rotating, the outer tracks move faster under the read/write head than the inner tracks.

To compensate for this, the inner tracks are recorded with slower bit rates.

Tr. 1-17: 7820 bytes
Tr. 18-24: 7170 bytes
Tr. 25-30: 6300 bytes
Tr. 31-35: 6020 bytes

To fit some additional sectors on a disk, original disks sometimes use higher bit rates on inner tracks.

Copy protections also may change the bit rate within a track.

Slowed down motor during recording

Another trick to squeeze in some more bytes on each track is to slow down the motor during recording.

The disk will rotate slower and thus more bytes are written in one turn.

Sync Trickery

GCR-Requirements:

no more than two ‘0’ Bits
no more than eight ‘1’ Bits

WHY?

‘1’ bit resynchronizes read electronics
Sync >= twelve ‘1’ bits in a row

0101011001111111111111111101110100110111010010
no framing Sync-Signal defined framing

Killer Track:
Whole Track consists of Sync Signal

Missing Syncs:
Bit Framing after two many 0 Bits unreliable

Emulation Success

Copy Protection	*D64*	*G64*	*Used by*
Read Errors	X	X	1984, 1985
Tracks 35-40	X	X	Firebird, Para Protect
Half Tracks		X	
Wide Tracks		(X)	EA, Activision
Long Tracks/Custom format		X	Datasoft
Slowed down motor		X	v-max!
Sync counting		X	Epyx (early Vorpal)
Nonstandard bitrates		X	Vorpal, Rapidlok
Bitrate changes in track			
Sector synchronization			Rapidlok (Accolade)
00 Bytes			Datasoft, EA, Rainbow Arts