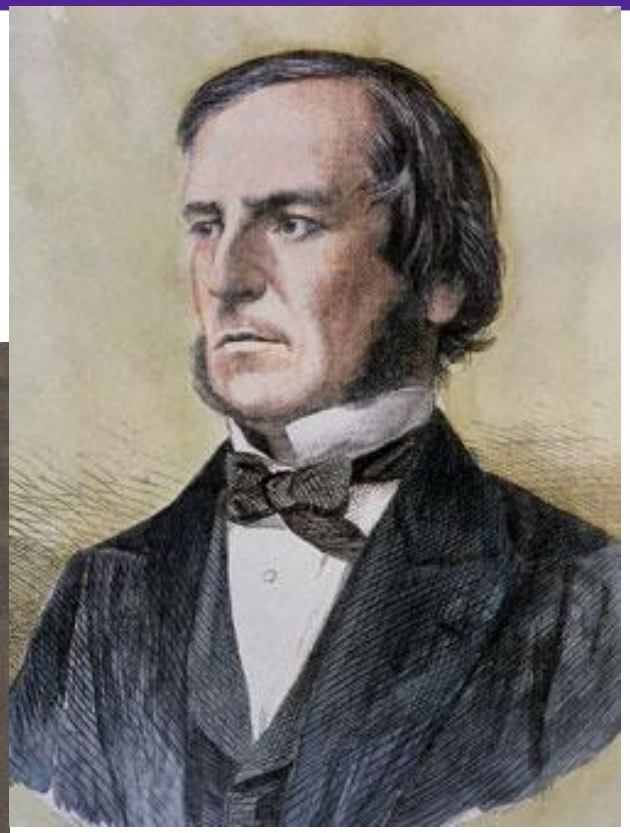
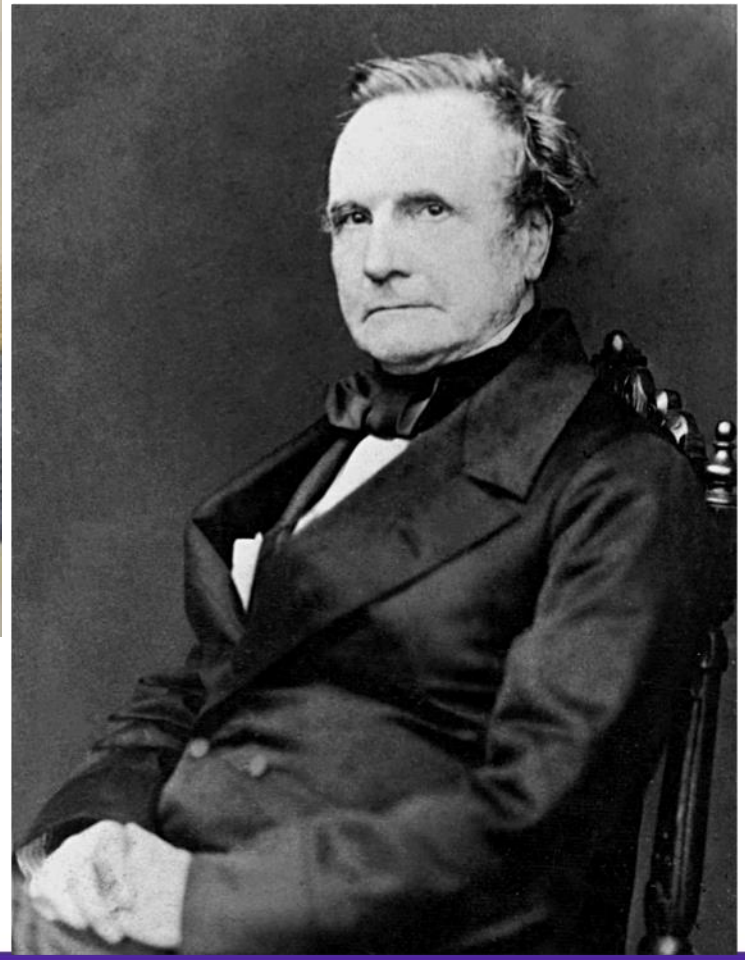
Encoding Data





George Stibitz

- 1937, he completed his "Model K"
  - Named after his Kitchen Table
- Capable of performing addition on two binary numbers

Complex Numerical Calculator

- Competed his Complex Numerical Calculator in 1940
  - able to perform calculations on complex numbers
  - could be operated remotely

Image Source: Computer History Museum

Video Link

Binary - Natural Numbers

128	64	32	16	8	4	2	1
0	0	1	0	1	0	1	0

0*128	0*64	1*32	0*16	1*8	0*4	1*2	0*1

32 + 8 +2 = 42

Binary Data Types

- Unsigned Integer (Natural Number)
- Signed Integer
- Float

Negative Numbers

- One's Complement - Just invert the bits
- Sign Bit: 0 is positive, 1 is negative

0	0	1	0	1	0	1	0	**42**

1	1	0	1	0	1	0	1	**-42**

One's Complement Addition

0	0	1	0	1	0	1	0	**42**

+

1	1	0	1	0	1	0	1	**-42**

=

1	1	1	1	1	1	1	1	**-0**

Hmm. That's not quite right…

Two’s Complement

- Two's Complement - Invert the bits and add 1

0	0	1	0	1	0	1	0	**42**

invert

1	1	0	1	0	1	0	1	

plus 1

1	1	0	1	0	1	1	0	-42

Two's Complement Addition

0	0	1	0	1	0	1	0	**42**

+

1	1	0	1	0	1	1	0	**-42**

=

0	0	0	0	0	0	0	0	**0**

That Works!

Other Values (2s Complement)

Binary	Unsigned	Signed
00000000	0	0
00000001	1	1
00000010	2	2
01111110	126	126
01111111	127	127
10000000	128	-128
10000001	129	-127
10000010	130	-126
11111110	254	-2
11111111	255	-1

Integer Overflow

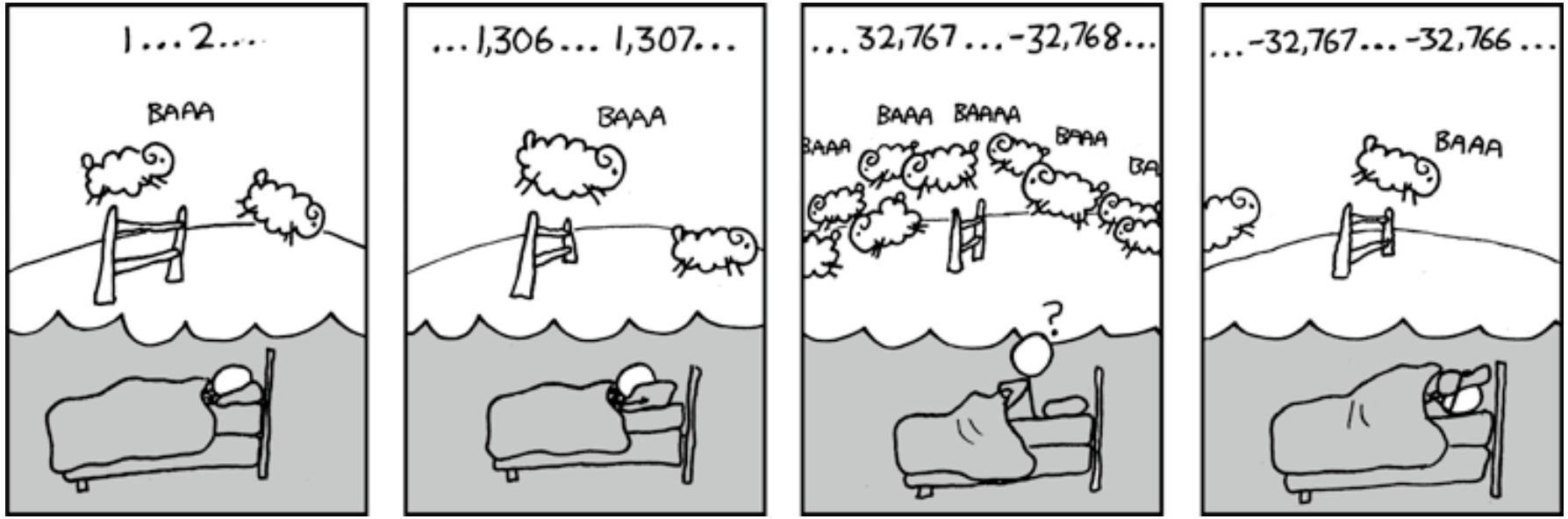


Image Source: [Randall Munroe (XKCD)]

Range Values

- 8 Bit numbers
  - Unsigned: $0 \rightarrow 2^8 - 1$
  - Signed: $-(2^7) \rightarrow 2^7 - 1$
- General Numbers - n bits
  - Unsigned: $0 \rightarrow 2^n - 1$
  - Signed: $-(2^{n-1}) \rightarrow 2^{n-1} - 1$

Rational Numbers

The decimal point can “float” around

$$1.2345 = \underbrace{12345}_{\text{mantissa}} \times \overbrace{10^{-4}}^{\text{exponent}}$$

Floating Point

- IEEE 754 Standard - 16 bits (Half) The exponent has a bias of 15
- The leading one of the mantissa is implied

-	Exponent					Mantissa									
0	0	1	0	1	0	0	1	0	1	0	1	0	1	0	1

Floating Point Example

-	Exponent					Mantissa								
0	1	0	1	0	0	0	1	0	1	0	0	0	0	0	0

Mantissa: (1).01010 = 1 + 1/4 + 1/16 = 1.3125

Exponent: 10100 – 01111 = 00101 = 1 + 4 = 5

Value: $1.3125 * 2^5 = 42$

$1.01010 * 2^5 = 101010 = 42$

Range of Values

- -65504 → +65504
- 5.96046 x 10^{-8} : minimum positive
- 0 11111 0000000000 = infinity
- 1 11111 0000000000 = -infinity
- 0 01101 0101010101 ≈ 0.33325 ≈ 1/3

Not exact, but not bad either

Learn More!

Real World

- Integer - 32 bits
- Long Integer - 64 bits
- Half - 16 bits (5 + 10)
- Float (Single) - 32 bits (8 + 23)
- Double - 64 bits (11 + 52)

Text - ASCII

Dec	Hx	Oct	Char	Dec	Hx	Oct	Html	Chr	Dec	Hx	Oct	Html	Chr	Dec	Hx	Oct	Html	Chr
0	0	000	NUL (null)	32	20	040		Space	64	40	100	@	@	96	60	140	`	`
1	1	001	SOH (start of heading)	33	21	041	!	!	65	41	101	A	A	97	61	141	a	a
2	2	002	STX (start of text)	34	22	042	"	"	66	42	102	B	B	98	62	142	b	b
3	3	003	ETX (end of text)	35	23	043	#	#	67	43	103	C	C	99	63	143	c	c
4	4	004	EOT (end of transmission)	36	24	044	$	$	68	44	104	D	D	100	64	144	d	d
5	5	005	ENQ (enquiry)	37	25	045	%	%	69	45	105	E	E	101	65	145	e	e
6	6	006	ACK (acknowledge)	38	26	046	&	&	70	46	106	F	F	102	66	146	f	f
7	7	007	BEL (bell)	39	27	047	'	'	71	47	107	G	G	103	67	147	g	g
8	8	010	BS (backspace)	40	28	050	(	(	72	48	110	H	H	104	68	150	h	h
9	9	011	TAB (horizontal tab)	41	29	051	)	)	73	49	111	I	I	105	69	151	i	i
10	A	012	LF (NL line feed, new line)	42	2A	052	*	*	74	4A	112	J	J	106	6A	152	j	j
11	B	013	VT (vertical tab)	43	2B	053	+	+	75	4B	113	K	K	107	6B	153	k	k
12	C	014	FF (NP form feed, new page)	44	2C	054	,	,	76	4C	114	L	L	108	6C	154	l	l
13	D	015	CR (carriage return)	45	2D	055	-	-	77	4D	115	M	M	109	6D	155	m	m
14	E	016	SO (shift out)	46	2E	056	.	.	78	4E	116	N	N	110	6E	156	n	n
15	F	017	SI (shift in)	47	2F	057	/	/	79	4F	117	O	O	111	6F	157	o	o
16	10	020	DLE (data link escape)	48	30	060	0	0	80	50	120	P	P	112	70	160	p	p
17	11	021	DC1 (device control 1)	49	31	061	1	1	81	51	121	Q	Q	113	71	161	q	q
18	12	022	DC2 (device control 2)	50	32	062	2	2	82	52	122	R	R	114	72	162	r	r
19	13	023	DC3 (device control 3)	51	33	063	3	3	83	53	123	S	S	115	73	163	s	s
20	14	024	DC4 (device control 4)	52	34	064	4	4	84	54	124	T	T	116	74	164	t	t
21	15	025	NAK (negative acknowledge)	53	35	065	5	5	85	55	125	U	U	117	75	165	u	u
22	16	026	SYN (synchronous idle)	54	36	066	6	6	86	56	126	V	V	118	76	166	v	v
23	17	027	ETB (end of trans. block)	55	37	067	7	7	87	57	127	W	W	119	77	167	w	w
24	18	030	CAN (cancel)	56	38	070	8	8	88	58	130	X	X	120	78	170	x	x
25	19	031	EM (end of medium)	57	39	071	9	9	89	59	131	Y	Y	121	79	171	y	y
26	1A	032	SUB (substitute)	58	3A	072	:	:	90	5A	132	Z	Z	122	7A	172	z	z
27	1B	033	ESC (escape)	59	3B	073	;	;	91	5B	133	[	[	123	7B	173	{	{
28	1C	034	FS (file separator)	60	3C	074	<	<	92	5C	134	\	\	124	7C	174			|
29	1D	035	GS (group separator)	61	3D	075	=	=	93	5D	135	]	]	125	7D	175	}	}
30	1E	036	RS (record separator)	62	3E	076	>	>	94	5E	136	^	^	126	7E	176	~	~
31	1F	037	US (unit separator)	63	3F	077	?	?	95	5F	137	_	_	127	7F	177	&#127;	DEL

Source: www.LookupTables.com

Image Source: ASCIItable.com

Text - ASCII

01100110011011110110010011101000111
10010010000001110100011101101101111

- 01100110 (102) – f
- 01101111 (111) – o
- 01110010 (114) – r
- 01110100 (116) – t
- 01111001 (121) – y

- 00100000 (32) – sp
- 01110100 (116) – t
- 01110111 (119) – w
- 01101111 (111) – o

Images

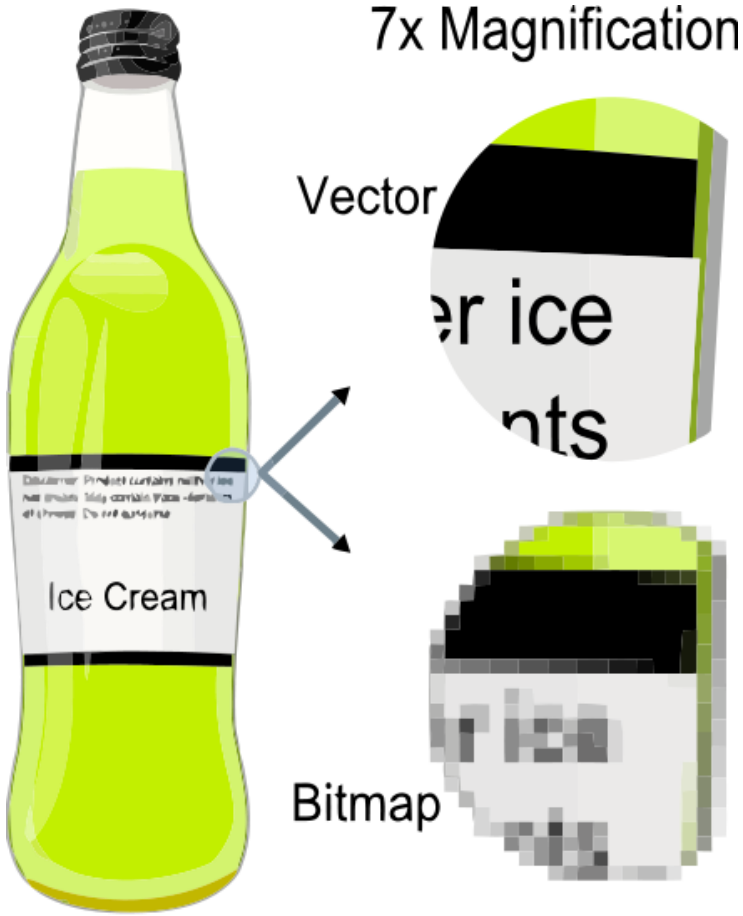


Image Source: Wikipedia

Scalable Vector Graphics (SVG)

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  xmlns="http://www.w3.org/2000/svg">
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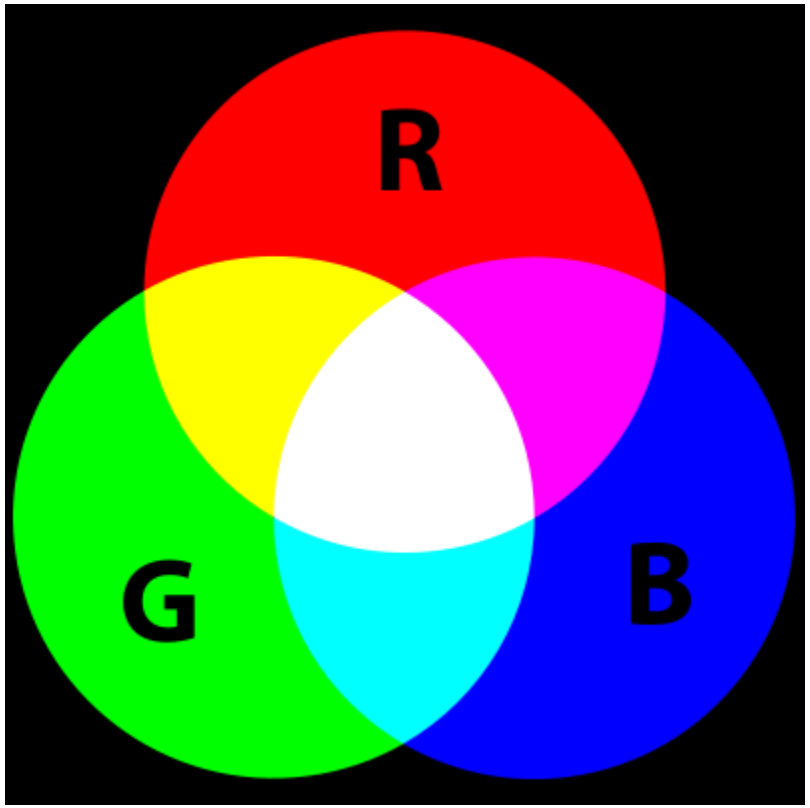
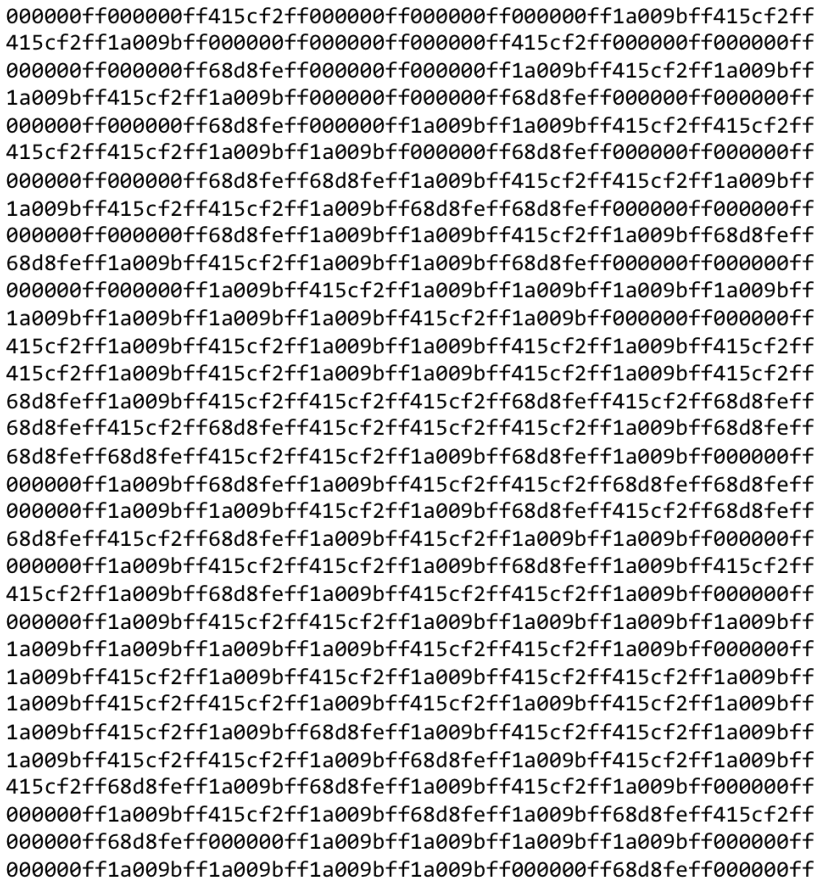
   0.00 C 270.29 1.10 269.84 2.22 269.41 3.34 C
  270.05 3.42 271.34 3.57 271.98 3.65 C 271.83
  2.43 271.66 1.21 271.49 0.00 L 320.83 0.00 C
  320.62 1.16 320.43 2.32 320.27 3.48 C 320.88
  3.49 322.11 3.50 322.73 3.51 C 322.60 2.64
  322.35 0.89 322.23 0.01....
```

RGB Colors



Bitmap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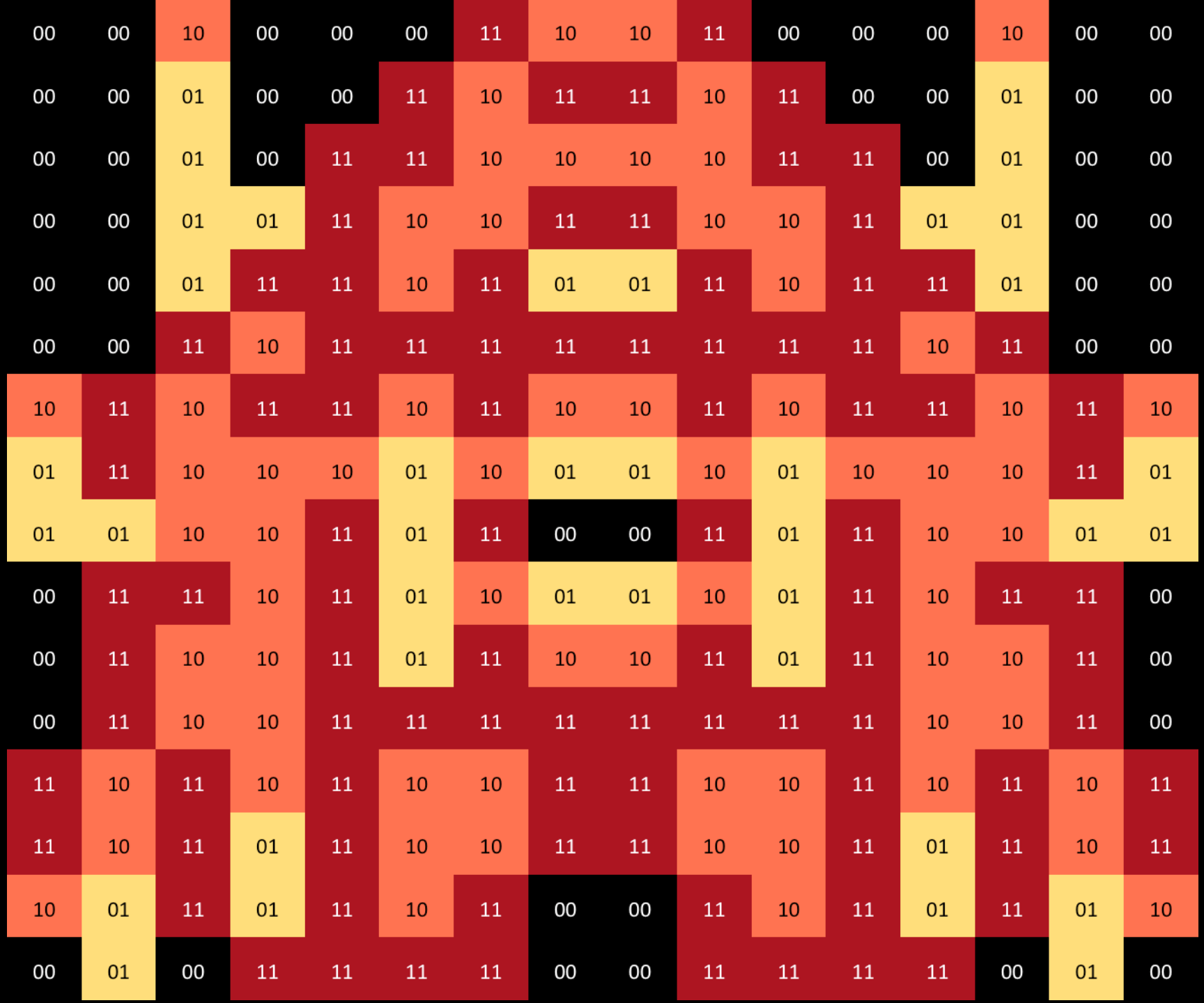
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00 00 01 00 11 11 10 10 10 10 11 11 00 01 00 00
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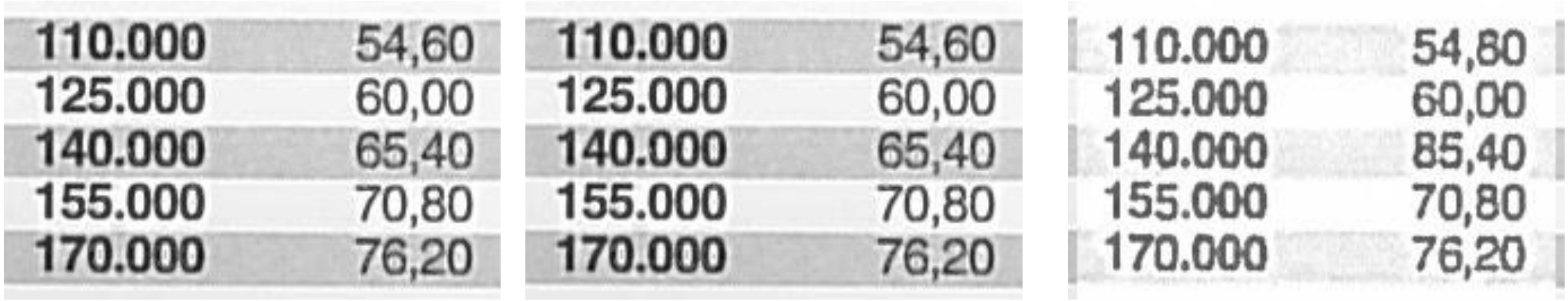
00 00 01 11 11 10 11 01 01 11 10 11 11 01 00 00
00 00 11 10 11 11 11 11 11 11 11 11 10 11 00 00
10 11 10 11 11 10 11 10 10 11 10 11 11 10 11 10
01 11 10 10 10 01 10 01 01 10 01 10 10 10 11 01
01 01 10 10 11 01 11 00 00 11 01 11 10 10 01 01
00 11 11 10 11 01 10 01 01 10 01 11 10 11 11 00
00 11 10 10 11 01 11 10 10 11 01 11 10 10 11 00
00 11 10 10 11 11 11 11 11 11 11 11 10 10 11 00
11 10 11 10 11 10 10 11 11 10 10 11 10 11 10 11
11 10 11 01 11 10 10 11 11 10 10 11 01 11 10 11
10 01 11 01 11 10 11 00 00 11 10 11 01 11 01 10
00 01 00 11 11 11 11 00 00 11 11 11 11 00 01 00

Compression

- How much wood could a woodchuck chuck if a woodchuck could chuck wood?
- How much 1 2 a 13 3 if a 13 2 3 1?
  - wood = 1
  - could = 2
  - chuck = 3

Image Compression



110.000	54,60
125.000	60,00
140.000	65,40
155.000	70,80
170.000	76,20

110.000	54,60
125.000	60,00
140.000	65,40
155.000	70,80
170.000	76,20

110.000	54,80
125.000	60,00
140.000	85,40
155.000	70,80
170.000	76,20

Image Source: D. Kriesel

Read more here