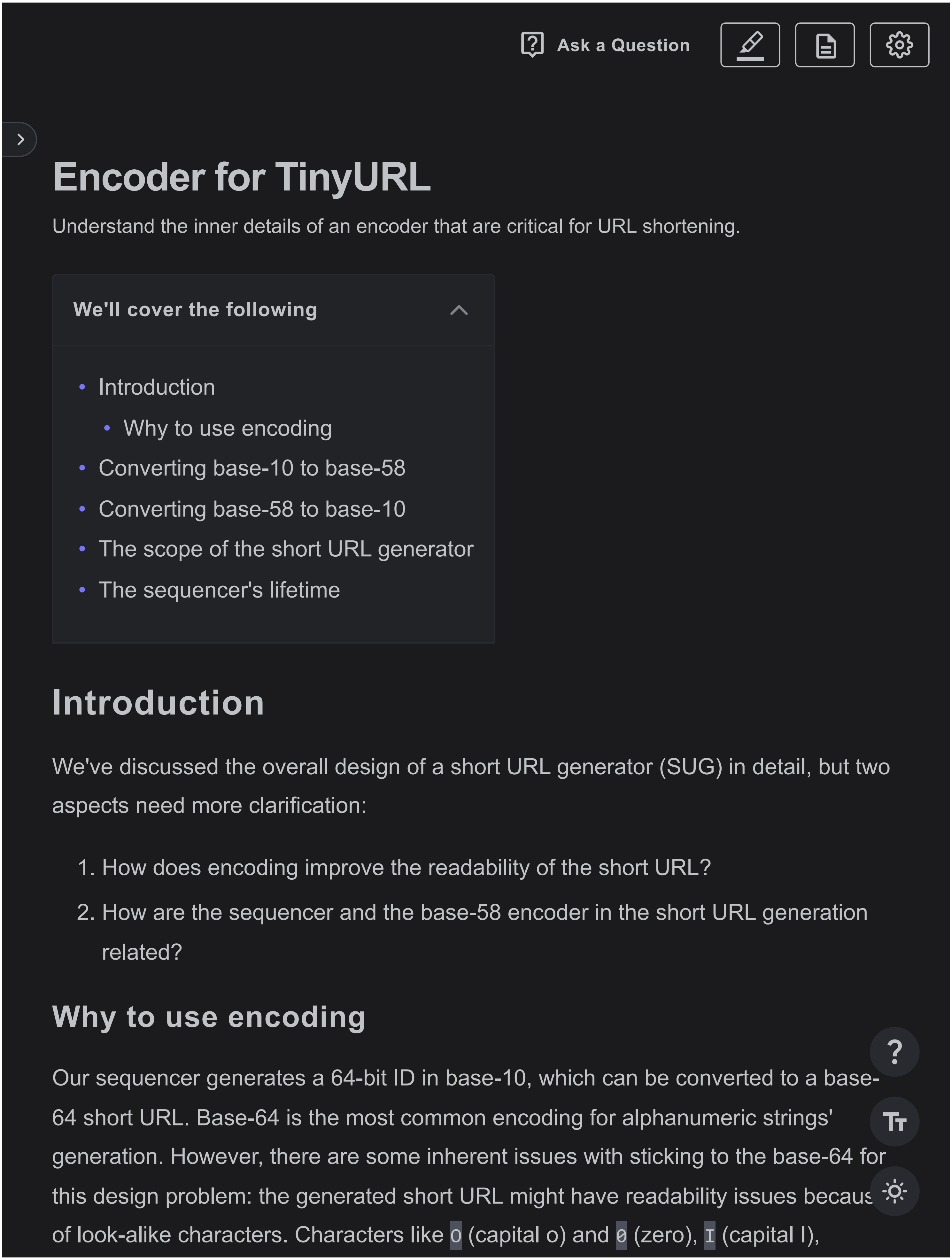


Encoder for TinyURL

Understand the inner details of an encoder that are critical for URL shortening.

We'll cover the following

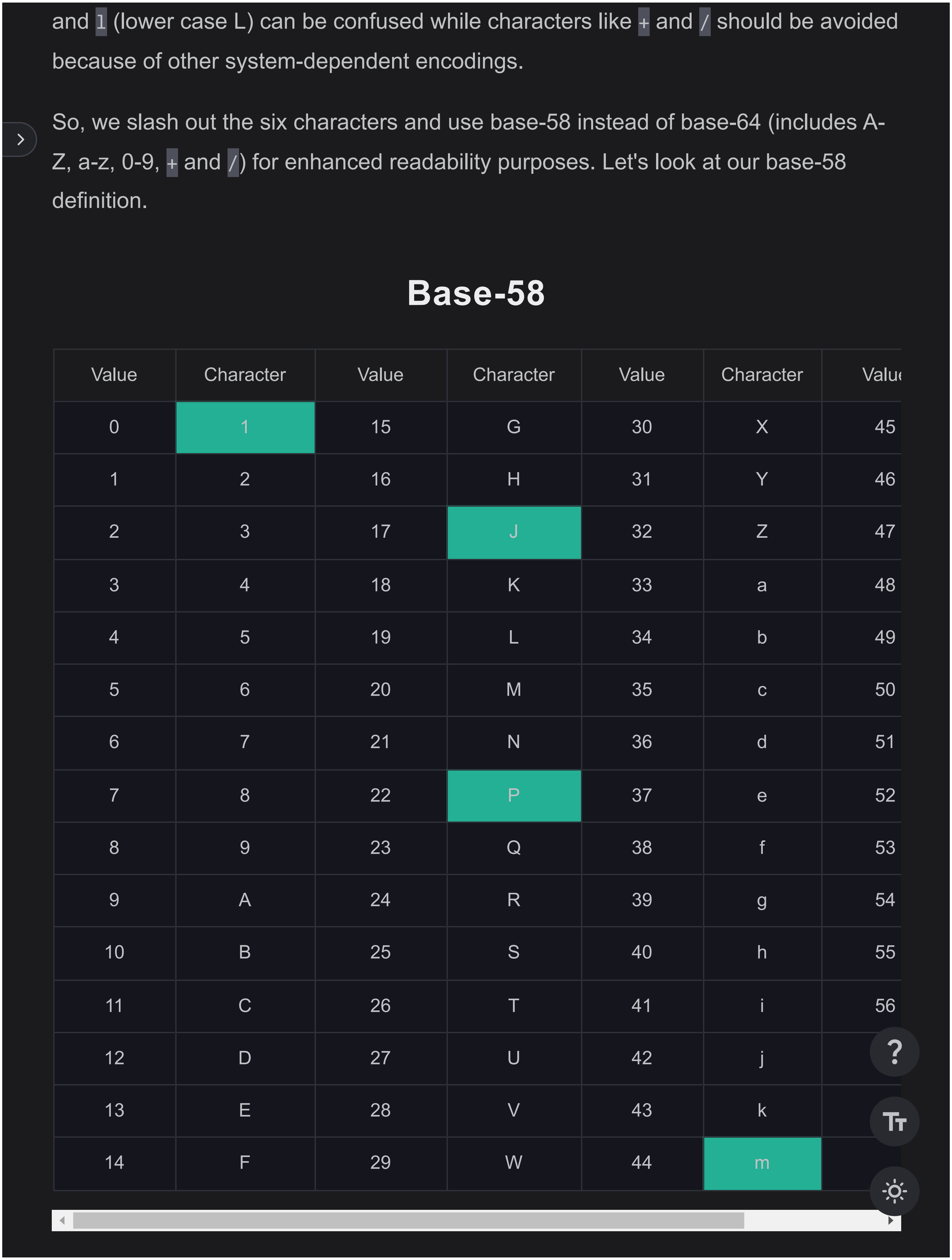
Introduction

We've discussed the overall design of a short URL generator (SUG) in detail, but two aspects need more clarification:

1. How does encoding improve the readability of the short URL?
2. How are the sequencer and the base-58 encoder in the short URL generation related?

Why to use encoding

Our sequencer generates a 64-bit ID in base-10, which can be converted to a base-64 short URL. Base-64 is the most common encoding for alphanumeric strings' generation. However, there are some inherent issues with sticking to the base-64 for this design problem: the generated short URL might have readability issues because of look-alike characters. Characters like `O` (capital o) and `0` (zero), `I` (capital I),



and `l` (lower case L) can be confused while characters like `+` and `/` should be avoided because of other system-dependent encodings.

So, we slash out the six characters and use base-58 instead of base-64 (includes A-Z, a-z, 0-9, `+` and `/`) for enhanced readability purposes. Let's look at our base-58 definition.

Base-58

Value	Character	Value	Character	Value	Character	Valu
0	1	15	G	30	X	45
1	2	16	H	31	Y	46
2	3	17	J	32	Z	47
3	4	18	K	33	a	48
4	5	19	L	34	b	49
5	6	20	M	35	c	50
6	7	21	N	36	d	51
7	8	22	P	37	e	52
8	9	23	Q	38	f	53
9	A	24	R	39	g	54
10	B	25	S	40	h	55
11	C	26	T	41	i	56
12	D	27	U	42	j	
13	E	28	V	43	k	
14	F	29	W	44	m	

> The highlighted cells contain the succeeding characters of the omitted ones: `0`, `O`, `I`, and `l`.

Converting base-10 to base-58

Since we're converting base-10 numeric IDs to base-58 alphanumeric IDs, explaining the conversion process will be helpful in grasping the underlying mechanism as well as the overall scope of the SUG. To achieve the above functionality, we use the **modulus** function.

Process: We keep dividing the base-10 number by 58, making note of the remainder at each step. We stop where there is no remainder left. Then we assign the character indexes to the remainders, starting from assigning the recent-most remainder to the left-most place and the oldest remainder to the right-most place.

Example: Let's assume that the selected unique ID is `2468135791013`. The following steps show us the remainder calculations:

Base-10 = 2468135791013

1. $2468135791013 \,\%\, 58 = 17$
2. $42554065362 \,\%\, 58 = 6$
3. $733690782 \,\%\, 58 = 4$
4. $12649841 \,\%\, 58 = 41$
5. $218100 \,\%\, 58 = 20$
6. $3760 \,\%\, 58 = 48$
7. $64 \,\%\, 58 = 6$
8. $1 \,\%\, 58 = 1$

Now, we need to write the remainders in order of the most recent to the oldest order

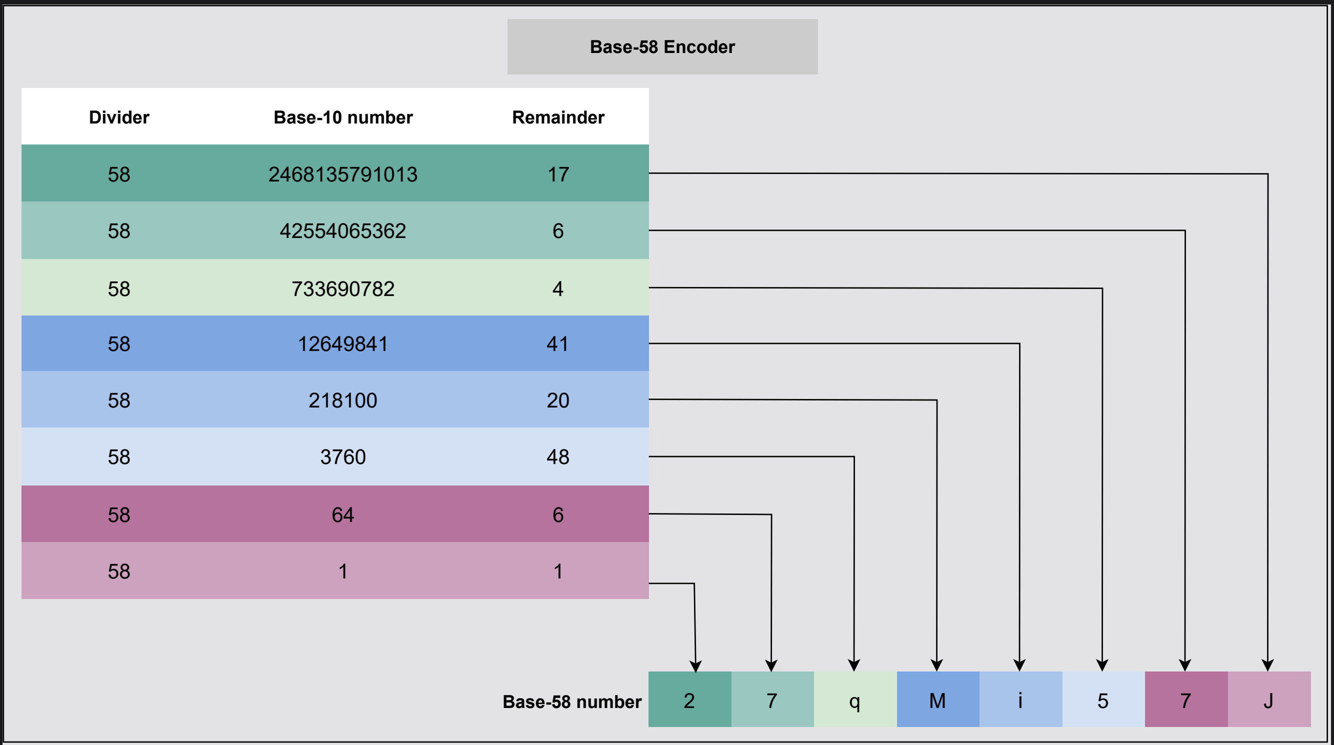
Base-58 = [1] [6] [48] [20] [41] [4] [6] [17]

Using the table above, we can write the associated characters with the remainders written above.

Base-58 = 27qMi57J

> **Note:** Both the base-10 numeric IDs and base-64 alphanumeric IDs have 64-bits, as per our sequencer design.

Let's see the example above with the help of the following illustration.



Base-58 Encoder

Divider	Base-10 number	Remainder
58	2468135791013	17
58	42554065362	6
58	733690782	4
58	12649841	41
58	218100	20
58	3760	48
58	64	6
58	1	1

How a base-10 number is converted into a base-58 alphanumeric short URL

Converting base-58 to base-10

The decoding process holds equal importance as the encoding process, as we use a decoder in case of custom short URLs generation, as explained in the design lesson.

Process: The process of converting a base-58 number into a base-10 number is al straightforward. We just need to multiply each character index (value column from the

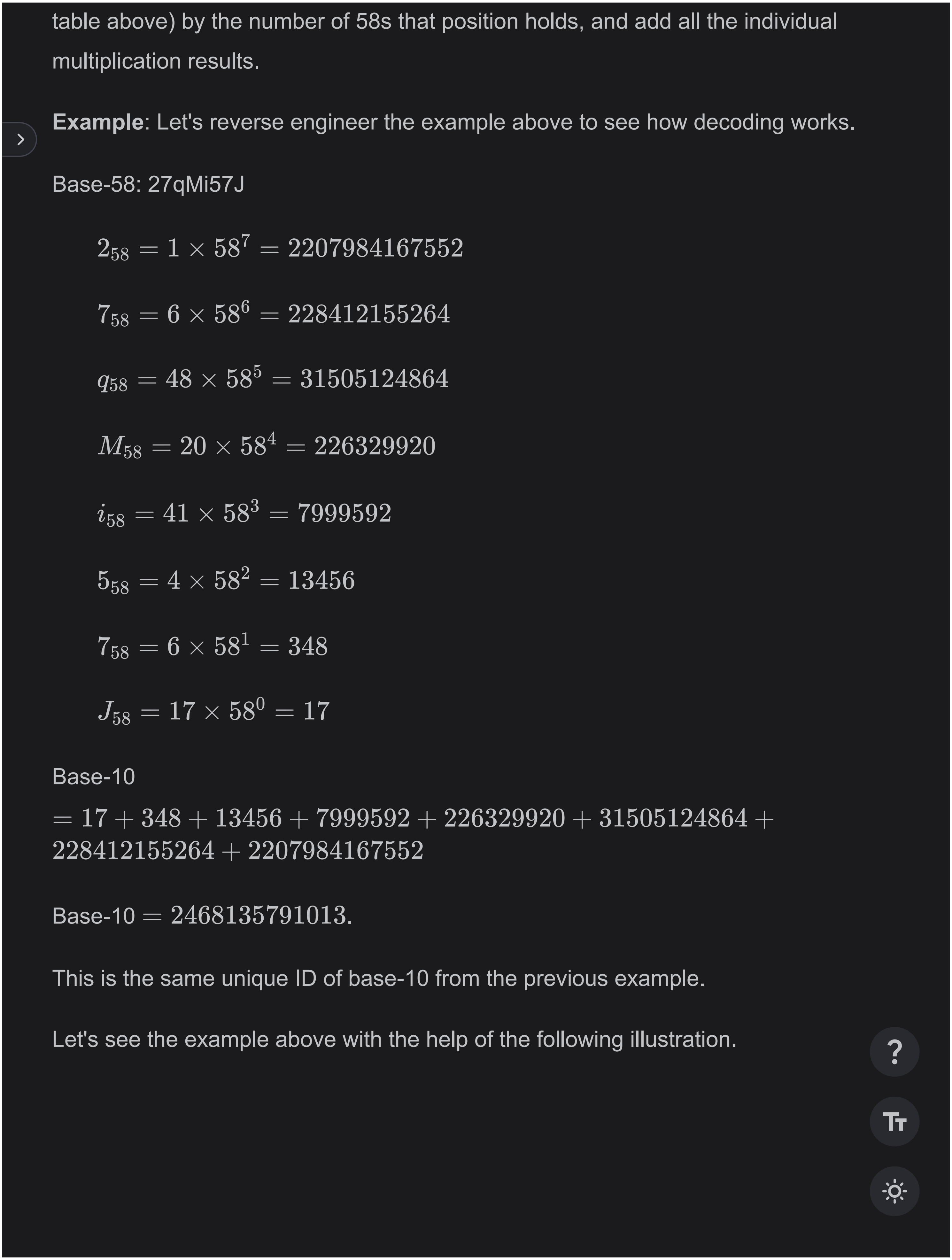


table above) by the number of 58s that position holds, and add all the individual multiplication results.

Example: Let's reverse engineer the example above to see how decoding works.

Base-58: 27qMi57J

$$2_{58} = 1 \times 58^7 = 2207984167552$$

$$7_{58} = 6 \times 58^6 = 228412155264$$

$$q_{58} = 48 \times 58^5 = 31505124864$$

$$M_{58} = 20 \times 58^4 = 226329920$$

$$i_{58} = 41 \times 58^3 = 7999592$$

$$5_{58} = 4 \times 58^2 = 13456$$

$$7_{58} = 6 \times 58^1 = 348$$

$$J_{58} = 17 \times 58^0 = 17$$

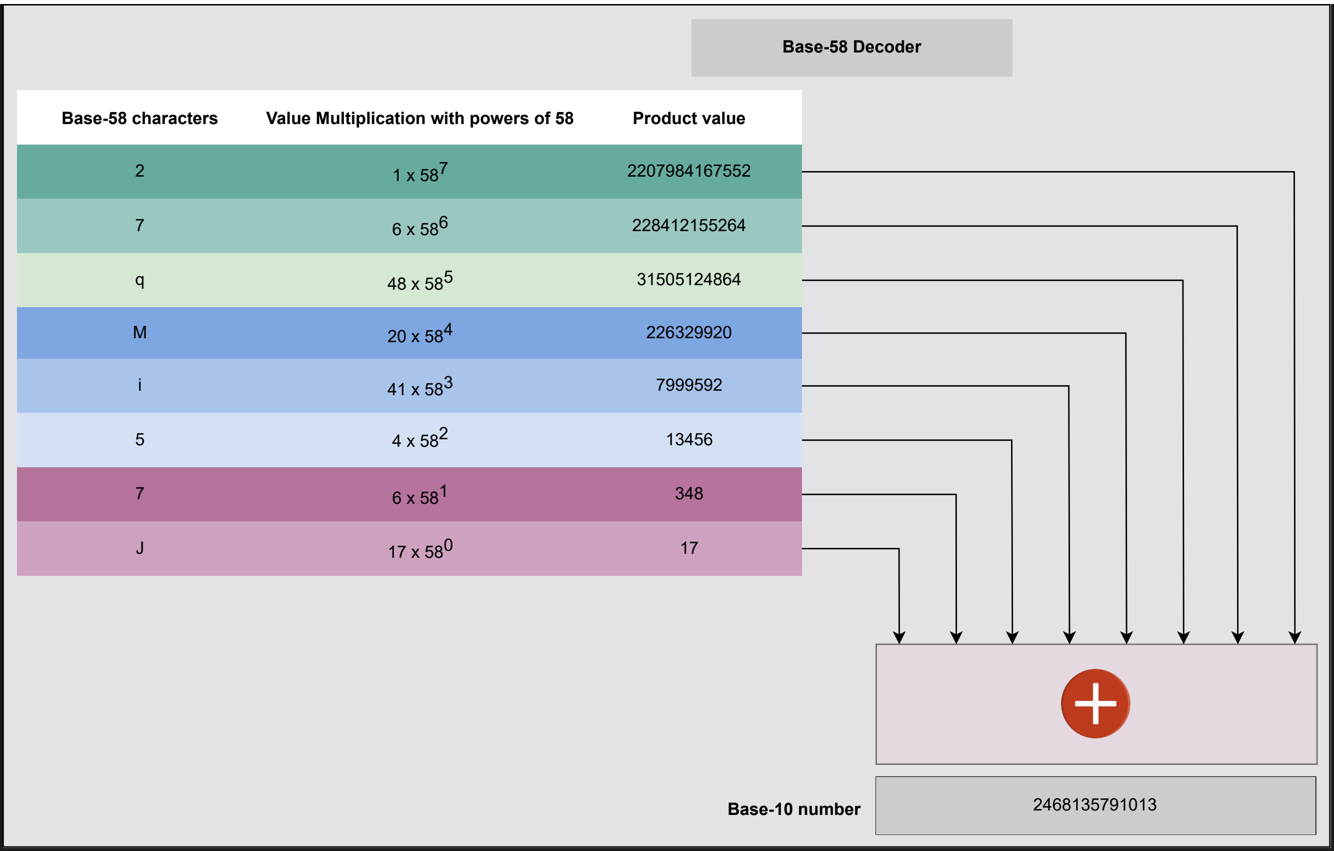
Base-10

$= 17 + 348 + 13456 + 7999592 + 226329920 + 31505124864 + 228412155264 + 2207984167552$

Base-10 $= 2468135791013.$

This is the same unique ID of base-10 from the previous example.

Let's see the example above with the help of the following illustration.



Base-58 characters	Value Multiplication with powers of 58	Product value
2	1×58^7	2207984167552
7	6×58^6	228412155264
q	48×58^5	31505124864
M	20×58^4	226329920
i	41×58^3	7999592
5	4×58^2	13456
7	6×58^1	348
J	17×58^0	17

How a base-58 number is converted into a base-10 numeric ID

The scope of the short URL generator

The short URL generator is the backbone of our URL shortening service. The output of this short URL generator depends on the design-imposed limitations, as given below:

- The generated short URL should contain alphanumeric characters.
- None of the characters should look alike.
- The minimum default length of the generated short URL should be six characters.

These limitations define the scope of our short URL generator. We can define the scope, as shown below:

- **Starting range**: Our sequencer can generate a 64-bit binary number that ranges from $1 \rightarrow (2^{64} - 1)$. To meet the requirement for the minimum length of a sh

URL, we can select the sequencer IDs to start from at least 10 digits, i.e., 1 Billion.

- **Ending point**: The maximum number of digits in sequencer IDs that map into the short URL generator's output depends on the maximum utilization of 64 bits, that is, the largest base-10 number in 64-bits. We can estimate the total number of digits in any base by calculating these two points:
  - The numbers of bits to represent one digit in a base-n. This is given by $log_2 n$.
  - $Number\ of\ digits\ = \frac{Total\ bits\ available}{Number\ of\ bits\ to\ represent\ one\ digit}$

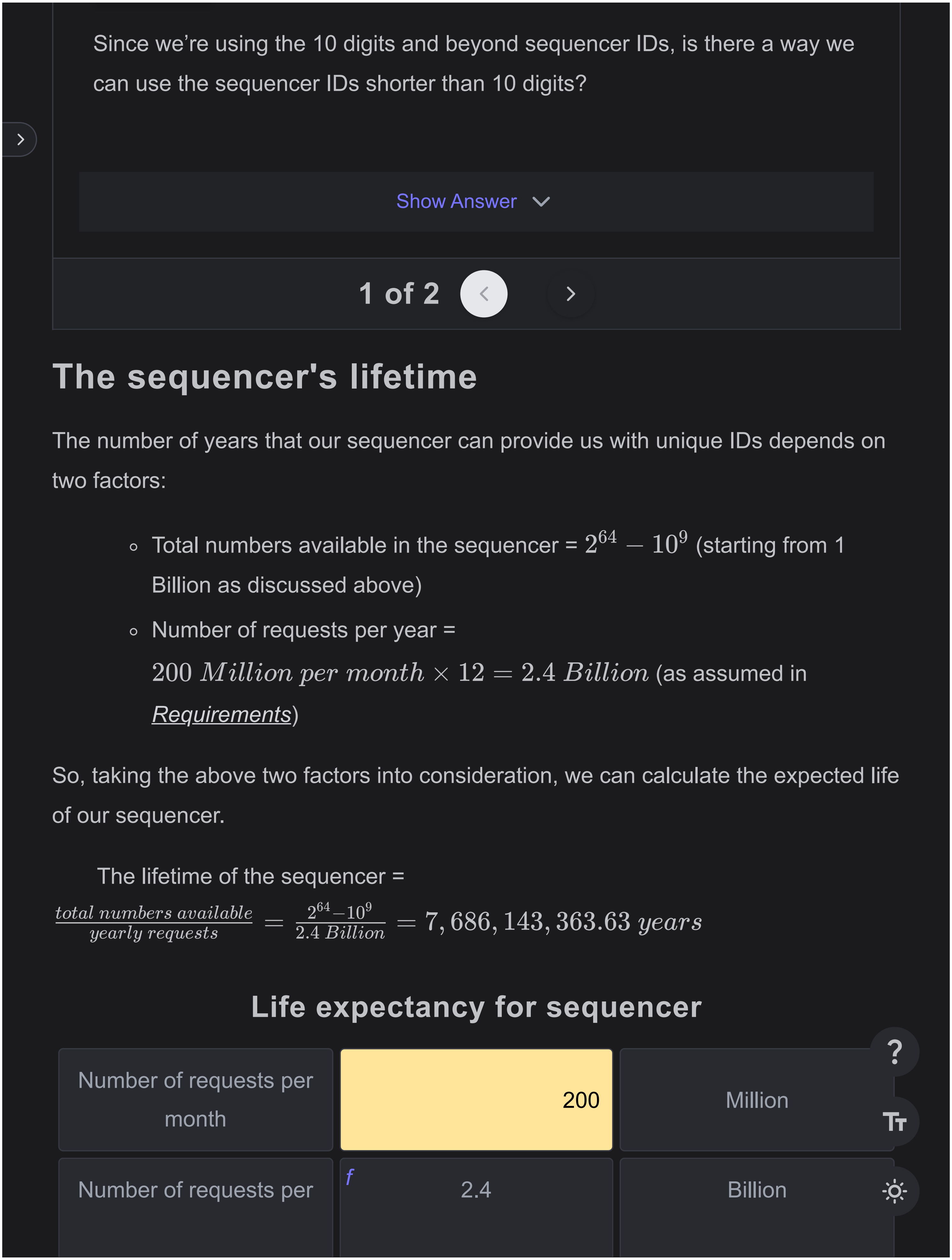
Let's see the calculations above for both the base-10 and base-58 mathematically:

- **Base-10:**
  - The number of bits needed to represent one decimal digit = $log_2 10$ = 3.13
  - The total number of decimal digits in 64-bit numeric ID = $\frac{64}{3.13} = 20$
- **Base-58:**
  - The number of bits needed to represent one decimal digit = $log_2 58 = 5.85$

> **Maximum digits**: The calculations above show that the maximum digits in the sequencer generated ID will be 20 and consequently, the maximum number of characters in the encoded short URL will be 11.

Quiz

Question 1



Since we're using the 10 digits and beyond sequencer IDs, is there a way we can use the sequencer IDs shorter than 10 digits?

The sequencer's lifetime

The number of years that our sequencer can provide us with unique IDs depends on two factors:

- Total numbers available in the sequencer = $2^{64} - 10^9$ (starting from 1 Billion as discussed above)
- Number of requests per year = $200\ Million\ per\ month \times 12 = 2.4\ Billion$ (as assumed in *Requirements*)

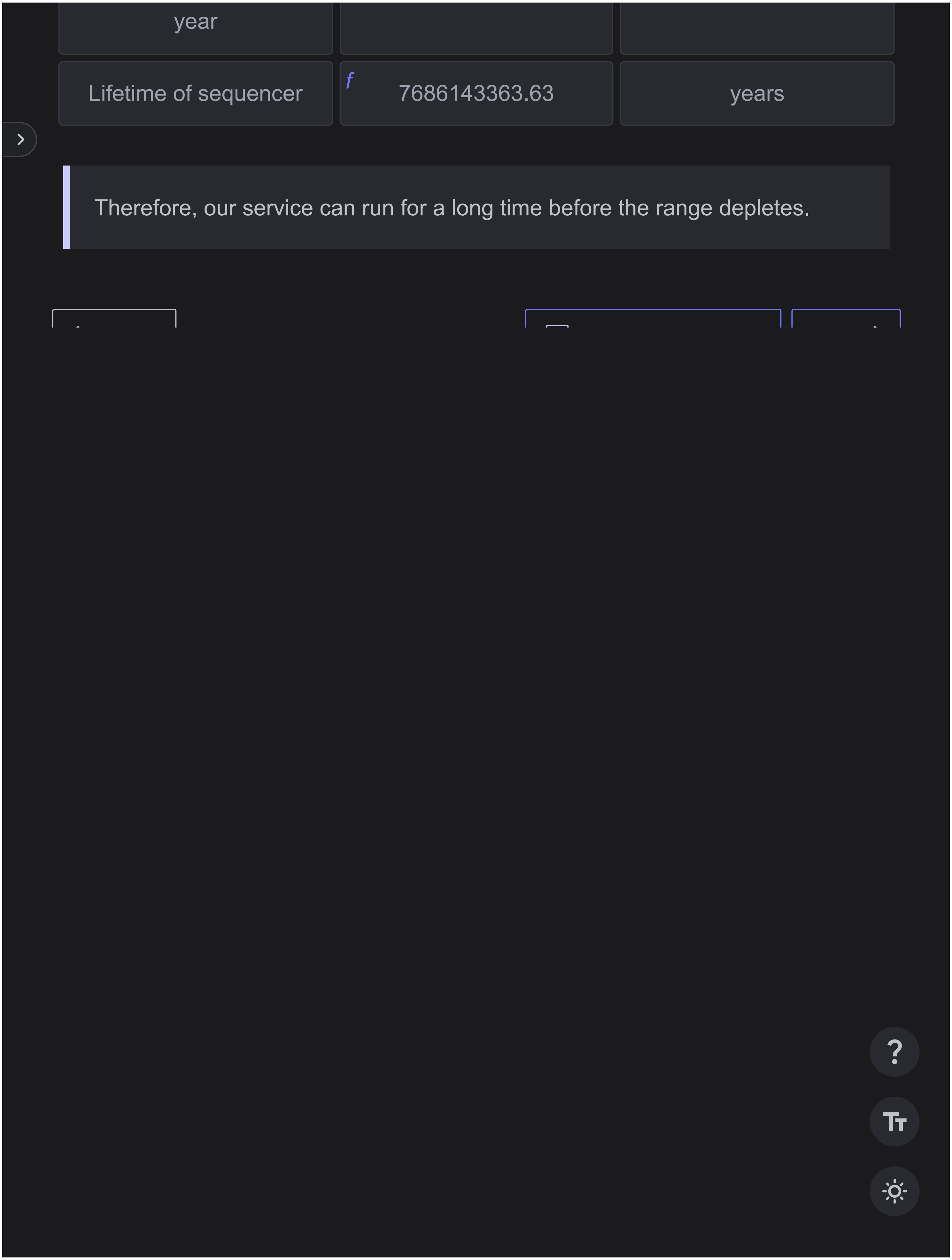
So, taking the above two factors into consideration, we can calculate the expected life of our sequencer.

The lifetime of the sequencer =

$$\frac{total\ numbers\ available}{yearly\ requests} = \frac{2^{64} - 10^9}{2.4\ Billion} = 7,686,143,363.63\ years$$

Life expectancy for sequencer

Number of requests per month	200	Million
Number of requests per	*f* 2.4	Billion



year		
Lifetime of sequencer	7686143363.63	years

> Therefore, our service can run for a long time before the range depletes.