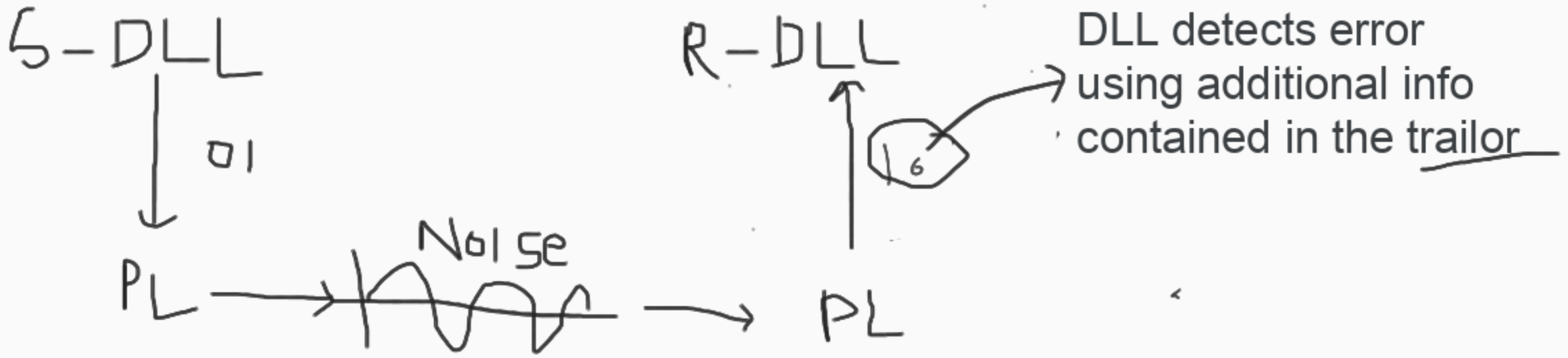
DLL: Error Control
- ED — Error Detection- CRC
- EC — Error Correction

Error

A condition when the receiver's information does not match with the sender's information.

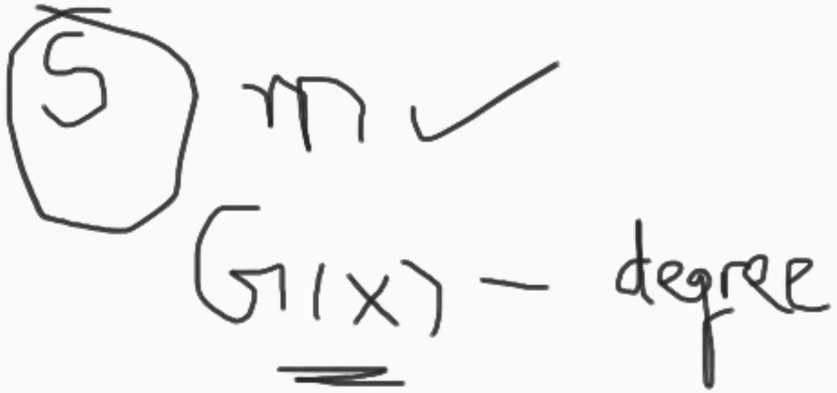
During transmission, digital signals suffer from noise that can introduce errors in the binary bits travelling from sender to receiver, i.e. a 0 bit may change to 1 or a 1 bit may change to 0



Generating polynomial G(x) is same for sender and receiver

sender

-msg m bits + check r bits [m+r] //use crc to calculate the value of r
-append r at the end of m
-total msg length = m+r
-



For ex, If G(x)=x^3+1

degree is 3
hence, r=3 bits

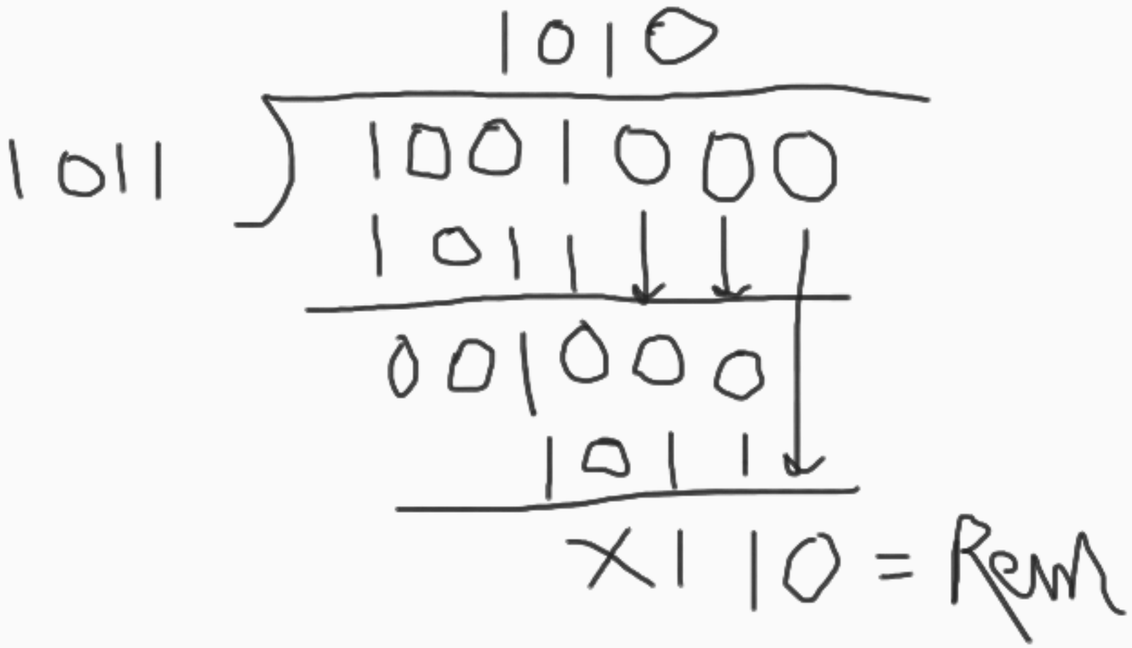
Given

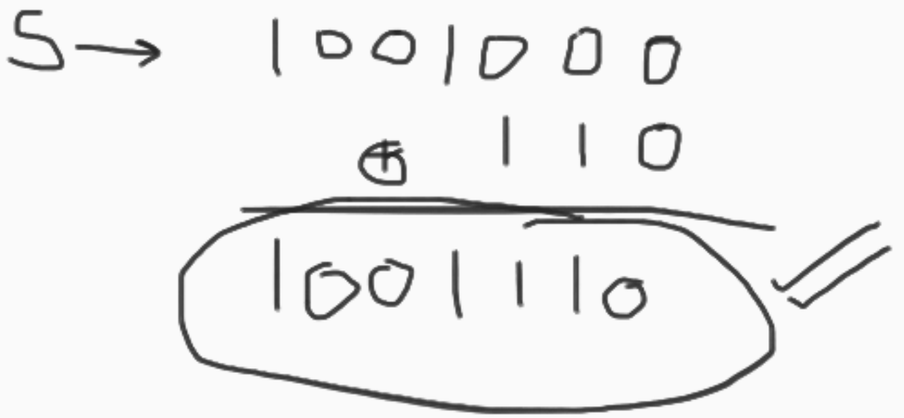
msg -m bits
G(x) -degree of G(x)
r will be same as degree

for example, m=1001
G(x) = 1011= 1x^3+0x^2+1x^1+1x^0 = x3 + x + 1
thus, degree of G(x) is 3
i.e. 3 check bits will be used

-append r-0's to the end of m
~~-divide m+0r by G(x)~~

**modulo 2 division => output will be 0 or 1.
-- mod-2-division is implemented using xor
bits same => o/p 0
~~bits~~ bits diff=> o/p 1

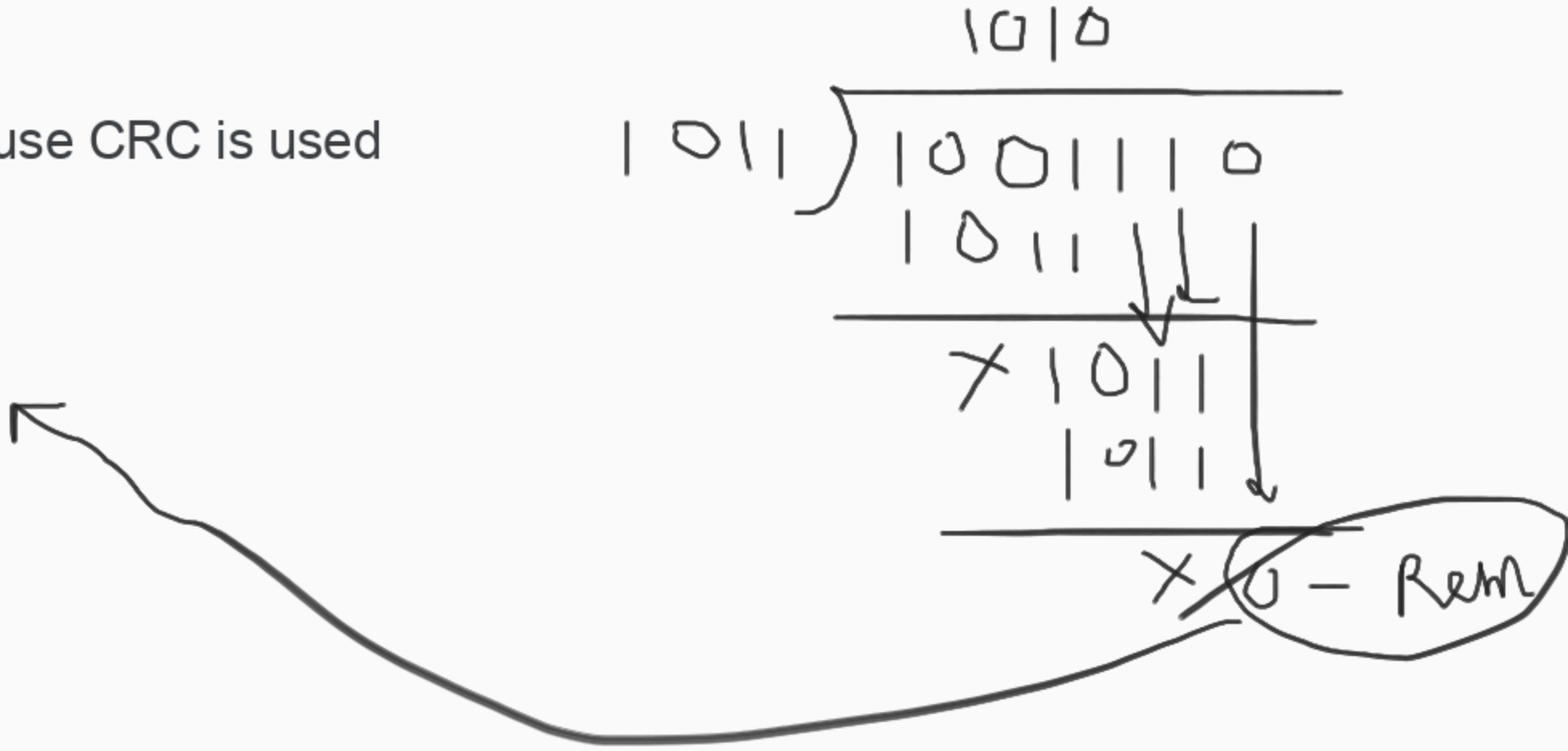




Without error

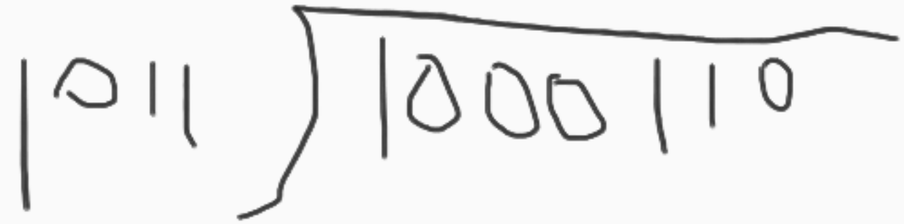
R will get 1001110
-G(x) will be known because CRC is used
-G(x) will be 1011.

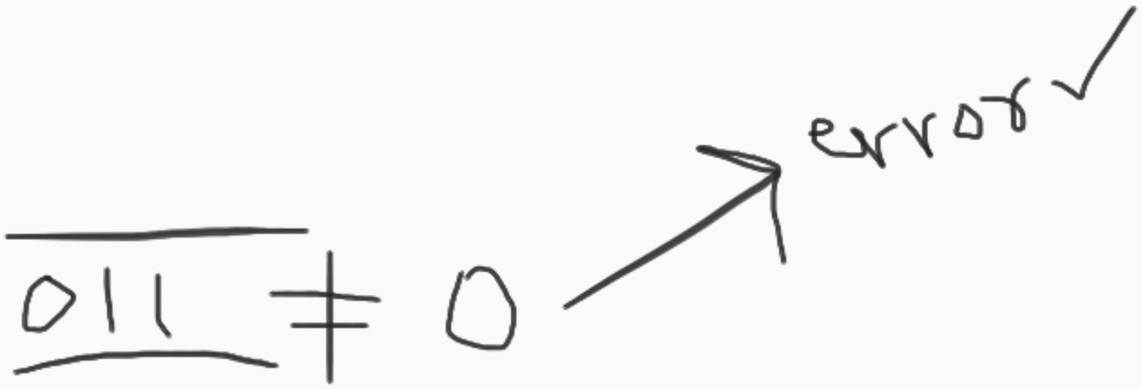
-- M / G(x)
--find remainder
if remainder = 0, no error
else, error is present



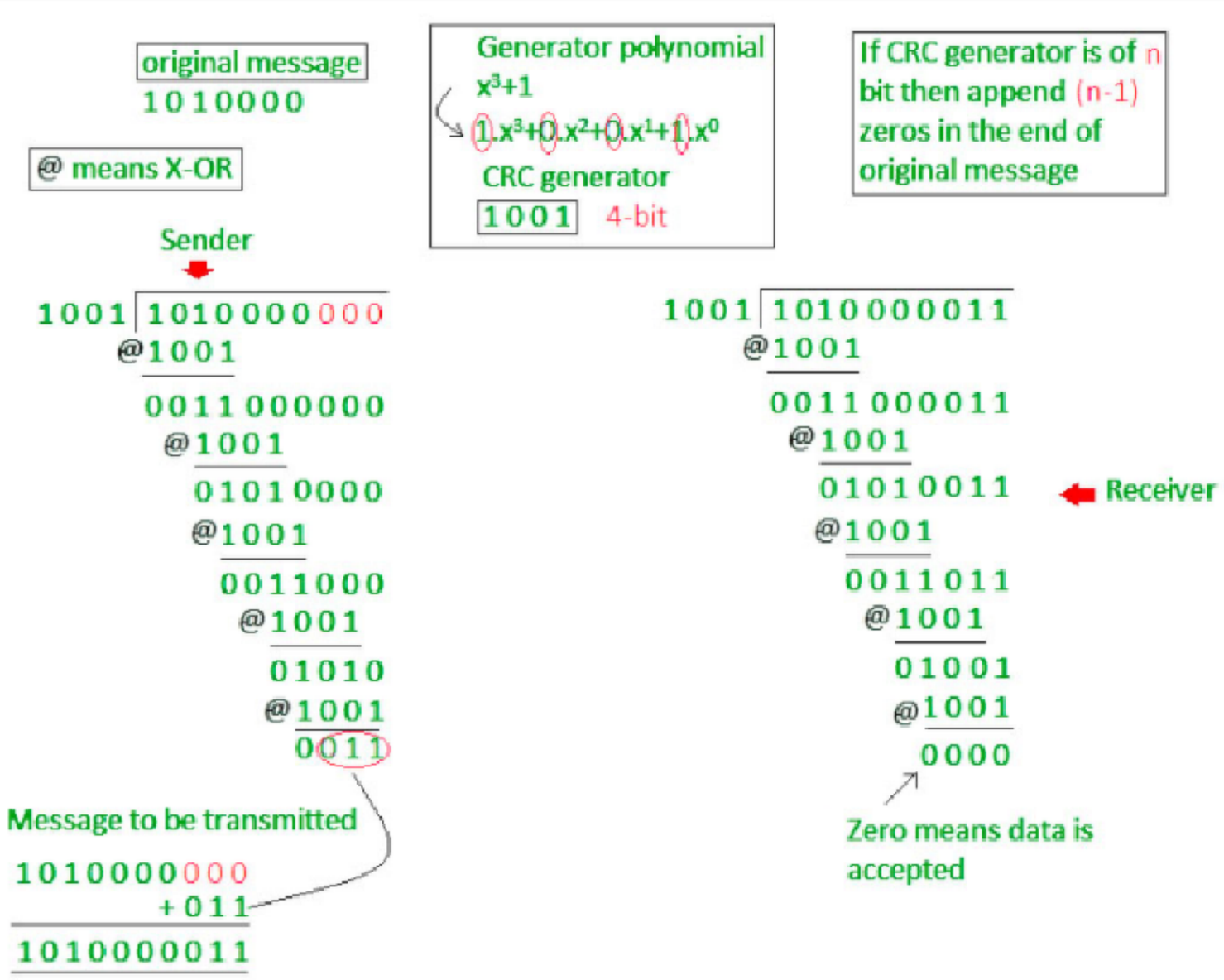
With error

-R has got 1000110





Example :


original message
1010000
@ means X-OR
Generator polynomial
x^3+1
$1.x^3+0.x^2+0.x^1+1.x^0$
CRC generator
1001 4-bit
If CRC generator is of n bit then append (n-1) zeros in the end of original message
Sender
1001 | 1010000000
@1001
0011000000
@1001
01010000
@1001
0011000
@1001
01010
@1001
0011
Message to be transmitted
1010000000
+011
1010000011
1001 | 1010000011
@1001
0011000011
@1001
01010011
@1001
0011011
@1001
01001
@1001
0000
Receiver
Zero means data is accepted

Problem-01:

A bit stream 1101011011 is transmitted using the standard CRC method. The generator polynomial is x^4+x+1. What is the actual bit string transmitted?

$x^4 + x + 1$

$1x^4\ 0x^3\ 0x^2\ 1x^1 + 1x^0$

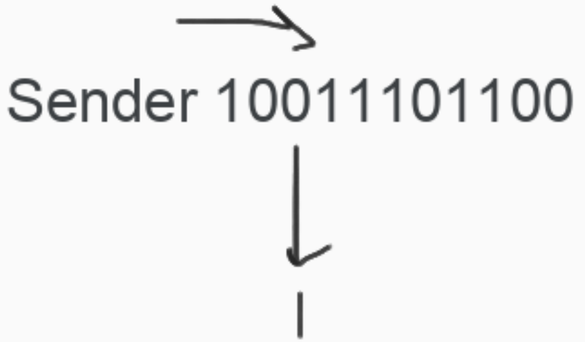
1 0 0 1 1

```
                1 1 0 0 0 0 1 0 1 0
          ┌──────────────────────────
1 0 0 1 1 │ 1 1 0 1 0 1 1 0 1 1 0 0 0 0
          │ 1 0 0 1 1
          │ ---------
          │   1 0 0 1 1
          │   1 0 0 1 1
          │   ---------
          │     0 0 0 0 1
          │     0 0 0 0 0
          │     ---------
          │       0 0 0 1 0
          │       0 0 0 0 0
          │       ---------
          │         0 0 1 0 1
          │         0 0 0 0 0
          │         ---------
          │           0 1 0 1 1
          │           0 0 0 0 0
          │           ---------
          │             1 0 1 1 0
          │             1 0 0 1 1
          │             ---------
          │               0 1 0 1 0
          │               0 0 0 0 0
          │               ---------
          │                 1 0 1 0 0
          │                 1 0 0 1 1
          │                 ---------
          │                   0 1 1 1 0
          │                   0 0 0 0 0
          │                   ---------
          │                     1 1 1 0   ← Remainder
```

Problem-02:

A bit stream 10011101 is transmitted using the standard CRC method. The generator polynomial is x^3+1.

1. What is the actual bit string transmitted?
2. Suppose the third bit from the left is inverted during transmission. How will receiver detect this error?




```
          1 0 0 0 1 1 0 0
        ---------------------
1 0 0 1 | 1 0 0 1 1 1 0 1 0 0 0
          1 0 0 1
          ---------
          0 0 0 0 1
            0 0 0 0
            -------
            0 0 0 1 1
              0 0 0 0
              -------
              0 0 1 1 0
                0 0 0 0
                -------
                0 1 1 0 1
                  1 0 0 1
                  -------
                  0 1 0 0 0
                    1 0 0 1
                    -------
                    0 0 0 1 0
                      0 0 0 0
                      -------
                      0 0 1 0 0
                        0 0 0 0
                        -------
                        0 1 0 0   <-- CRC
```