# Bitcoin Mechanics

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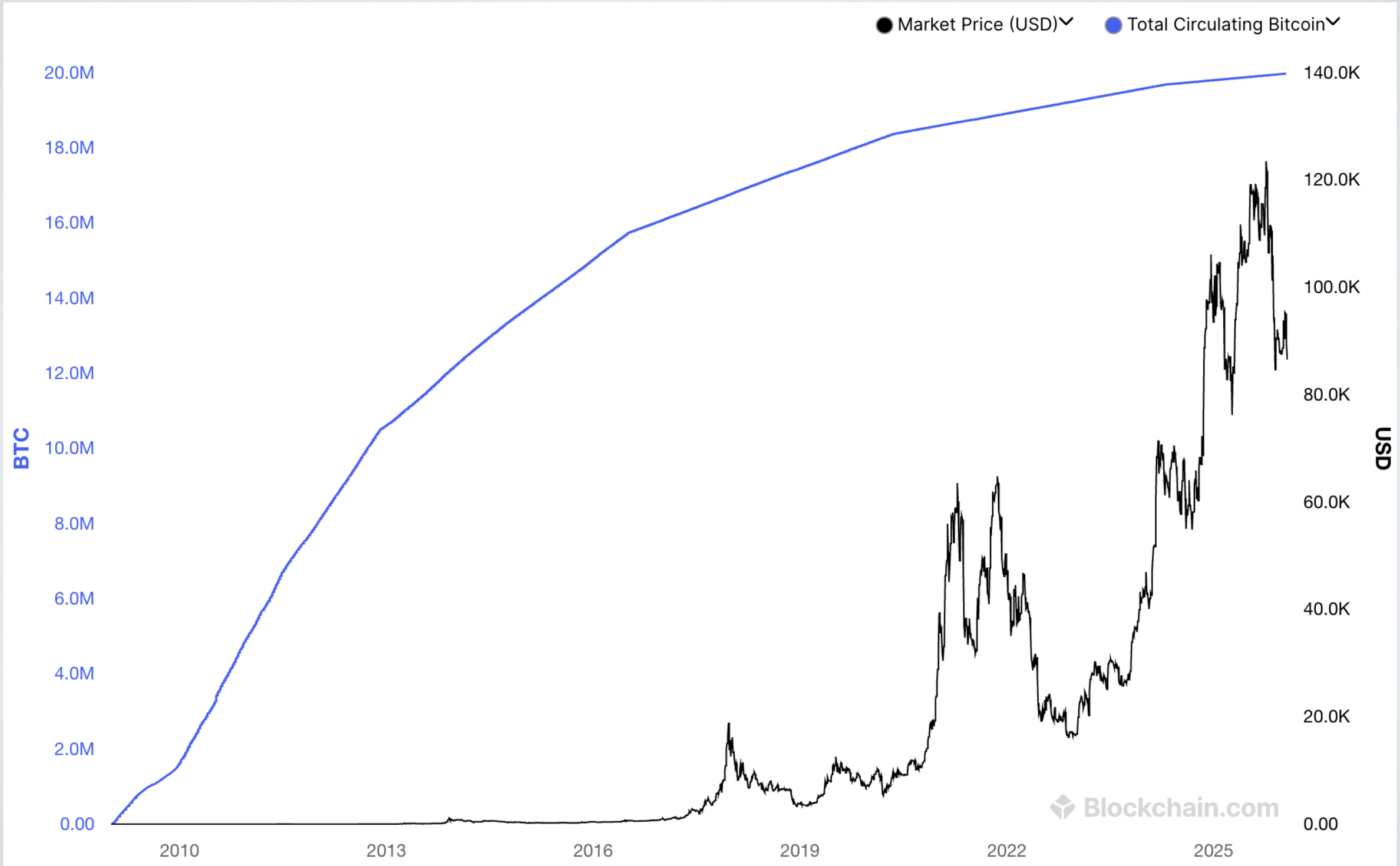
# Mined Bitcoin and Price



# Bitcoin in a Nutshell

- Uses Elliptic Curve Public Keys (secp256k1) and ECDSA signature algorithm
- UTXO Blockchain (Unspent Transaction Output)
- Consensus : Proof of Work
- Block time : ~10 minutes
- Bitcoin are created through block reward

# Bitcoin Properties

You need to convince 51% of the mining power to

- remove a block **(safety)**
- prevent a transaction to be confirmed **(liveness)**

# Anatomy of a Bitcoin Transaction

| Field | Size (in bytes) | Description |
|---|---|---|
| Version | 4 | Transaction version number |
| Input Count | 1-9 | Number of inputs in the transaction |
| Inputs | 41+ (per input) | List of transaction inputs (UTXOs being spent) |
| Output Count | 1-9 | Number of outputs in the transaction |
| Output | 34+ (per output) | List of transaction outputs (recipients and amounts) |
| Locktime | 4 | Specifies when the transaction can be included in a block |
| Witness (signatures) | variable | Witness data for SegWit transactions |

# Building the blockchain

1. Transactions are broadcasted on the network
2. The nodes verify each transaction before adding them to their local mempool of unconfirmed transactions
3. Miners select transactions from the mempool (maximizing the Maximal) Extractable Value MEV) and start mining the next block
4. Once a nonce matching the current difficulty is found, the miner broadcast the block on the network
5. The nodes verify each block before adding it to the blockchain. The transactions are confirmed and the mempool is updated

➡ New transactions cannot use input UTXO of transactions that have not been confirmed yet

✓ Data is always consistent for a given chain and no double spending attack for a given chain (however there might be competing chains with double spent UTXOs)

# Mining awards

- ➡ Miners verify/broadcast blocks transactions and broadcast and are rewarded for that work by 2 means:
  - A **Block Reward**
    Currently 3.125 BTC - Block reward halves every four years
    The only way BTC is created (max 21M BTC in total that will be reached 2140)
  - and all **Transaction Fees**
    (Total Input Value − Total Output Value)

- ➡ The block reward and the transactions are fees are added together in the **Coinbase transaction** (first transaction in the block)

# Transaction Fee

How to calculate the fee

- Determine the current fee rate per byte
  (depends on network traffic)
- Estimate the size of the transaction in bytes (inputs + outputs)
- Multiply the transaction size by the fee rate to get the total fee

➡ Adding a fee is not an obligation but necessary in practice for the transaction to be picked

◉ A transaction with an underpaid fee may remain unconfirmed for a long time, especially during network congestion

✓ In practice, fee can be used to cancel/modify an unconfirmed transaction
(by emitting a new transaction for the same utxo with higher fee)

# Anatomy of a Bitcoin Block (80 bytes)

| Field | Size (in bytes) | Description |
|---|---|---|
| Version | 4 | Block version number |
| Previous Block Hash | 32 | Hash of the previous block header |
| Merkle Root | 32 | Hash summarizing all transactions in the block |
| Timestamp | 4 | UNIX epoch time when the block was mined |
| Difficulty Target | 4 | Compact representation of the current mining difficulty |
| Nonce | 4 | Number adjusted by miners to meet the difficulty target |

# Block Size Limit

**Before 2017** : 1 MB (~2000 transactions/block)

**After 2017** and the *Segregated Witness upgrade* (BIP-141)

➡ The signatures (a.k.a witness) are stored outside of the main block structure allowing transaction to use less space

✓ Each block has a maximum weight of 4 million weight units (new metric introduced) which is roughly 4 MB

# Propagation Time

According to the paper "*Information propagation in the bitcoin network*" by Decker and Wattenhofer (2013):

*The* ***median time*** *until a node receives a block is* ***6.5 seconds*** *whereas* ***the mean*** *is at* ***12.6 seconds***.

*The long tail of the distribution means that even* ***after 40 seconds there still are 5% of nodes that have not yet received the block***

# Bitcoin Script

# The language

Input and Output addresses are actually scripts

- Stack-based language (simplistic)
- Cryptography primitives
- No loop (not Turing complete ... but no halting problem)

See all instructions
https://wiki.bitcoinsv.io/index.php/Opcodes_used_in_Bitcoin_Script

# The mechanics

**`scriptPubKey`** (transaction output)

the locking script that specified the condition that needs to be fulfilled to use the UTXO

**`scriptSig`** (transaction input)

the unlocking script (transaction input) provided by the user who wants to use the UTXO

➡ The program **`scriptSig|scriptPubKey`** must return **`true`** for a transaction to be valid

# Op Codes

| Op Code | Description |
|---|---|
| `OP_CHECKSIG` | Takes (i.e pull from stack) public key and signature and returns (i.e push) **`TRUE`** or **`FALSE`** if the signature match |
| `OP_DUP` | Duplicates the element at the top of the stack |
| `OP_EQUAL` | Takes two inputs and returns **`TRUE`** or **`FALSE`** if the two values are equal |
| `OP_VERIFY` | Marks the transaction as valid if the top of the stack is **`TRUE`** |
| `OP_EQUALVERIFY` | Same as **`OP_EQUAL`** combine with **`OP_VERIFY`** |
| `OP_CHECKMULTISIG` | Similar to **`OP_CHECKSIG`** but checking multiple in a row |
| `OP_HASH256` | Takes an input and returns it hash |
| `OP_MAX` | Takes two values and returns the biggest one |
| `OP_RETURN` | Abort and fail |

# Pay to Public Key Hash (P2PKH)

The payer sends bitcoin to another address

```
scriptPubKey: OP_DUP OP_HASH160 <pubKeyHash?> OP_EQUALVERIFY OP_CHECKSIG
scriptSig:    <sig> <pubKey>
```

✓ The UTXO does not reveal Alice's public key

# Pay to Script Hash (P2SH)

The payer can specify a redeeming script (BIP16)

```
scriptPubKey: OP_HASH160 <redemptionScriptHash> OP_EQUAL
scriptSig:    [<sign>...<sig>] <redeemScript>
```

✓ Can specify complex conditions for when UTXO can be spent

# Example of P2SH : Multi-Signature

## Spending a UTXO requires 2-out-of-3 signatures

```
scriptPubKey: <2> <pubKey1> <pubKey2> <pubKey3> <3> <OP_CHECKMULISIG>
scriptSig:    <0> <sig1> <sig3> <redeemScript>
```

# Null Data

This script is used to store arbitrary data (limit 40 bytes)

```
scriptPubKey: <OP_RETURN> <DATA>
```

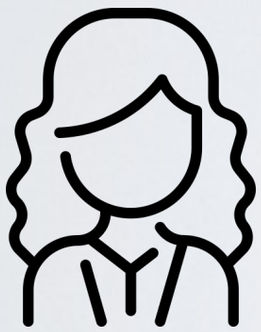
# Escrow Transactions

Pay 50 to 2-of-3 Alice Bob Judy

[Pay 50 to Bob]$_{\text{Alice}}$

# Escrow dispute

[Pay 50 to Alice]Judy



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