

Lesson 6 - Rust / DeFi

Today's topics

- Rust Lifetimes
- DeFi Introduction
- DeFi on Solana
- Tokens on Solana

Rust - Lifetimes

See [Docs](#)

Every reference in Rust has a *lifetime*, which is the scope for which that reference is valid. Most of the time, lifetimes are implicit and inferred

```
fn main() {  
    let r;  
    {  
        let x = 5;  
        r = &x;  
    }  
    println!("r: {}", r);  
}
```

We would get an error message from this code, since the reference created with

```
r = &x;
```

has gone out of scope when we try to print `r` on the last line.

The compiler uses the `borrow checker` to check that the lifetimes of references are valid.

This example will compile

```
fn main() {  
    let x = 5;                // -----+---  
    'b                        //          |  
    let r = &x;               // --+--- 'a  |  
                               //      |   |  
    println!("r: {}", r);    //      |   |  
                               // --+      |  
}                             // -----+
```

since the data has a longer lifetime than the reference, we can be sure that the reference will always refer to something valid.

A more complex example

```
fn main() {  
    let string1 = String::from("abcd");  
    let string2 = "xyz";  
  
    let result = longest(string1.as_str(),  
string2);  
    println!("The longest string is {}",  
result);  
}  
  
fn longest(x: &str, y: &str) -> &str {  
    if x.len() > y.len() {  
        x  
    } else {  
        y  
    }  
}
```

Here we have references as the function parameters since we don't want to take ownership. If we try to compile this, we get an error, because the compiler doesn't know whether the return is a reference to `x` or to `y`

and the compiler cannot judge whether the references would always be valid.

To help the compiler, we need to be more explicit about the lifetimes involved.

To do this we use the lifetime annotation `'` followed by a parameter , for example

```
'a
```

This then follows the `&` in the reference to give for example

```
&'a i32
```

or

```
&'a mut i32
```

 for a mutable reference.

We can then use this annotation in our function signatures to specify the lifetimes of the parameters.

For example

```
fn main() {  
    let string1 = String::from("abcd");  
    let string2 = "xyz";  
  
    let result = longest(string1.as_str(),  
string2);  
    println!("The longest string is {}",  
result);  
}
```

```

}

fn longest<'a>(x: &'a str, y: &'a str) ->
&'a str {
    if x.len() > y.len() {
        x
    } else {
        y
    }
}

```

The function signature now tells Rust that for some lifetime `'a`, the function takes two parameters, both of which are string slices that live at least as long as lifetime `'a`.

The function signature also tells Rust that the string slice returned from the function will live at least as long as lifetime `'a`.

When we specify the lifetime parameters in this function signature, we're not changing the lifetimes of any values passed in or returned. Rather, we're specifying that the borrow checker should reject any values that don't adhere to these constraints.

Note that the `longest` function doesn't need to know exactly how long `x` and `y` will live, only that some scope can be substituted for `'a` that will satisfy this signature.

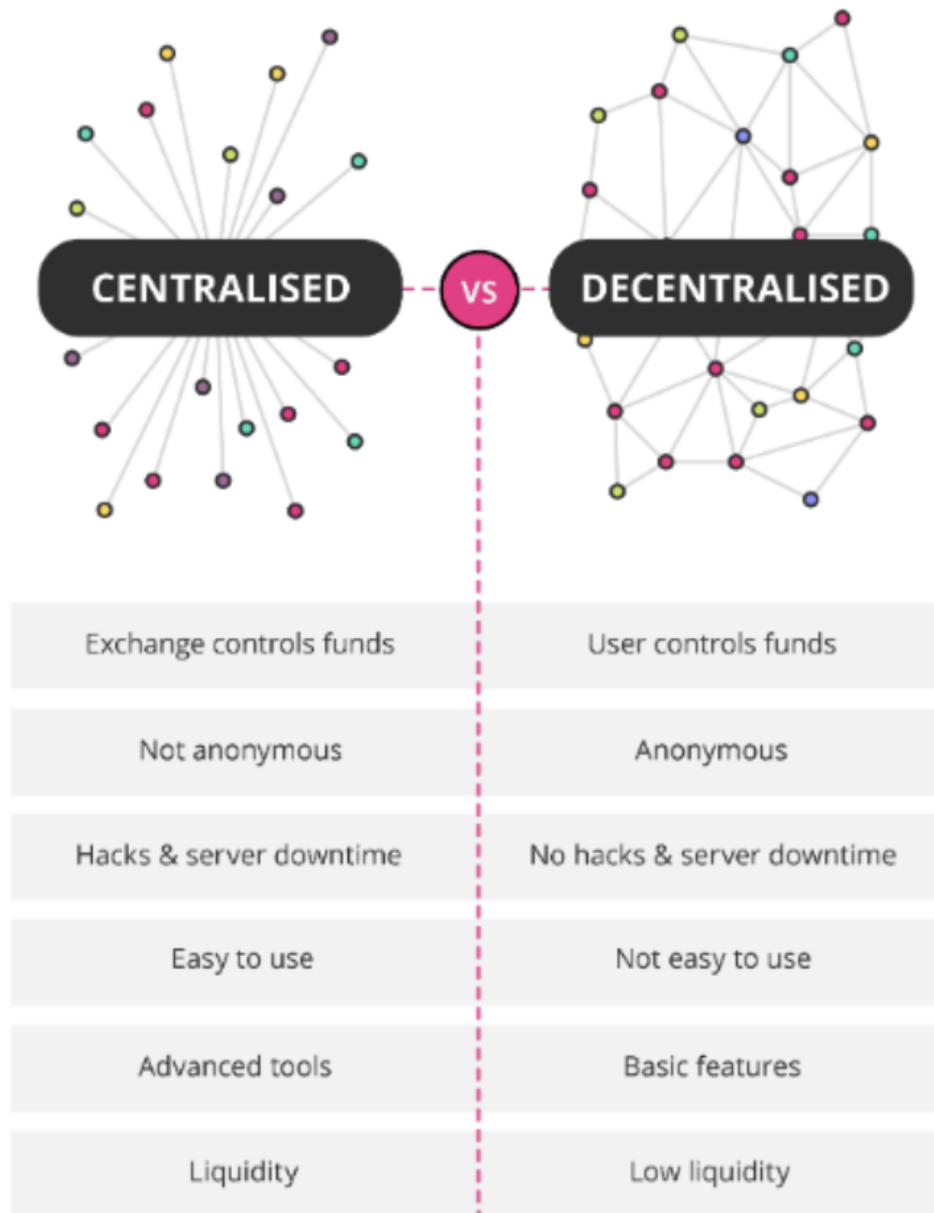
DeFi Introduction

The main areas of DeFi include

- Exchanges
- Asset management
- Stablecoins
- Lending / Borrowing
- Remittance

Introduction

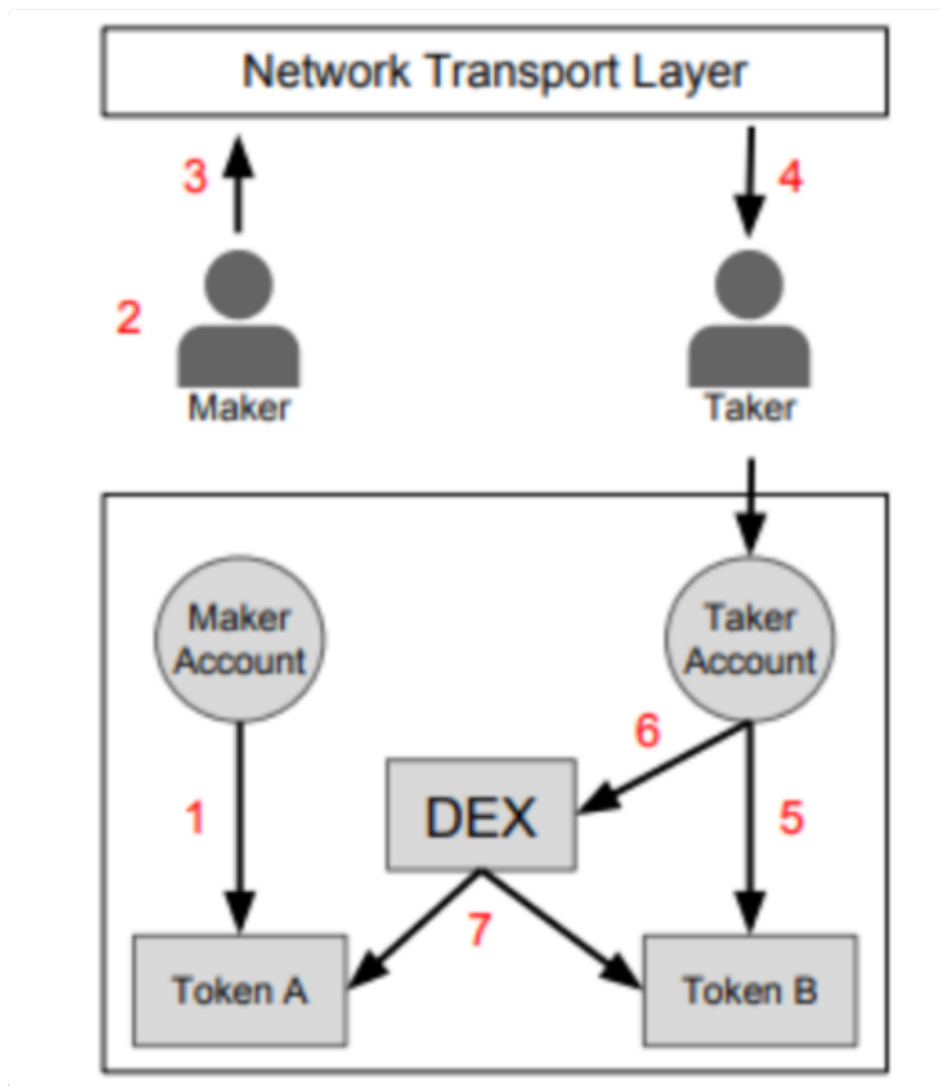
Decentralised Exchanges are a protocol to provide asset exchange without the platform holding the users assets



Decentralised Exchanges allow for more 'democratisation' since token creators do not need their tokens to be listed by the exchange (costly permissioning)

Decentralised Exchange History

Early Exchanges - 0x Protocol



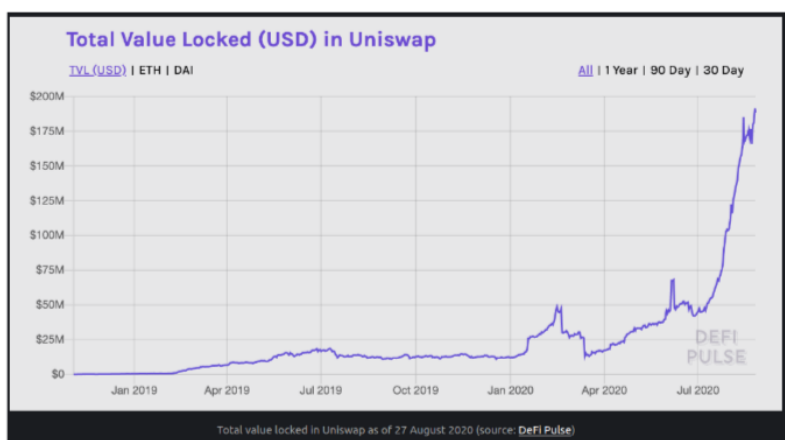
1. Maker approves the decentralized exchange (DEX) contract to access their balance of Token A.
2. Maker creates an order to exchange Token A for Token B, specifying a desired exchange rate, expiration time (beyond which the order cannot be filled), and signs the order with their private key.

3. Maker broadcasts the order over any arbitrary communication medium.
4. Taker intercepts the order and decides that they would like to fill it.
5. Taker approves the DEX contract to access their balance of Token B.
6. Taker submits the makers signed order to the DEX contract.
7. The DEX contract authenticates makers signature, verifies that the order has not expired, verifies that the order has not already been filled, then transfers tokens between the two parties at the specified exchange rate.

The first ideas came from Vitalik, Nick Johnson and Martin Koppelman in 2016 in a [Reddit post](#)

It was followed by an implementation from Hayden Adams and launched in Nov 2018

- Launched in 2018, Uniswap is a DEX featuring an AMM
- Solves the problem of illiquid assets since anyone can set up a liquidity pool



- Truly Decentralised
- Allows swap between any ERC20 pairs
- The code is robust

V2 Launched May 2020 allowing direct token swaps - halving gas fees

It solved many of the problems of the initial exchanges such as lack of incentives to provide liquidity for rarely traded assets. It relies on a smart contract acting as an automatic market maker (AMM)

Automatic Market Makers

Incentivising Users

- Users deposit funds into a liquidity pool, for example ETH and USDT

- This pool (a token pair) allows users to exchange (or maybe lend or borrow) tokens
- Interacting with the exchange incurs fees
- These fees are paid to the liquidity providers

They are characterised as constant function market makers.

From [Constant Function Market Makers](#)

The term “constant function” refers to the fact that any trade must change the reserves in such a way that the product of those reserves remains unchanged (i.e. equal to a constant).

The technique and pricing for this is often referred to as XYK , since we are looking to maintain the ration of 2 tokens (X,Y) so this should always be equal to a constant K

[Swap](#)[Pool](#)[Vote](#)[Charts[↗]](#)

Swap



ETH ▾

1

Balance: 0 ETH

~\$ 2,847.34



USDT ▾

2845.56

Balance: 0 USDT

~\$ 2,850.73 (0.119%)



1 USDT = 0.0003514 ETH ⓘ

Insufficient ETH balance



Add Liquidity

Clear All

UNI

ETH



Select Pair



ETH



UNI



0.3% fee tier

1% select

Edit

Deposit Amounts



ETH

1

Balance: 0 ETH (Max)

~\$ 2,847.22



UNI

36.1374

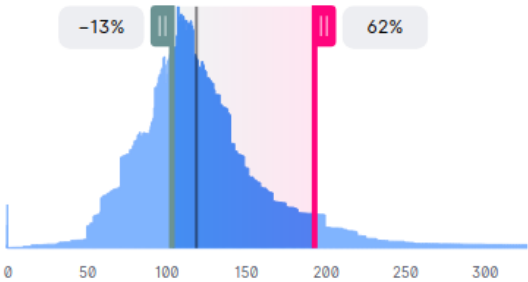
Balance: 0 UNI (Max)

~\$ 862.921

Set Price Range



Current Price: 118.94 UNI per ETH



Min Price



103.94



UNI per ETH

Max Price



192.82



UNI per ETH

Full Range

Insufficient UNI balance

Typically the liquidity provider receives LP tokens when they add liquidity, say ETH and USDT

Later they can take liquidity by providing LP tokens to the contract and will receive back ETH and USDT.

Ideally they will make a profit

Note that on Uniswap v3 LP positions are given by NFTs as opposed to the ERC-20 tokens used in Uniswap V1 and V2.

See [Intro to AMMs](#)

Price Impact / Slippage / Impermanent Loss

Price Impact

Each swap changes the price of the underlying tokens, in terms of each other, a large transaction can substantially impact a token's price.

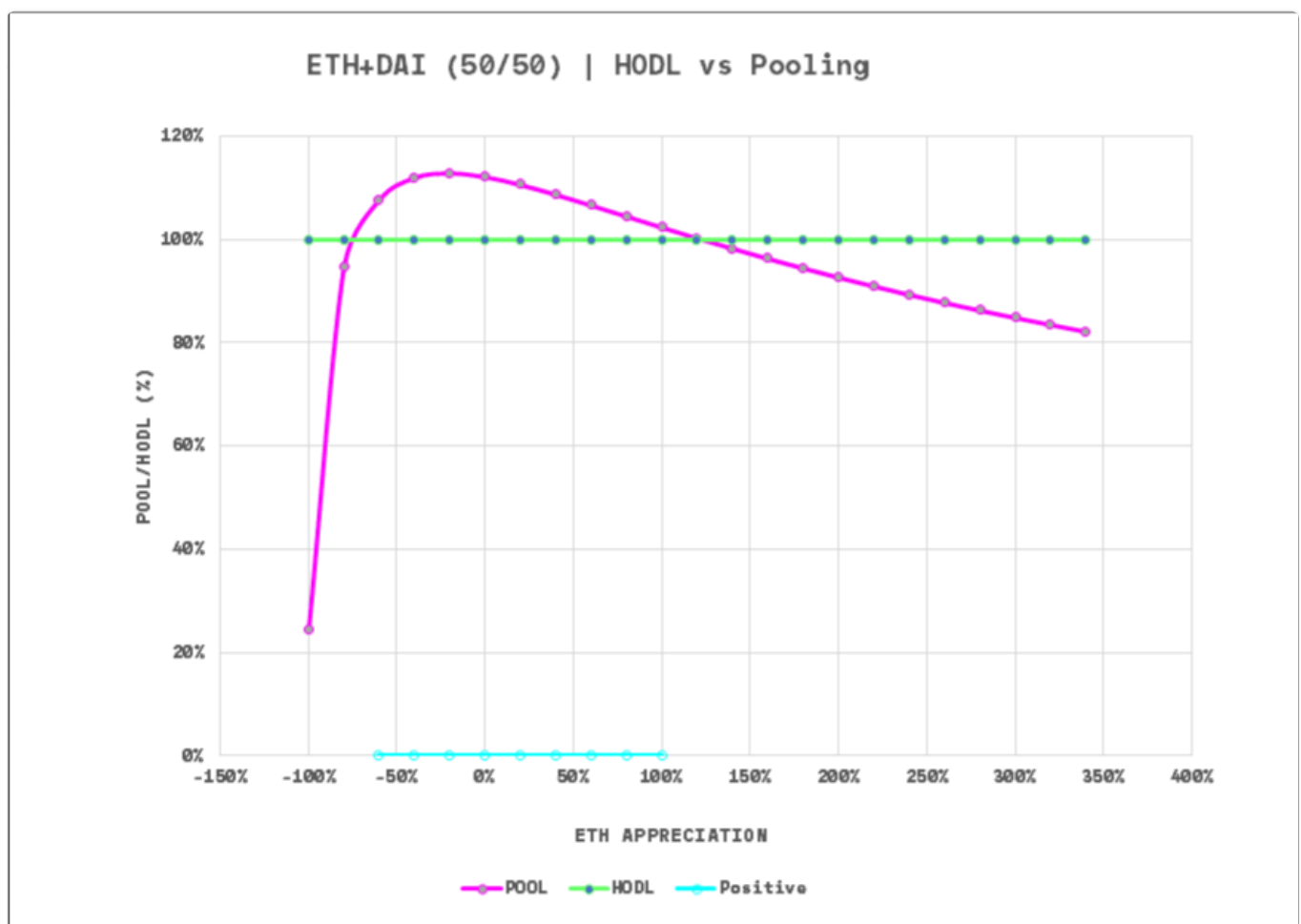
Slippage

Slippage is the aggregated price impact of other traders from the time you submit a trade

to the time your trade executes on the blockchain. Similar to price impact, deep liquidity pools help mitigate slippage.

Impermanent Loss

Impermanent loss occurs when the **value of your percentage-based share of a liquidity pool** is *less* at the time of withdraw than the **value of the amount of tokens you deposited**, at the time of withdraw, had you never deposited them and held them instead.



While liquidity providers can use stablecoins, yields, and rewards to help lessen the impact

of impermanent loss they can also reduce this by using liquidity pools that use ratios other than 50/50.

Composability

A multitude of DeFi applications ("Money LEGOs") can be connected to create new financial products.

See [Monolith article](#)

The applications on the Ethereum network can run interchangeably, and they all support ETH and other ERC-20 tokens. They can be used in endless combinations, with no third party intermediary controlling any element of the network activity. Composability is a core basis of DeFi, and it's what's helped the ecosystem grow so quickly.

Risks associated with composability

There are the usual risks associated with a protocol or smart contracts, but in addition there is a risk when combining products.

The contracts for one application may be secure until combined with those of another application. For example, on 12th March 2020, a

crash in the price of ETH wreaked havoc for DeFi protocols as holders rushed to exit their positions. A gas price spike caused a lag across price oracles, leading to widespread liquidations in protocols like Maker.

Compound

Compound III is an EVM compatible protocol that enables supplying of crypto assets as collateral in order to borrow the *base asset*. Accounts can also earn interest by supplying the base asset to the protocol.

The initial deployment of Compound III is on Ethereum and the base asset is USDC.







Yield Farming

Yield Farming at its simplest is a means of earning rewards for depositing tokens. Users are rewarded for providing liquidity. Different strategies are used by investors to maximise their rewards from the many DeFi projects.

Compound and yearn.finance introduced this area to DeFi

June 2020 BAT token

USDNative					
Assets	Market size	Total borrowed	Deposit APY	Borrow APR	
				Variable	Stable
 Basic Attention Token...	1.85M	1.47M	110.63 % 30D 1.51 % Avg.	193.70 % 30D 4.23 % Avg.	199.70 %
 WBTC Coin (WBTC)	143.78	127.03	24.17 % 30D 0.76 % Avg.	28.87 % 30D 1.36 % Avg.	38.04 %
 sUSD	332.92K	281.76K	14.03 % 30D 6.60 % Avg.	16.58 % 30D 8.07 % Avg.	—
 Binance USD (BUSD)	254.55K	216.03K	14.57 % 30D 5.38 % Avg.	17.17 % 30D 6.78 % Avg.	—

An innovative financial product

Does a risk free loan with no collateral required, of virtually any value , with an extremely low fee (say 0.09 %) seem to good to be true ?

Imagine that line 2 in this contract increases the account balance by 5

Processing a transaction

Initial account balance = 5

line 1
line 2
line 3
line 4
line 5

Process flow

Final account balance = 10

Transactions are atomic

Initial account balance = 5

EVM reverts transaction


Final account balance = 5

line 1
line 2
line 3
line 4
line 5

Process flow



DeFi on Solana



Learn ▾Developers ▾Solutions ▾Network ▾Community ▾

Q Search


DEFI

DeFi made fast, seamless, and easy

High transaction throughput. Ultra low fees. Low latency. Capital efficiency. Solana is made for builders.

START BUILDING

READ DOCS



11B+

Total value locked

430M

avg 24h volume

\$0.18

avg transaction fee (stats as of 12/28/21)

DeFi on Solana

From [DeFiLlama](#)



TVL								
Name	Category	TVL ↕	1d Change ↕	7d Change ↕	1m Change ↕	Fees 24h ↕	Revenue 24h ↕	Monthly Avg 1Y ↕
> 1 Marinade	Liquid Staking	Ⓢ \$2.015b	+0.51%	+4.21%	+45.13%	\$378,383	\$14,759	
🔖 2 Jito		Ⓢ \$1.844b	+1.01%	+5.68%	+67.54%			
> 3 Kamino		Ⓢ \$1.377b	-3.21%	+4.93%	+152%			
> 4 marginfi	Dexes	Ⓢ \$875.61m	-6.90%	+2.20%	+36.08%			
🔖 5 Raydium		\$689.23m	-0.31%	+23.70%	+238%	\$426,916	\$51,230	\$116.93m
🔖 6 BlazeStake		Ⓢ \$542.06m	+0.33%	+19.03%	+40.58%			
🔖 7 Jupiter Perpetual E...	Derivatives	\$386.38m	-0.11%	+2.06%	+75.35%			
🔖 8 Drift	Derivatives	\$350.47m	+0.64%	+8.01%	+72.38%			
🔖 9 Solend	Lending	\$285.83m	+0.11%	-1.83%	+31.71%	\$46,562	\$14,478	\$2.74m
> 10 Meteora	Dexes	Ⓢ \$274.91m	-1.24%	+0.74%	+29.23%			
🔖 11 Orca		\$259.47m	-6.22%	-3.97%	+24.81%			
> 12 Parcl		\$185.45m	+0.06%	+5.98%	+34.90%			
> 13 Sanctum	Liquid Staking	Ⓢ \$103.37m	+3.03%	+21.46%	+286%			
🔖 14 JPool		Ⓢ \$64.57m	+0.24%	+3.54%	+48.54%			
🔖 15 01		\$62.77m	+0.25%	+3.58%	+41.01%			
🔖 16 Ondo Finance	RWA	Ⓢ \$39.03m	-0.72%	+273%	+274%			

Example from Raydium

An avenue for the evolution of DeFi

Light-speed **swaps**. Next-level **liquidity**. Friction-less **yield**.

Launch app >

Read docs 📖

TOTAL VALUE LOCKED

\$ 1,158,609,868

TOTAL TRADING VOLUME

\$ 98,366,975,925

built on **SOLANA**

Swap

Liquidity

From

Balance: 0



SOL

Max Half

1

\$31.83



1 SOL = 28.44643 ORCA

Price Impact Warning



To

Balance: --



ORCA

Max Half

28.44643

\$25.45

Swapping Through

SOL → USDC → ORCA

Minimum Received

28.164782 ORCA

Price Impact

20.95%

More information

Insufficient SOL balance



SOL

Price

\$31.87

24H%

+1.62%



~970M

market cap

\$1.5

average mint cost

(stats as of 12/29/21)

5.7M+

NFTs

WHY SOLANA

– Get started with the best reference implementations. Ecosystem projects provide resources to launch your NFT on Solana in **record speed.**

On-chain, always

From auctions to perpetual royalties coded right into the NFT, Solana supports a fully decentralized on-chain experience for artists and collectors.

LEARN MORE

NFT Standard

Focus on the artwork, not writing a new smart contract. The Solana NFT standard and minting program offers extreme customizability, with ecosystem-wide support.

LEARN MORE

Permanent storage

Configure the best web3 storage option for your project, whether permanent, decentralized storage provided by ARweave, or other popular standards like IPFS.

LEARN MORE

We will look at NFT projects such as [Metaplex](#) in later lessons.

Tokens on Solana

Token Program

See [Docs](#)

The token program is part of the [solana program library](#) which is a collection of on-chain programs targeting the [Sealevel parallel runtime](#) , covering a number of areas such as

- tokens
- governance
- name service
- token swaps
- lending

The Solana token program is heavily used, its program id is

: [TokenkegQfeZyiNwAJbNbGKPFXCWuBvf9Ss623VQ5DA](#)

The program is used to create tokens with functionality similar to the ERC20 and ERC721 (NFT) standards.

[Comparison with Ethereum](#)

Ethereum doesn't have any built in support for tokens, they rely on

- A standard to be followed - for example ERC20
- Libraries to be created by third parties to provide implementations

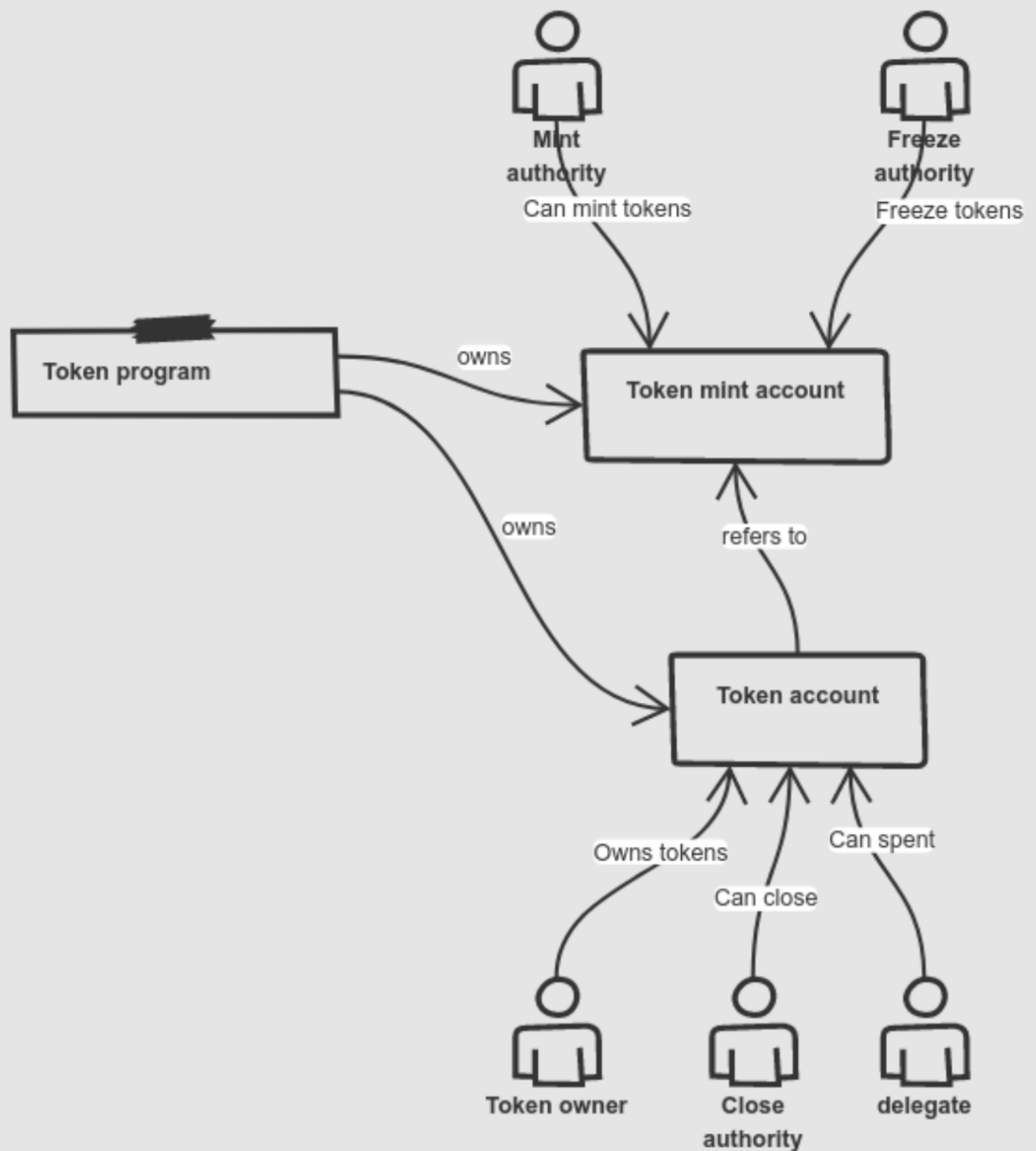
If you want to create a token on Ethereum, you will need to write and deploy a contract.

Understanding the Accounts involved

See these articles

[article 1](#)

[article 2](#)



When we create a token we need to create a token mint account which contains details about the token and who can do administrative functions.

This doesn't hold user's balances, those are held in the token account.

Any user who desires to hold any given token, needs a token account for the corresponding token.

The overall process is

1. Create token
2. Mint tokens to an account
3. Transfer tokens to other users

Behind the scenes these are running various functions.

For example when minting the tokens

We first call `InitializeMint`

This takes some parameters that are stored in a struct


```
pub struct Mint {  
    /// Optional authority used to mint new  
    tokens. The mint authority may only be  
    provided during mint creation. If no mint  
    authority is present then the mint has a  
    fixed supply and no further tokens may be  
    minted.  
    pub mint_authority: COption<Pubkey>,  
  
    /// Total supply of tokens.  
    pub supply: u64,  
  
    /// Number of base 10 digits to the right  
    of the decimal place.  
    pub decimals: u8,  
  
    /// Is `true` if this structure has been  
    initialized  
    pub is_initialized: bool,  
  
    /// Optional authority to freeze token  
    accounts.  
    pub freeze_authority: COption<Pubkey>,  
  
}
```

This then calls `InitializeAccount` which sets up the account struct

```
pub struct Account {  
    /// The mint associated with this account  
    pub mint: Pubkey,  
    /// The owner of this account.  
    pub owner: Pubkey,  
    /// The amount of tokens this account  
    holds.  
    pub amount: u64,  
    /// If `delegate` is `Some` then  
    `delegated_amount` represents  
    /// the amount authorized by the delegate  
    pub delegate: COption<Pubkey>,  
    /// The account's state  
    pub state: AccountState,  
    /// If is_native.is_some, this is a native  
    token, and the value logs the rent-exempt  
    reserve. An  
    /// Account is required to be rent-exempt,  
    so the value is used by the Processor to  
    ensure that  
    /// wrapped SOL accounts do not drop below  
    this threshold.  
    pub is_native: COption<u64>,  
    /// The amount delegated  
    pub delegated_amount: u64,
```

```
/// Optional authority to close the  
account.  
pub close_authority: COption<Pubkey>,  
  
}
```

Next the `MintTo` instruction is called, taking

- Public key of the mint
- Address of the token account to mint to
- The mint authority
- Amount to mint
- Signing accounts if `authority` is a multisig
- SPL Token program account

This will mint tokens to the destination account

Transfer

To transfer tokens we invoke the function `process_transfer` this transfers a certain amount of token from a source account to a destination account:

We pass in the source and destination accounts and the amount.

The program will check that

1. Neither source account nor destination account is frozen
2. The source account's mint and destination account's mint are the same
3. The transferred `amount` is no more than source account's token amount

Note the source and destination can be the same.

BURN

Burn is the opposite of Mint and removes tokens, from the supply and the given account.

Approve

This allows transfer of a certain amount by a delegate.

- Only one delegate is possible per account / token.
- A new approval will override the previous one.

Revoke

Removes the approval

Freeze / Thaw Account

This will freeze / unfreeze the account preventing / allowing transfers / mints to it.

Token-2022 Program

Note that extensions have been added to the token program to produce the Token-2022

Mint extensions currently include:

- confidential transfers
- transfer fees
- closing mint
- interest-bearing tokens
- non-transferable tokens

Account extensions currently include:

- memo required on incoming transfers
 - immutable ownership
 - default account state
-

Associated Token Account Program

Why do we need an associated token account program ?

- A user may own arbitrarily many token accounts belonging to the same mint which makes it difficult for other users to know which account they should send tokens to and introduces friction into many other aspects of token management.

This program introduces a way to *deterministically* derive a token account key from a user's main System account address and a token mint address, allowing the user to create a main token account for each token they own. We call these accounts *Associated Token Accounts*.

- In addition, it allows a user to send tokens to another user even if the beneficiary does not yet have a token account for that mint. Unlike a system transfer, for a token transfer to succeed the recipient must have a token account with the compatible mint already, and somebody needs to fund that token account. If the recipient must fund it

first, it makes things like airdrop campaigns difficult and just generally increases the friction of token transfers. The Associated Token Account program allows the sender to create the associated token account for the receiver, so the token transfer just works.

From [QuickNode Guide](#)

"The Solana Token Program derives "a token account key from a user's main System account address and a token mint address, allowing the user to create a main token account for each token they own" (Source: spl.solana.com). That account is referred to as an Associated Token Account or "ATA." Effectively an ATA is a unique account linked to a user and a specific token mint."

Aaron's Account

Wallet ID 9r9F...EBqX

Aaron's \$USDC ATA
ID Hyc9...JfBE

Aaron's \$SAMO ATA
ID a97Q...42Lg

Aaron's nth ATA
ID xxxx...xxxx

Mitchel's Account

Wallet ID 4izK...GdTT

Mitchel's \$USDC ATA
ID 42n3f...SViq

Mitchel's \$SAMO ATA
ID hG3S...j7dh

Mitchel's nth ATA
ID xxxx...xxxx

Using the command line tools to create tokens

We can use the `spl-token-cli` tool to create tokens. There is detailed [documentation](#) available

Setup

Make sure you have Rust and the Solana CLI installed then

Install the SPL token CLI

```
cargo install spl-token-cli
```

If you have a missing `libudev` dependency you can install on linux with

```
sudo apt install -y pkg-config libusb-1.0-0-dev libftdi1-dev  
sudo apt-get install libudev-dev
```

Check which network you are configured for

```
solana config get
```

You can set the required cluster with

```
solana config set --url  
https://api.devnet.solana.com
```

If you don't have a key pair, then generate one

```
mkdir ~/my-solana-wallet
```

```
solana-keygen new --outfile ~/my-solana-wallet/my-keypair.json
```

display the result with

```
solana-keygen pubkey ~/my-solana-wallet/my-keypair.json
```

verify your address

```
solana-keygen verify <PUBKEY> ~/my-solana-wallet/my-keypair.json
```

and set the keypair

```
solana config set --keypair ~/my-solana-wallet/my-keypair.json
```

Airdrop yourself some tokens

```
solana airdrop 1
```

Creating a fungible token

```
spl-token create-token
```

You should see something like

```
Creating token
```

```
AQoKYV7tYpTrFZN6P5oUufbQKAUr9mNYGe1TTJC9wa  
jM
```

```
Signature:
```

```
47hsLFxWRCg8azaZZPSnQR8DNTRsGyPNfUK7jqyzgt  
7wf9eag3nSnewqoZrVZHKm8zt3B6gzxhr91gdQ5qYr  
sRG4
```

Note that this doesn't have a supply yet

You can test this with

```
spl-token supply <Token ID>
```

Now create an account to hold the token

```
spl-token create-account <Token ID>
```

```
Creating account
```

```
7UX2i7SucgLMQcfZ75s3VXmZZY4YRUyJN9X1RgfMoD  
Ui
```

```
Signature:
```

```
42Sa5eK9dMEQyvD9GMHuKxXf55WLZ7tfjabUKDhNoZ
```

```
RAxj9MsnN7omriWMEHXL3aYpjZ862qocRLVikvkh  
kyfy
```

Mint some tokens into that account

```
spl-token mint <Token ID> 100
```

You can check the token balance for an account with

```
spl-token balance <Token ID>
```

and the supply with

```
spl-token supply <Token ID>
```

If you want a summary of the tokens that you own, use

```
spl-token accounts
```

Transferring tokens

See [Docs](#)

```
spl-token transfer <Token ID> <amount>  
<destination>
```

Note that the destination account must already be set up for that token

If the account is not already setup for that token you can use

```
spl-token transfer --fund-recipient <Token  
ID> <amount> <destination>
```

The alternative is for the receiver to first set up their account to receive that token

```
spl-token create-account <Token ID>
```

They can then receive tokens by the sender using

```
spl-token transfer <Token ID> <amount>  
<destination>
```

Non Fungible Tokens

To create an NFT we

1. Create a token with zero decimal places

```
spl-token create-token --decimals 0
```

2. Setup the account as for a fungible token

1.

```
spl-token create-account <Token ID>
```

3. Mint 1 token to that account

1.

```
spl-token mint <Token ID> 1  
    <Account>
```

4. Disable future minting:

```
spl-token authorize <Token ID> mint --  
disable
```

You can check the token details with

```
$ spl-token account-info <Token ID>
```

```
spl-token supply <Token ID>
```