# Understanding event logs on the Ethereum blockchain

mycrypto on Medium

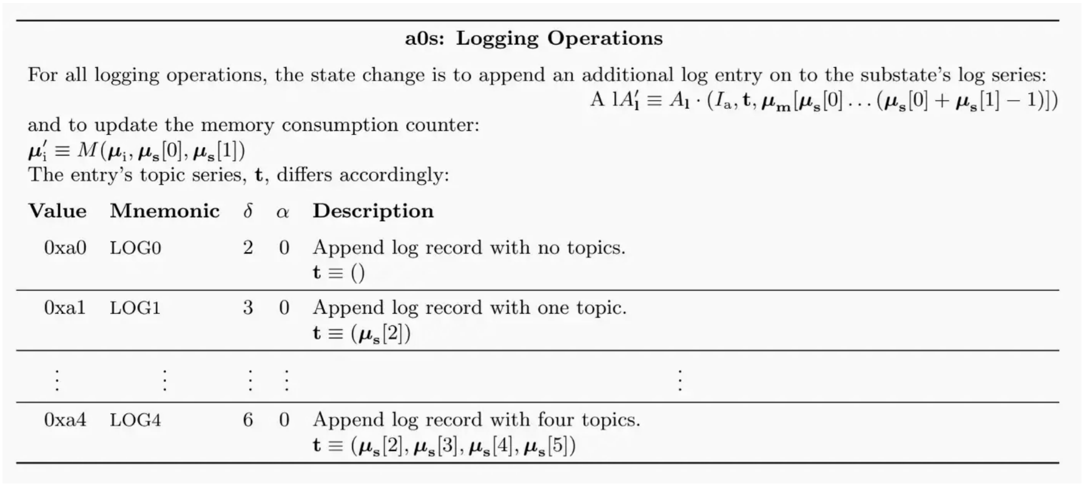
## Contents

Most transactions have an event log, but those event logs can be hard to read.

## Logging in Ethereum

The EVM currently has 5 opcodes for emitting event logs: LOG0, LOG1, LOG2, LOG3, and LOG4.

These opcodes can be used to create log records. A log record can be used to describe an event within a smart contract, like a token transfer or a change of ownership.



**a0s: Logging Operations**

For all logging operations, the state change is to append an additional log entry on to the substate's log series:

$$A\ 1A'_{\mathbf{l}} \equiv A_{\mathbf{l}} \cdot (I_a, \mathbf{t}, \boldsymbol{\mu}_{\mathbf{m}}[\boldsymbol{\mu}_{\mathbf{s}}[0] \dots (\boldsymbol{\mu}_{\mathbf{s}}[0] + \boldsymbol{\mu}_{\mathbf{s}}[1] - 1)])$$

and to update the memory consumption counter:

$\boldsymbol{\mu}'_i \equiv M(\boldsymbol{\mu}_i, \boldsymbol{\mu}_{\mathbf{s}}[0], \boldsymbol{\mu}_{\mathbf{s}}[1])$

The entry's topic series, **t**, differs accordingly:

| Value | Mnemonic | $\delta$ | $\alpha$ | Description |
|---|---|---|---|---|
| 0xa0 | LOG0 | 2 | 0 | Append log record with no topics. $\mathbf{t} \equiv ()$ |
| 0xa1 | LOG1 | 3 | 0 | Append log record with one topic. $\mathbf{t} \equiv (\boldsymbol{\mu}_{\mathbf{s}}[2])$ |
| ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |
| 0xa4 | LOG4 | 6 | 0 | Append log record with four topics. $\mathbf{t} \equiv (\boldsymbol{\mu}_{\mathbf{s}}[2], \boldsymbol{\mu}_{\mathbf{s}}[3], \boldsymbol{\mu}_{\mathbf{s}}[4], \boldsymbol{\mu}_{\mathbf{s}}[5])$ |

Figure 1: Ethereum Yellowpaper

Each log record consists of both topics and data. Topics are 32-byte (256 bit) "words" that are used to describe what's going on in an event. Different opcodes (`LOG0 ... LOG4`) are needed to describe the number of topics that need to be included in the log record. For instance, `LOG1` includes one topic, while `LOG4` includes four topics. Therefore, the maximum number of topics that can be included in a single log record is four.

## Topics in Ethereum Log Records

The first part of a log record consists of an array of topics. These topics are used to describe the event. The first topic usually consists of the signature (a keccak256 hash) of the name of the event that occurred, including the types (`uint256`, `string`, etc.) of its parameters. One exception where this signature is not included as the first topic is when emitting anonymous events. Since topics can only hold a maximum of 32 bytes of data, things like arrays or strings cannot be used as topics reliably. Instead, it should be included as data in the log record, not as a topic. If you were to try including a topic that's larger than 32 bytes, the topic will be hashed instead. As a result, this hash can only be reversed if you know the original input. In conclusion, topics can be seen as indexed keys of the event that all map to the same value and only reliably be used for data that strongly narrows down search queries (like addresses).

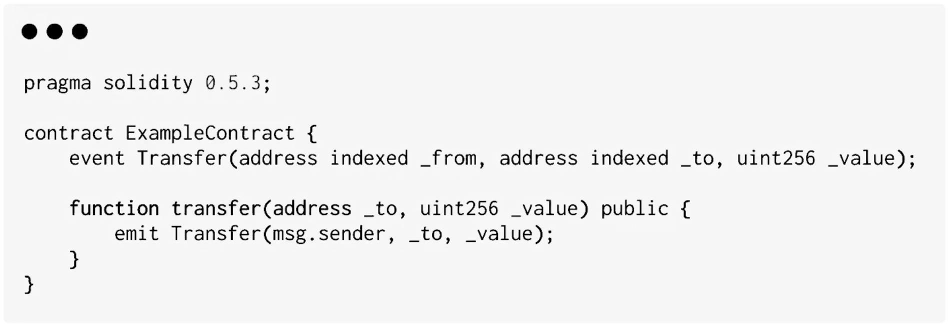
## Data in Ethereum Log Records

The second part of a log record consists of additional data. Topics and data work best together as there are upsides and downsides to each. For example, while topics are searchable, data is not. But, including data is a lot cheaper than including topics. Additionally, while topics are limited to 4 * 32 bytes, event data is not, which means it can include large or complicated data like arrays or strings. Therefore, the event data (if any) can be seen as the value.

Let's take a look at some examples to see how topics, data, and log records are used in the wild.

## Emitting events

The following contract implements the Transfer event, used by ERC20-compliant token contracts:



```
pragma solidity 0.5.3;

contract ExampleContract {
    event Transfer(address indexed _from, address indexed _to, uint256 _value);

    function transfer(address _to, uint256 _value) public {
        emit Transfer(msg.sender, _to, _value);
    }
}
```

Figure 2: Example Contract

Since this is not an anonymous event, the first topic will consist of the event signature:

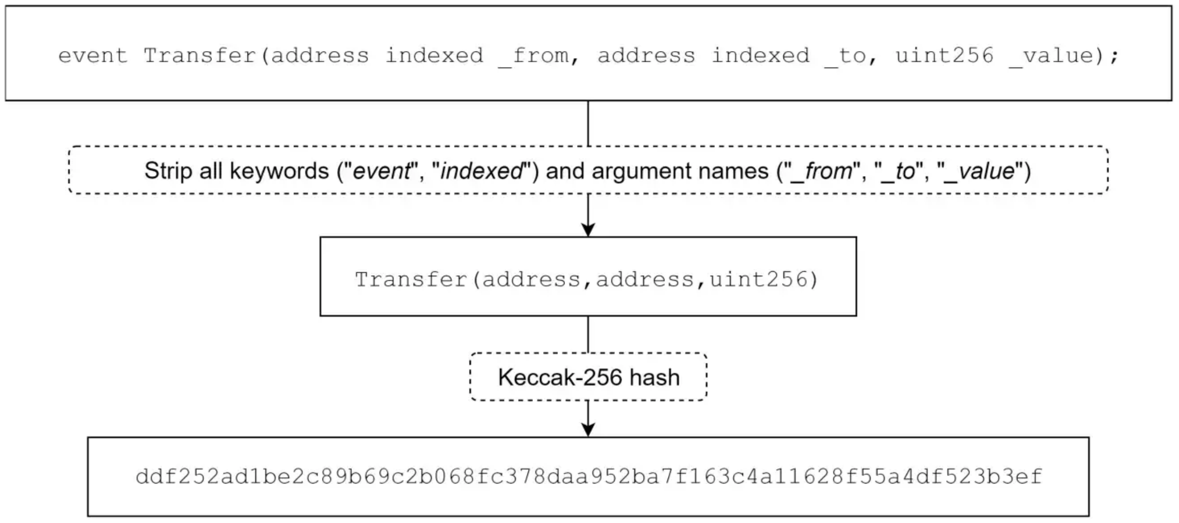

event Transfer(address indexed _from, address indexed _to, uint256 _value);
Strip all keywords ("event", "indexed") and argument names ("_from", "_to", "_value")
Transfer(address,address,uint256)
Keccak-256 hash
ddf252ad1be2c89b69c2b068fc378daa952ba7f163c4a11628f55a4df523b3ef

Figure 3: The signature of the Transfer event

Now, let's take a look at the arguments (from, to, value) of this Solidity event:

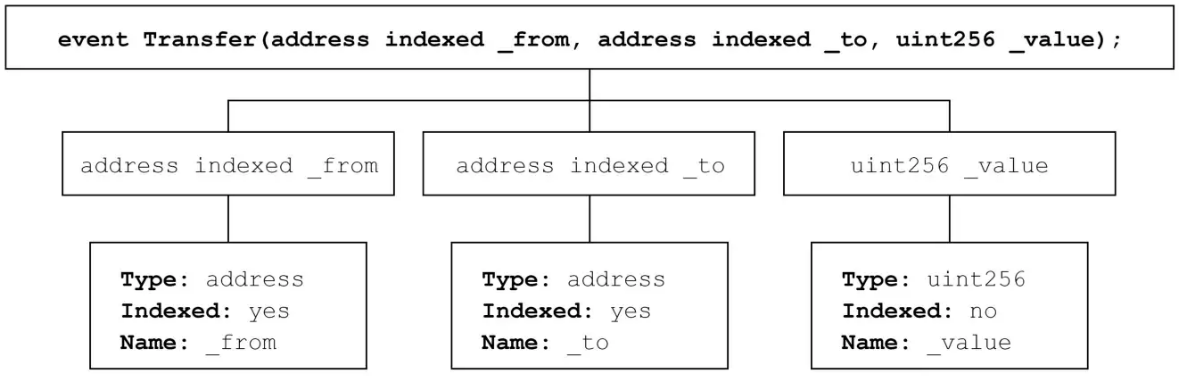


Figure 4: The arguments of the Transfer event

Since the first 2 arguments are declared as indexed, they are treated like additional topics. Our final argument will not be indexed, which means it will be attached as data (instead of a separate topic). This means we are able to search for things like "find all Transfer logs from address 0x0000… to address 0x0000…" or even "find all logs to address 0x0000…", but not for things like "find all Transfer logs with value x". We know this event will have 3 topics, which means this logging operation will use the `LOG3` opcode.

Now, we just need to understand how data (like our final argument) can be included. `LOG3` requires 5 arguments:

```
LOG3(memoryStart, memoryLength, topic1, topic2, topic3)
```

Event data is read from memory in the following fashion:

```
memory[memoryStart...(memoryStart + memoryLength)]
```

Luckily, higher-level smart contract programming languages like Solidity, Vyper, or Bamboo will handle

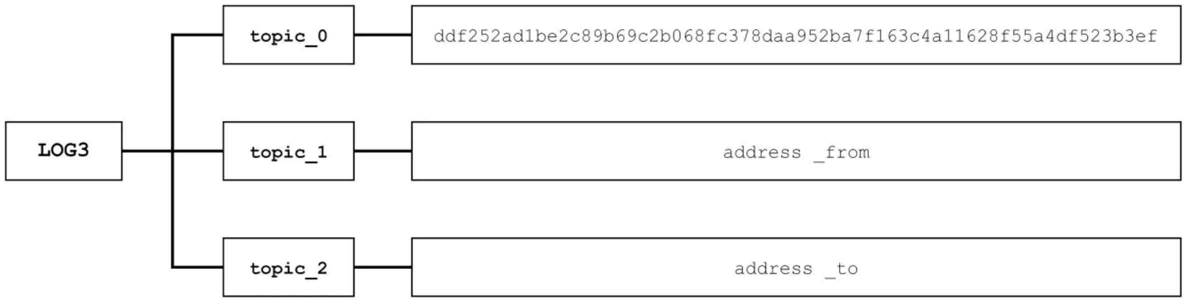
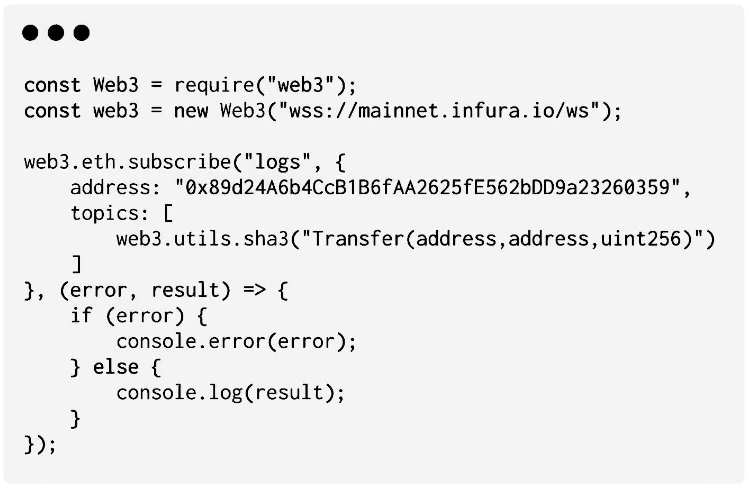

LOG3
topic_0
ddf252ad1be2c89b69c2b068fc378daa952ba7f163c4a11628f55a4df523b3ef
topic_1
address _from
topic_2
address _to

Figure 5: `LOG3`

writing event data to memory for us, which means you can usually pass data directly as a parameter when emitting logs.

### Retrieving event logs

Using web3, a popular JavaScript library used to interact with a local or remote Ethereum node, we are able to subscribe to new event logs:



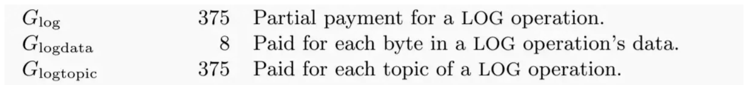
```
const Web3 = require("web3");
const web3 = new Web3("wss://mainnet.infura.io/ws");

web3.eth.subscribe("logs", {
    address: "0x89d24A6b4CcB1B6fAA2625fE562bDD9a23260359",
    topics: [
        web3.utils.sha3("Transfer(address,address,uint256)")
    ]
}, (error, result) => {
    if (error) {
        console.error(error);
    } else {
        console.log(result);
    }
});
```

Figure 6: Retriving event logs

This code will alert us whenever a new SAI token transfer has occurred, which can be useful for various applications. For example, a wallet interface could alert you whenever you receive tokens on your Ethereum address.

## Cost of logging operations



| | | |
|---|---|---|
| $G_{\text{log}}$ | 375 | Partial payment for a LOG operation. |
| $G_{\text{logdata}}$ | 8 | Paid for each byte in a LOG operation's data. |
| $G_{\text{logtopic}}$ | 375 | Paid for each topic of a LOG operation. |

Figure 7: Basic gas cost

The base cost of logging operations is 375 gas. On top of that, every included topic costs an additional 375 gas. Finally, each byte of data costs 8 gas.

$$\begin{array}{ll}
G_{log} + G_{logdata} \times \boldsymbol{\mu}_{\mathbf{s}}[1] & \text{if} \quad w = \text{LOG0} \\
G_{log} + G_{logdata} \times \boldsymbol{\mu}_{\mathbf{s}}[1] + G_{logtopic} & \text{if} \quad w = \text{LOG1} \\
G_{log} + G_{logdata} \times \boldsymbol{\mu}_{\mathbf{s}}[1] + 2G_{logtopic} & \text{if} \quad w = \text{LOG2} \\
G_{log} + G_{logdata} \times \boldsymbol{\mu}_{\mathbf{s}}[1] + 3G_{logtopic} & \text{if} \quad w = \text{LOG3} \\
G_{log} + G_{logdata} \times \boldsymbol{\mu}_{\mathbf{s}}[1] + 4G_{logtopic} & \text{if} \quad w = \text{LOG4}
\end{array}$$

Figure 8: Gas cost by operation

That's actually pretty cheap! Let's imagine an ERC-20 token transfer. First, we have a base cost of 375 gas. Second, the Transfer event contains 3 topics, which is an additional 375 * 3 = 1125 gas. Finally, we add 8 gas for each byte of data included. Since the data only contains the value of the ERC-20 transfer, which can be a maximum of 32 bytes ($2^2 56$), the maximum amount of gas needed to account for the data of the logging operation would be 8 * 32 = 256 gas. This adds up to a total gas cost of 1756 gas. For reference, a standard ether (non-token) transfer costs 21000 gas, or more than 10x that!

If we assume a gas price of 1 gwei, the total cost of the operation would be 1756 gwei, the equivalent of 0.000001756 ETH. If the current price of ETH is around $200, this would only add up to $.0003512. Keep in mind that this is the price of storing data on the blockchain worldwide, likely forever.

### Disclaimer

This is just the cost of a logging operation itself. Any Ethereum transaction starts at 21000 gas, and the transaction's input data costs up to 16 gas per byte. Typically, to transfer & log an ERC-20 token, it costs between 40,000–60,000 gas.

## Conclusion

Logs are an elegant way to store tiny amounts of data on the Ethereum blockchain for a small price. Specifically, event logs are useful to let other people know something has happened without them having to query contracts individually.