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**Title:**

How to test an OAuth2/OpenID Connect based system?

**Abstract:**

Delegation of the authorization/authentication via leveraging of OAuth2/OpenID Connect (OIDC) is more and more common in modern systems but how to ensure that no weaknesses were left during the implementation and the configuration or such systems? Let's we show you some key points to verify…

**GitHub repository associated that will be moved to public when blog post will be released:**

<https://github.com/ExcelliumSA/OAuth2OIDC-Study>

**SEO rules indicated by Mathilde:**

* Paragraphs with fewer than 300 words.
* Keyword used as much as possible: *oauth, oidc, test*
* Presence of sections.

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**Note:** In the content below, all figure captions refer to the image file that Mathilde must use when she creates the blog post. So it's normal if the caption do not describe the figure.

# Introduction

This post presents a collection of security oriented validation points that should be verified on a system using **OAuth/OpenID Connect** (OpenID Connect will be called **OIDC** in the rest of the post). Therefore, it assumes you are familiar with all the concepts related to OAuth/OIDC. All references to OAuth refer to **OAuth 2.0**.

If it is not the case then you can refer to this free online course named "*Introduction to OAuth 2.0 and OpenID Connect*" [1] kindly created and provided by Dr. Philippe De Ryck [2] or the several tutorials from ConnectId [3].

Note that this post is mainly a security-oriented feedback following a complete focused training that I have recently taken on the OAuth/OIDC topics.

# Context

OAuth and OIDC address respectively the Authorization and Authentication aspects of a system. Therefore, any issues in these areas can have critical consequences from a security point of view like authentication or authorization bypass for example.

One of the challenges faced is that there are several actors involved as well as different communications exchanges.

Below is a **simplified example** of OAuth authorization code flow:

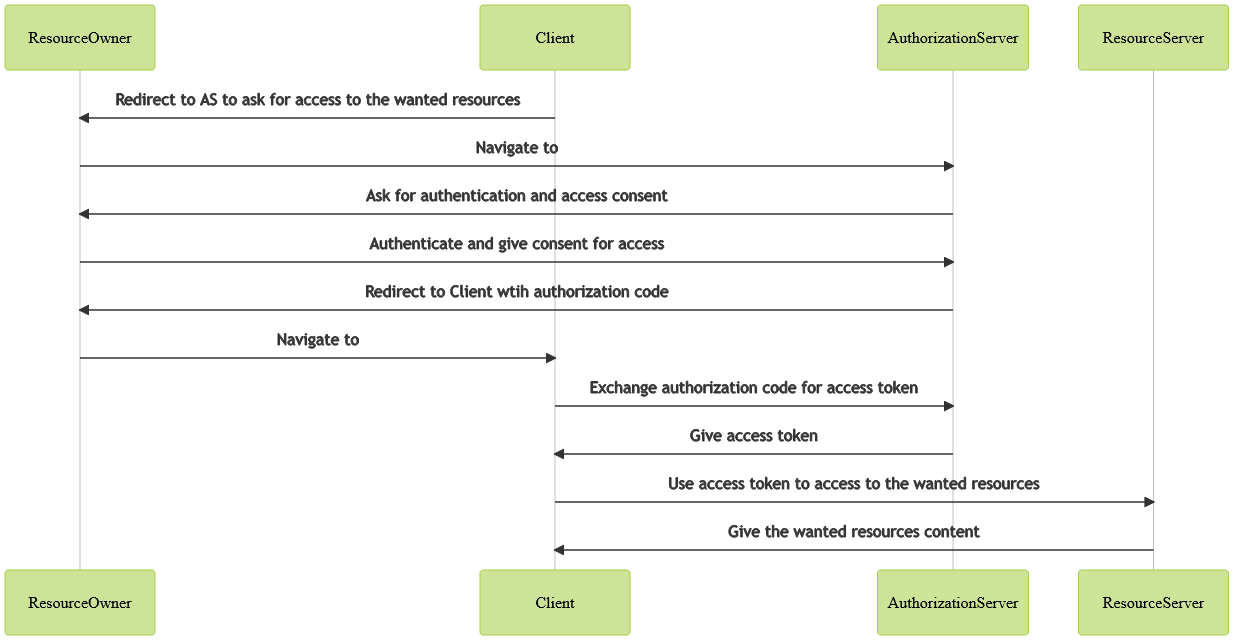


Figure 1: File Figure00.png

This makes the attack surface quite large. To make matters worse, leveraging OAuth/ODIC require to configure an **OpenID Provider** (OIDC) and/or an **Authorization Server** (OAuth). Note that depending on the context, sometimes, you must also provision the entire OpenID Provider/Authorization Server instance yourself. One time again, it's easy to introduce a weakness via insecure settings.

# Find my way in the fog

As I was totally new to the OAuth and OIDC world, I decided to take the course named "*Mastering OAuth 2.0 and OpenID Connect*" [4]. Indeed, OAuth and OIDC are more and more common in modern application architecture and my goal was to understand these new concepts/patterns in order to be able to identity/exploit/prevent security weaknesses.

Following the lessons, I decided to create a list of all pitfalls discovered during the training. The different modules of the course are oriented for developers but I simply converted the "attention points" into "security tests" as well as performing a "mental on-the-fly" penetration test on each feature/flow presented by the instructor to identify potential attack vector/scenario. It is obvious that the list is not exhaustive but it's a good foundation and it will evolve over the time with the growing of my experience in this field.

The list of validation points [5] was organized by actors in order to allow focusing on one actor if the scope of an assessment (code review, configuration review, penetration test, etc.) is targeting only a specific actor. Each validation point has a unique identifier in order to allow referencing it in a document, script, report and so on.

A table [6] is provided to indicate if a validation point is manual or can be automated. The automation status is based on the technical capabilities to create code that perform the target test, without human interaction, and give a reliable result with the same level of trust that it was performed manually. Once again this "automation status" cannot be accurate for you in you know how to automate it ☺

# Overview of the validation points

In addition to a representation using a "list" approach, a mind map was created in order to provide a higher overview of the collection of validation points.

Below is overview of the counter of tests identified (a validation point 🡨🡪 a test):

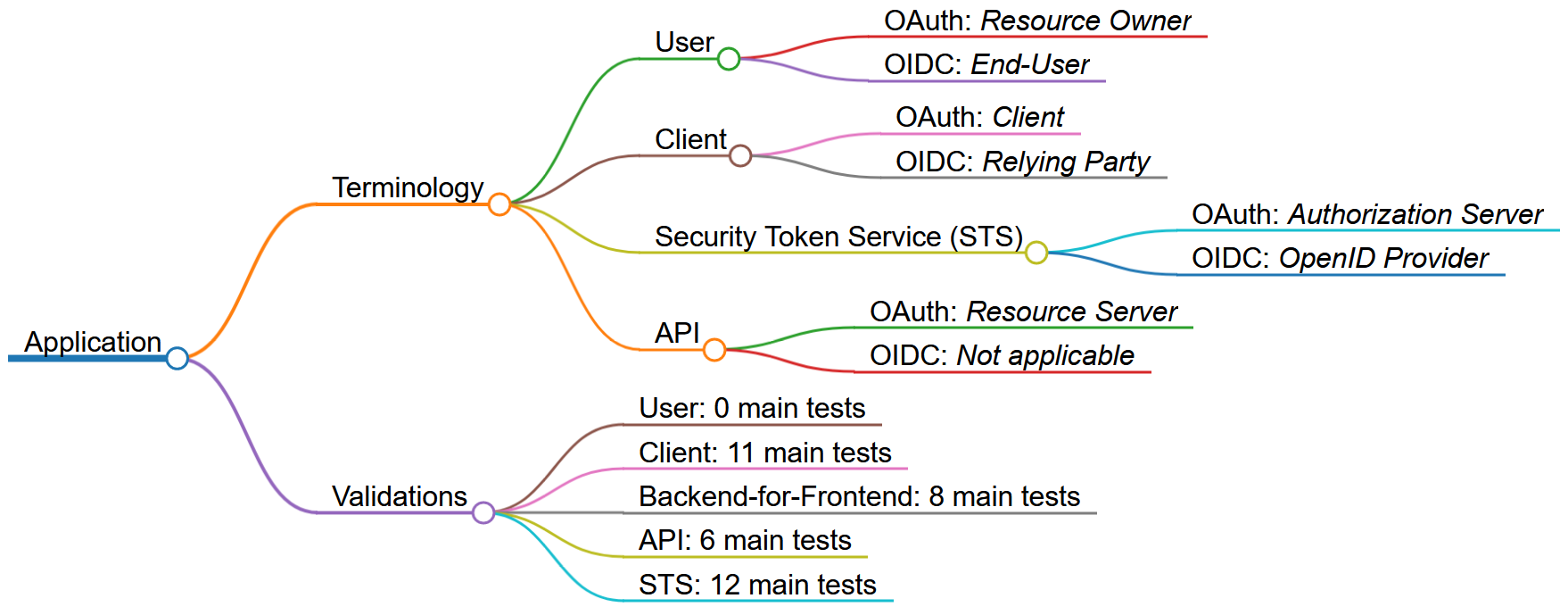


Figure 2: File Figure01.png

A total of 37 main tests were identified. The notion of "main tests" refer to the fact the some test contains "sub tests" but here, for simplicity, only the main tests were included in the count.

Example of main tests (identifier STS04):

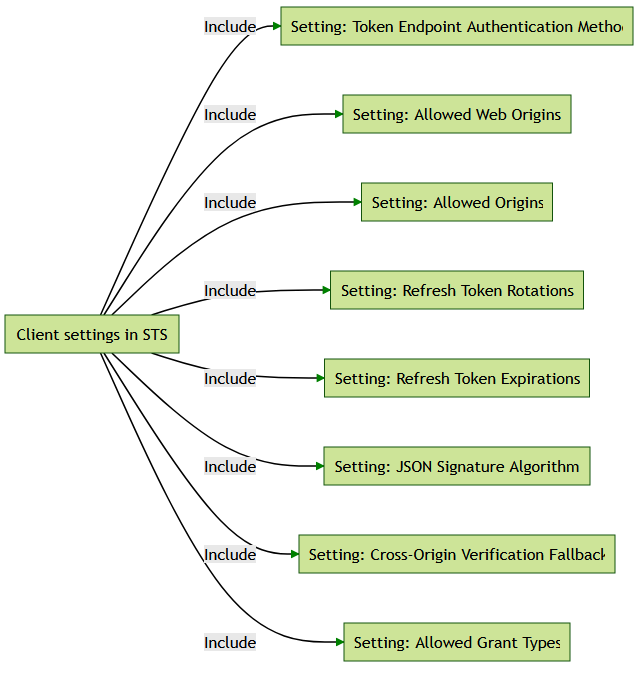


Figure 3: File Figure02.png

The detailed version of the mind map is available on the GitHub repository of the blog post [7].

# How to apply control?

In this section, I used a local lab based on Keycloak [8], to show how to perform some of the validation points from the list. A demo configuration is provided to allow you to reproduce the test performed [9].

## CLT01: For SPA, ensure that it uses the Authorization Code Flow with PKCE instead of the "Implicit" flow

In the demo app, when the login is used, the following request is sent to the "/auth" endpoint:

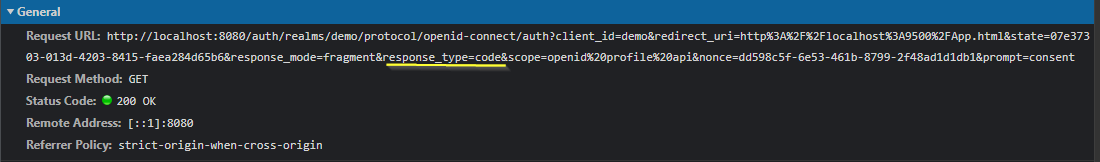


Figure 4: File Figure03.png

The parameter "response\_type" is set to "code". However, there is no parameter named "code\_challenge" so the flow used here is "Authorization Code" and not "Authorization Code with PKCE".

Consequence: It is possible to start a flow with an insecure mode implying that, if the authorization code is intercepted by an attacker then, it can be used to obtain access token before the Client use it (an authorization code is valid one time).

## STS04h: Allowed Grant Types (flow types enabled) and Response Modes for a client should be limited to one used

As seen in the previous test, the "Authorization Code" flow is used, but does the "Implicit" flow it is enabled?

Let's try to start such one…

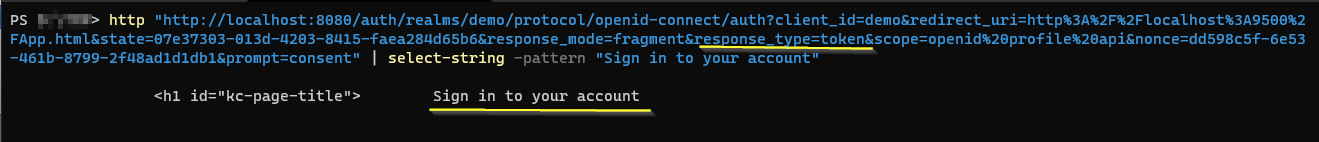


Figure 5: File Figure04.png

Login form is proposed so the flow is allowed. When it is not the case, the following error is received:

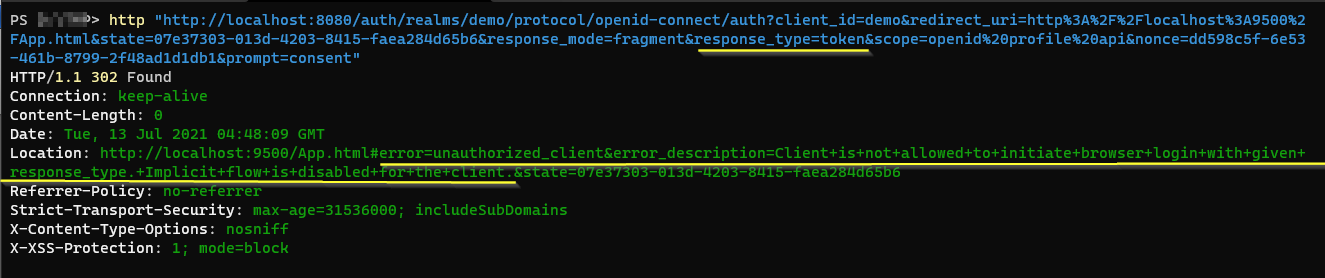


Figure 5: File Figure05.png

Consequence: It is possible to start a flow using the deprecated "Implicit" mode.

## STS12: Ensure that the STS reject any request specifying a scope that is not defined for the targeted API and prevent scope enumeration/discovery operation

In the web client app, the following scopes are used:

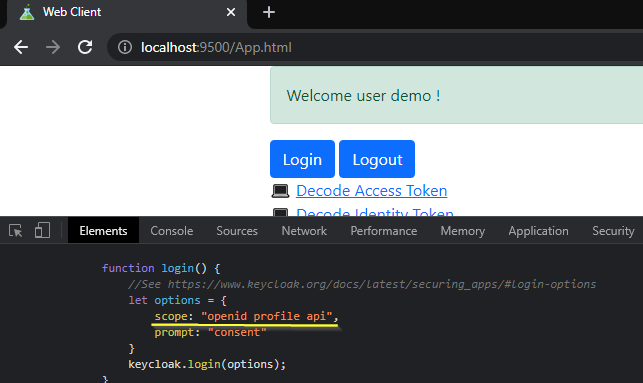


Figure 5: File Figure06.png

Keycloak allow defining optional scopes:

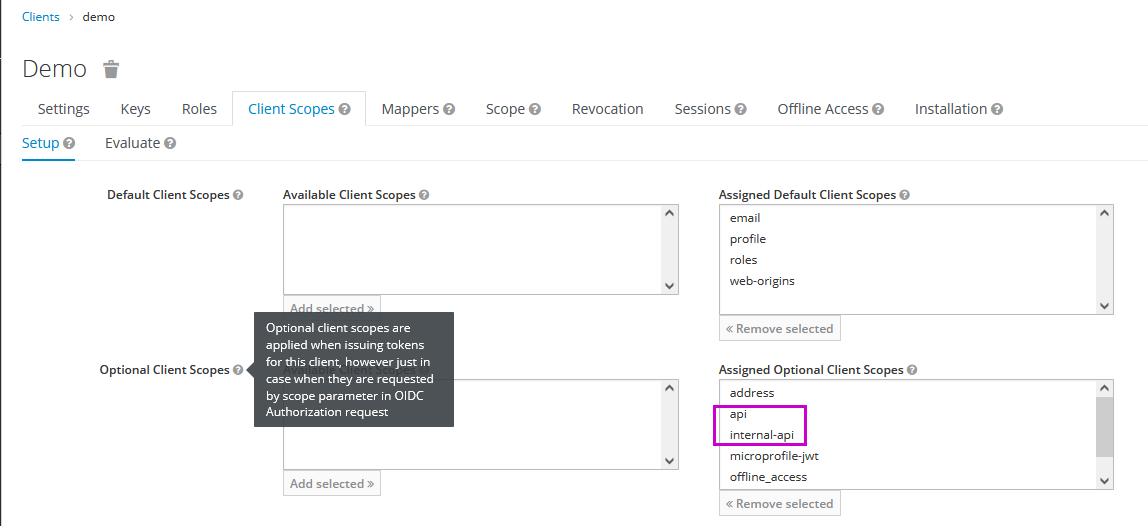


Figure 5: File Figure07.png

When a flow is started with an invalid scope, the following error is received:

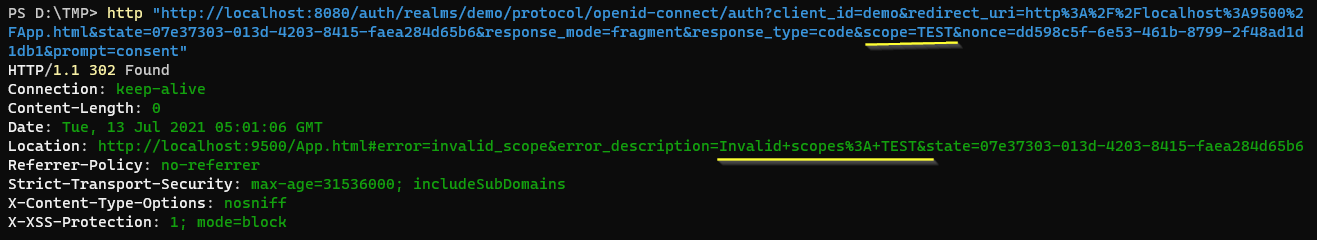


Figure 5: File Figure08.png

When a scope is valid then the login form is received with an HTTP 200.

Based on this discrepancy factor, it's possible to try the following scope enumeration using FFUF [10] with a dictionary of English words [11]:

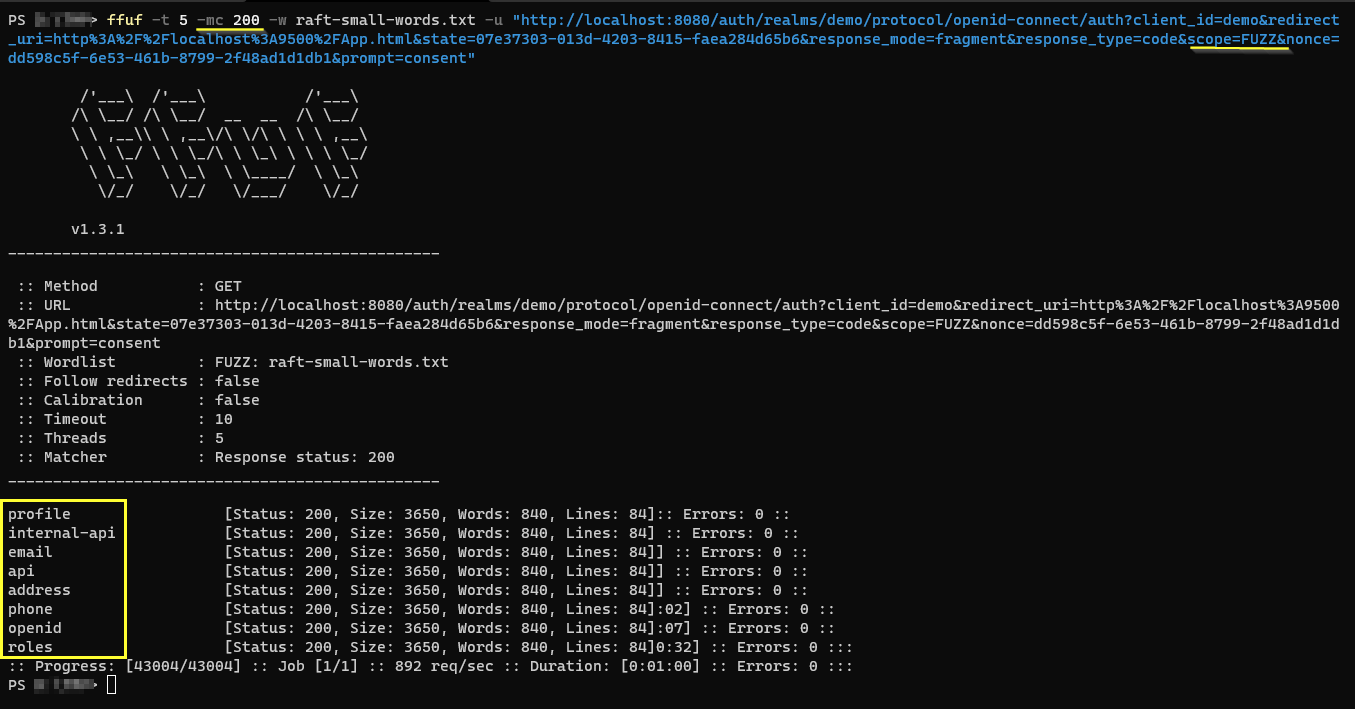


Figure 5: File Figure09.png

8 scopes, not present in the Client code, were identified.

Consequence: It is possible, for a Client, to potentially access to more resources if the User accept the new scope requested.

## STS00b: The STS do not support broken hashing algorithms like MD5 or SHA1 or even "plain"

The code verifier must have a minimum length of 43 positions according to the RFC [12], so, let's try to start an "Authorization Code with PKCE" flow with "plain" code challenge algorithm (**code\_challenge = code\_verifier**) and a weak code verifier:

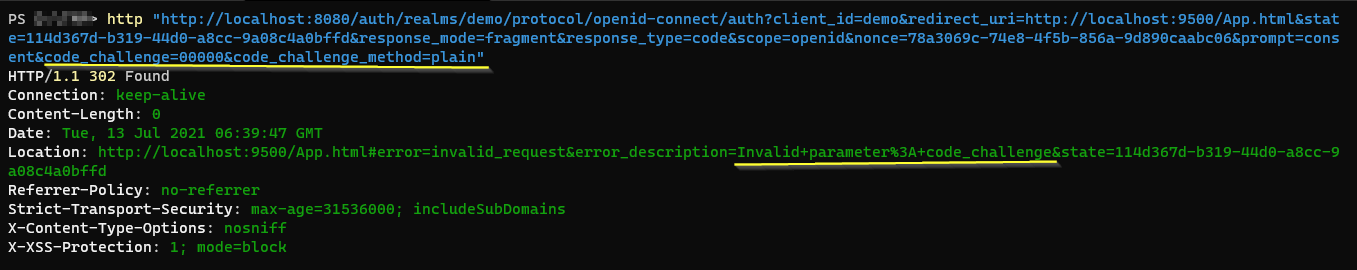


Figure 5: File Figure10.png

The "plain" algorithm is accepted but "code\_challenge" is rejected.

Let's try with a challenge having for value 43 x "0":

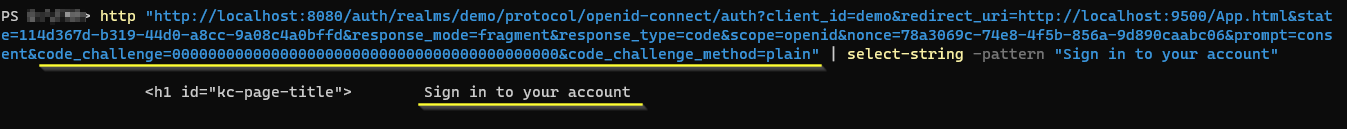


Figure 5: File Figure11.png

Now it is accepted and the flow is started.

Consequence: It is possible to start a flow that disable to protection added by PKCE. It causes the value of the code verifier to be disclosed during the start of the flow.

# Conclusion

OAuth 2.0 and OpenID Connect allow centralizing authentication and authorization management. On a side of the coin, it decreases the attack surface of the application by removing the need to implement some error-prone feature like for example authentication and account reset. However, on the other side, these new mechanisms are difficult to master and it is easy to introduce a weakness during the setup of the authentication/authorization flows.

Anyway, these mechanisms are a real added value from a security point of view and, like any system, it is just necessary to ensure that every component in the flow use secure/recommended settings. It's the main reason why the checklist was created, in order to be sure during a security assessment to review a maximum of aspects. I hope that this checklist will be useful, for the defender side as well, in order to allow them to review/monitor the configuration of the tiers involved.

# References

1. <https://courses.pragmaticwebsecurity.com/courses/introduction-to-oauth-2-0-and-openid-connect>
2. <https://pragmaticwebsecurity.com/about.html>
3. <https://connect2id.com/learn>
4. <https://courses.pragmaticwebsecurity.com/bundles/mastering-oauth-oidc>
5. <https://github.com/ExcelliumSA/OAuth2OIDC-Study/blob/main/OAauth2_OIDC_Security_Validations.md>
6. <https://github.com/ExcelliumSA/OAuth2OIDC-Study/blob/main/OAauth2_OIDC_Security_Validations.md#validation-automation-status>
7. <https://github.com/ExcelliumSA/OAuth2OIDC-Study/blob/main/OAauth2_OIDC_Security_Validations.png>
8. <https://www.keycloak.org/getting-started/getting-started-docker>
9. <https://github.com/ExcelliumSA/OAuth2OIDC-Study#lab>
10. <https://github.com/ffuf/ffuf>
11. <https://raw.githubusercontent.com/danielmiessler/SecLists/master/Discovery/Web-Content/raft-small-words.txt>
12. <https://datatracker.ietf.org/doc/html/rfc7636#section-4.1>