Exercise Report
(Lab2-M9)

|  |  |
| --- | --- |
| **Subject of this exercise:** | Study of Analog Phase-Locked Loop (APLL) |
| **Students – Student code:** | <me>-student code<myself> -student code<I> -student code |
| **Course/code:** | <course>, <group> |
| **Date & time:** | 20<YY>. <MM>. <DD>. |
| **Lecturer today:** |  |

Equipment in use, device under test

|  |  |
| --- | --- |
| Oszcilloscope | Agilent 54622A |
| Power supply | Agilent E3630 |
| Synchronizable function generators | Agilent 33220A-Option 001 |
| Digital multimeter (6½ digit) | Agilent 33401A |
| Digital multimeter (3½ digit) | Metex ME-22T |

Exercises



Test panel Fig.9‑1.

1. Measuring of the loop elements of the APLL
	1. **Obtaining the PD curve**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **θ2** [o] | **ud** [V] | **θe** [o] |  | **θ2** [o] | **ud** [V] | **θe** [o] |
| 180 | -0.03022  | -180 |  | 0 | 0.0491  | 0 |
| 170 | -0.17829  | -170 |  | -10 | 0.1974  | 10 |
| 160 | -0.3209  | -160 |  | -20 | 0.3403  | 20 |
| 150 | -0.4535  | -150 |  | -30 | 0.4726  | 30 |
| 140 | -0.5722  | -140 |  | -40 | 0.5915  | 40 |
| 130 | -0.673  | -130 |  | -50 | 0.6922  | 50 |
| 120 | -0.7533  | -120 |  | -60 | 0.7724  | 60 |
| 110 | -0.8103  | -110 |  | -70 | 0.8293  | 70 |
| 100 | -0.8422  | -100 |  | -80 | 0.8614  | 80 |
| 90 | -0.8484  | -90 |  | -90 | 0.8674  | 90 |
| 80 | -0.8286  | -80 |  | -100 | 0.8476  | 100 |
| 70 | -0.7834  | -70 |  | -110 | 0.8022  | 110 |
| 60 | -0.7137  | -60 |  | -120 | 0.7327  | 120 |
| 50 | -0.6227  | -50 |  | -130 | 0.641  | 130 |
| 40 | -0.5121  | -40 |  | -140 | 0.5305  | 140 |
| 30 | -0.3856  | -30 |  | -150 | 0.4039  | 150 |
| 20 | -0.2471  | -20 |  | -160 | 0.2655  | 160 |
| 10 | -0.10076  | -10 |  | -170 | 0.11925  | 170 |
| 0 | 0.0491  | 0 |  | -180 | -0.03037  | 180 |

When *θe* is small (|*θe*| < 45 o)

 ***ud*(*t*)** = ***Kd θe***

*ud1* = V

*ud2* = V

*θe1* = o

*θe2* = o

Kd’= [V/o]

**Kd = [V/rad]**

Measurement setup

<Block diagram>

**Matlab code:**

<PD curve - plot>

<Experience collected during the completion of the measurement>

* 1. **Obtaining VCO curve**

|  |  |
| --- | --- |
| **uf** [V] | **f2** [Hz] |
| -10,14 | 78700  |
| -8,00 | 81030  |
| -6,09 | 83110  |
| -4,09 | 85290  |
| -2,02 | 87540  |
| --0,04 | 89690  |
| 2,05 | 91980  |
| 4,05 | 94160  |
| 6,08 | 96370  |
| 8,00 | 98460  |
| 9,58 | 100180  |

Measurement setup

<Block diagram>

**Matlab code:**

<VCO curve - plot>

*uf1* = V

*uf2* = V

*f1* = kHz

*f2* = kHz

Kv’= [kHz/V]

**Kv= [k rad/Vs]**

<Experience collected during the completion of the measurement>

* 1. **Calculating the free-running frequency of the VCO**

Measurement setup

<Block diagram>



 f0 = kHz; ω0 = *k*

<Experience collected during the completion of the measurement>

VCO operation formula:

 ω2 = [rad/s].

1. Obtaining the locking- and tracking ranges of the APLL
	1. Obtaining the locking range

Measurement setup

<Block diagram>

The following videos are available for the accomplishment of the tasks:

<https://web.microsoftstream.com/video/cb984119-5a22-4c83-afd5-43def4a42845>

<https://web.microsoftstream.com/video/1b8a757d-773c-4c8a-8a6e-c7406a53918f>

<https://web.microsoftstream.com/video/30e9bcfe-35b3-4e28-be50-16e61a79b948>

1. method

*f1* = kHz

*f2* = kHz

2ΔfP= kHz

< ábra>

2. Lissajous’s method (Lissajou curve)

<Plot>

<Experience collected during the completion of the measurement>

* 1. **Obtaining tracking range**

*f1* = kHz

*f2* = kHz

2ΔfH= kHz

<Experience collected during the completion of the measurement>

1. Implementation of analog FM demodulator and obtaining its curve

Obtain the curve of FM demodulator

**ζ=1** Reference signal: 100 Hz → 0 dB

|  |  |
| --- | --- |
| **f** [Hz] | **uf** [dB] |
| **100** | **-0.00064303**  |
| 300 | 0.18337  |
| 500 | 0.4616  |
| 700 | 0.74474  |
| 900 | 0.97374  |
| 1100 | 1.13322  |
| 1300 | 1.22228  |
| 1500 | 1.2507  |
| 1700 | 1.22736  |
| 1900 | 1.16161  |
| 2100 | 1.0613  |
| 2300 | 0.93234  |
| 2500 | 0.78107  |
| 2700 | 0.60701  |
| 2900 | 0.41751  |
| 3100 | 0.21505  |
| 3300 | -0.0010619  |
| 3500 | -0.2267  |
| 3700 | -0.46052  |
| 3900 | -0.70269  |
| 4100 | -0.95055  |
| 4300 | -1.20346  |
| 4500 | -1.47079  |
| 4700 | -1.72217  |
| 4900 | -1.9869  |
| 5100 | -2.2545  |
| 5300 | -2.5228  |
| 5500 | -2.794  |
| 5700 | -3.0672  |
| 5900 | -3.3391  |
| 6100 | -3.6124  |

Measurement setup

<Block diagram>

**Matlab code:**

<FM demodulator curve - plot>

<Experience collected during the completion of the measurement>

1. Determination of APLL closed-loop transfer function
	1. **Determination of closed-loop transfer function, [H(s)]:**

**Matlab code:**

<Closed-loop transfer function - plot>

**Closed-loop transfer function when ζ=1:**

Parameters:

Kv= [rad/Vs]; Kd= [V/rad]; τ1= [s/rad];
τ2= [s/rad].

ζ= ; ωn= [rad/s]; ωb= [rad/s];

<Experience collected during the completion of the measurement>

* 1. **Determination of the error function, [1-H(s)]:**

**Matlab code:**

<Error-function - plot>

**Error function, when ζ=1:**

Parameters:

Kv= [rad/Vs]; Kd= [V/rad]; τ1= [s/rad];
τ2= [s/rad].

ζ= ; ωn= [rad/s].

<Experience collected during the completion of the measurement>

1. Implementation and measurement of digital FSK demodulator

Measurement in case of FSK with small deviation

 Settings:

 Frequency: 90 kHz

 Frequency hopping: 92 kHz

 Modulation frequency: 200 Hz

**ζ=1**

Measurement setup

<Block diagram>

The following videos are available for the accomplishment of the tasks:

<https://web.microsoftstream.com/video/1e1fb90a-ce0a-4ba2-be8e-5974a635beea>

<https://web.microsoftstream.com/video/87eff464-c512-476a-9d55-044da88f56bb>

<plot>

<Experience collected during the completion of the measurement>

Measurement of FSK with big deviation (collapsing the locked state, generating locking transient)

 Settings:

 Frequency: 90 kHz

 Frequency hopping: 97 kHz

 Modulation frequency: 200 Hz

**ζ=1**

< plot>

<Experience collected during the completion of the measurement>

1. Measurement of APLL dynamics characterized by two different damping factors (ζ= 1 and 0,25)
	1. **Hop in the frequency of the reference signal**

 Settings:

 Frequency: 90 kHz

 Frequency hopping: 92 kHz

 Modulation frequency: 200 Hz

**ζ=1**

< plot>

 Settings:

 Frequency: 90 kHz

 Frequency hopping: 92 kHz

 Modulation frequency: 200 Hz

**ζ=0,25**

< plot>

<Experience collected during the completion of the measurement>

* 1. **Perturbation applied on VCO input**

Measurement setup

<Block diagram>

The following videos are available for the accomplishment of the tasks:

<https://web.microsoftstream.com/video/6ef41c5d-bbff-4cfa-a476-507c1014f3cf>

<https://web.microsoftstream.com/video/94dc64aa-720c-4833-a11f-bdd07e14adaf>

<https://web.microsoftstream.com/video/a79b713d-a8fe-4b53-9e5b-ce1a2146859d>

<https://web.microsoftstream.com/video/aac09335-b401-4196-be3d-c83e7318c702>

Parameters of perturbation signal:

 Frequency:100Hz

 Amplitude: 1Vpp

 Waveform: square

 Duty cycle: 50%

 **ζ=1**

<plot>

Parameters of perturbation signal:

 Frequency:100Hz

 Amplitude: 1Vpp

 Waveform: square

 Duty cycle: 50%

 **ζ=0.25**

< plot>

<Experience collected during the completion of the measurement>

Complementary measurement tasks

1. Double-frequency component measured at the output of the phase detector

The following video is available for the accomplishment of the tasks
(where **ch1**: PDin1 and **ch2**: F(s)out ):

<https://web.microsoftstream.com/video/b01f626a-a16b-40f3-bdc7-75c1f3cbe671>

Measurement setup

<Block diagram>

<plot>

<Experience collected during the completion of the measurement>