Vhodno izhodne naprave

Laboratorijski vaji 7, 8 - LV1, LV2

Meritve dolžine, karakteristične impedance linije in različnih situacij z odboji

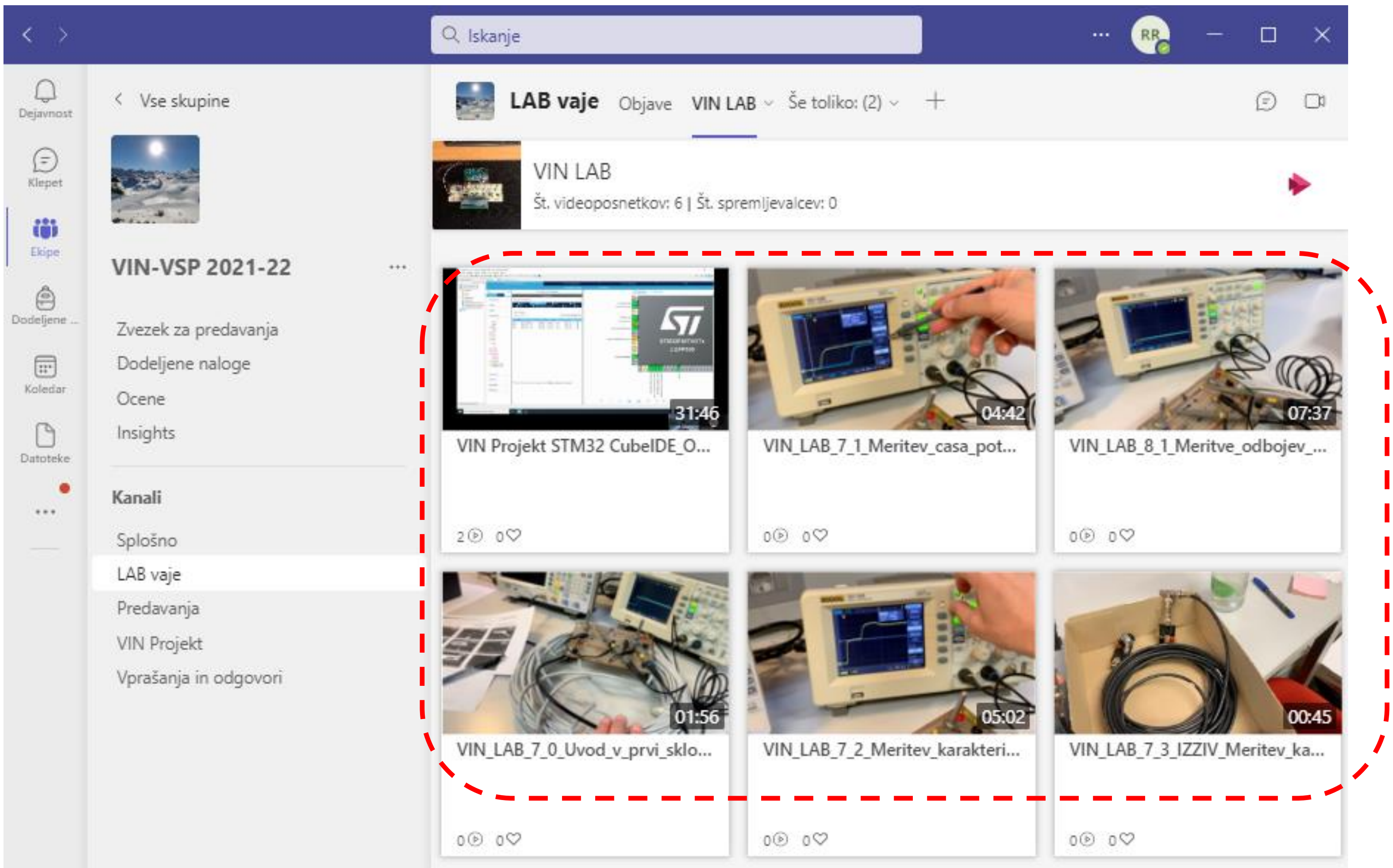
Laboratorijski vaji 7, 8 - LV1, LV2

- 7.0: Uvod v meritve prenosnih linij
- 7.1: LV1-1: Meritev dolžine linije (l)
- 7.2: LV1-2: Meritev karakteristične upornosti linije (R_0)
- 7.3: LV1-3: Izziv - Meritev karakteristične upornosti linije drugače (R_0)

- 8.1: LV2 : Meritve odbojev (razmerja Rv, Rb)
- 8.2: LV2 : Vpliv časa vzpona/padca – omejevanje odbojev
- 8.3: Odboji v praksi - omejevanje (zaključitve, „slew rate“)

Laboratorijski vaji 7, 8 - LV1, LV2

- MS Teams



Vhodno izhodne naprave

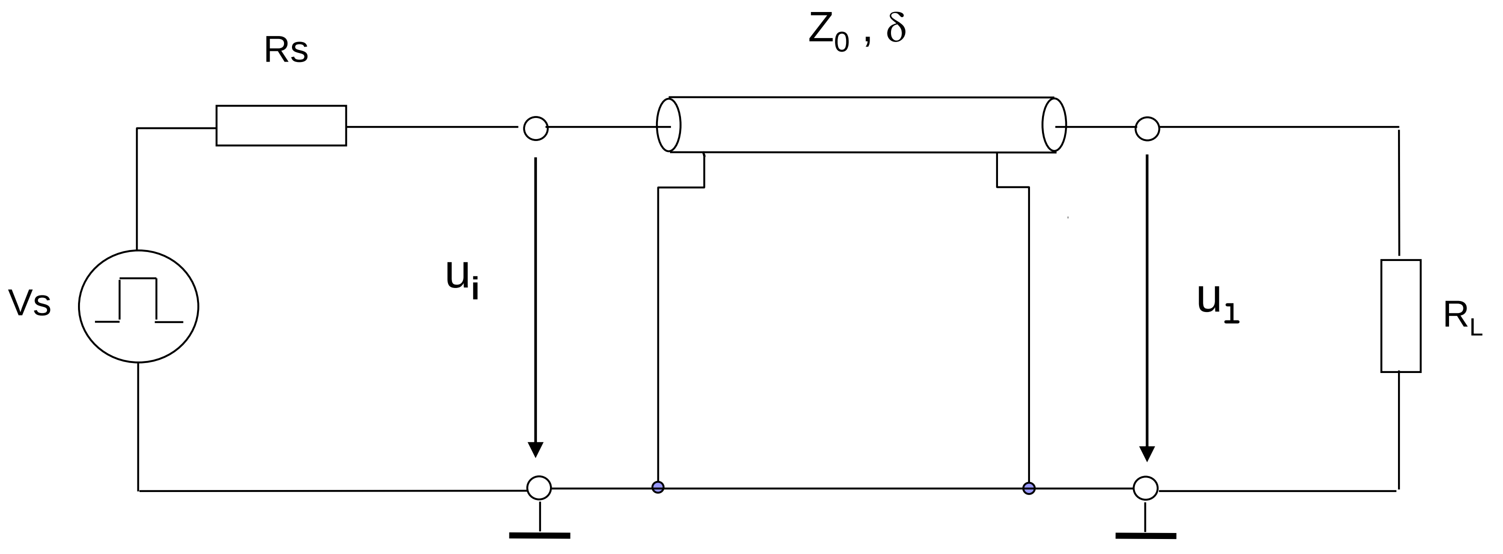
Laboratorijska vaja 7 - LV1

Meritve dolžine, karakteristične impedance linije

Laboratorijska vaja 7 - LV1

- 7.0: Uvod v meritve prenosnih linij
- 7.1: LV1-1: Meritev dolžine linije (l)
- 7.2: LV1-2: Meritev karakteristične upornosti linije (R_0)
- 7.3: LV1-3: Izziv - Meritev karakteristične upornosti linije drugače (R_0)

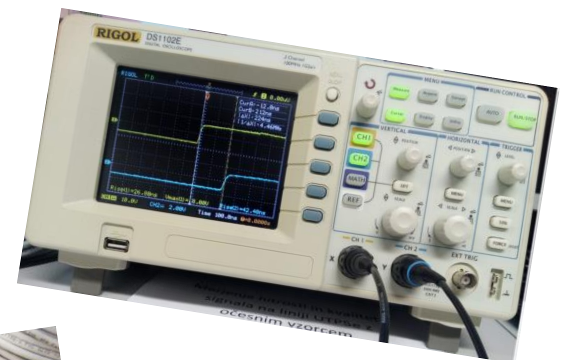
Model linije



V_S - Napetost izvora [V]
R_S - Upornost izvora - izhodna upornost oddajnika [Ω]
Z_0 - Karakteristična impedanca linije [Ω]
R_L - Upornost bremena - vhodna upornost sprejemnika [Ω]
δ - Zakasnitev signala na enoto dolžine [ns/m]
u_i - Napetost na vhodu v linijo [V]
u_1 - Napetost na izhodu linije [V]

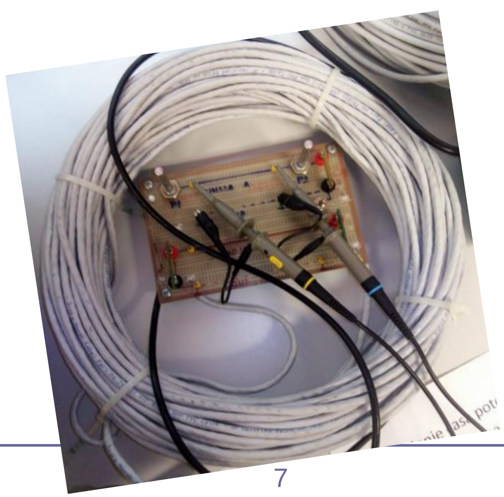
Seznam uporabljenih instrumentov:

- funkcijski generatorji HP 33120A, RIGOL DG 3101A
- osciloskopi RIGOL DS 1102E

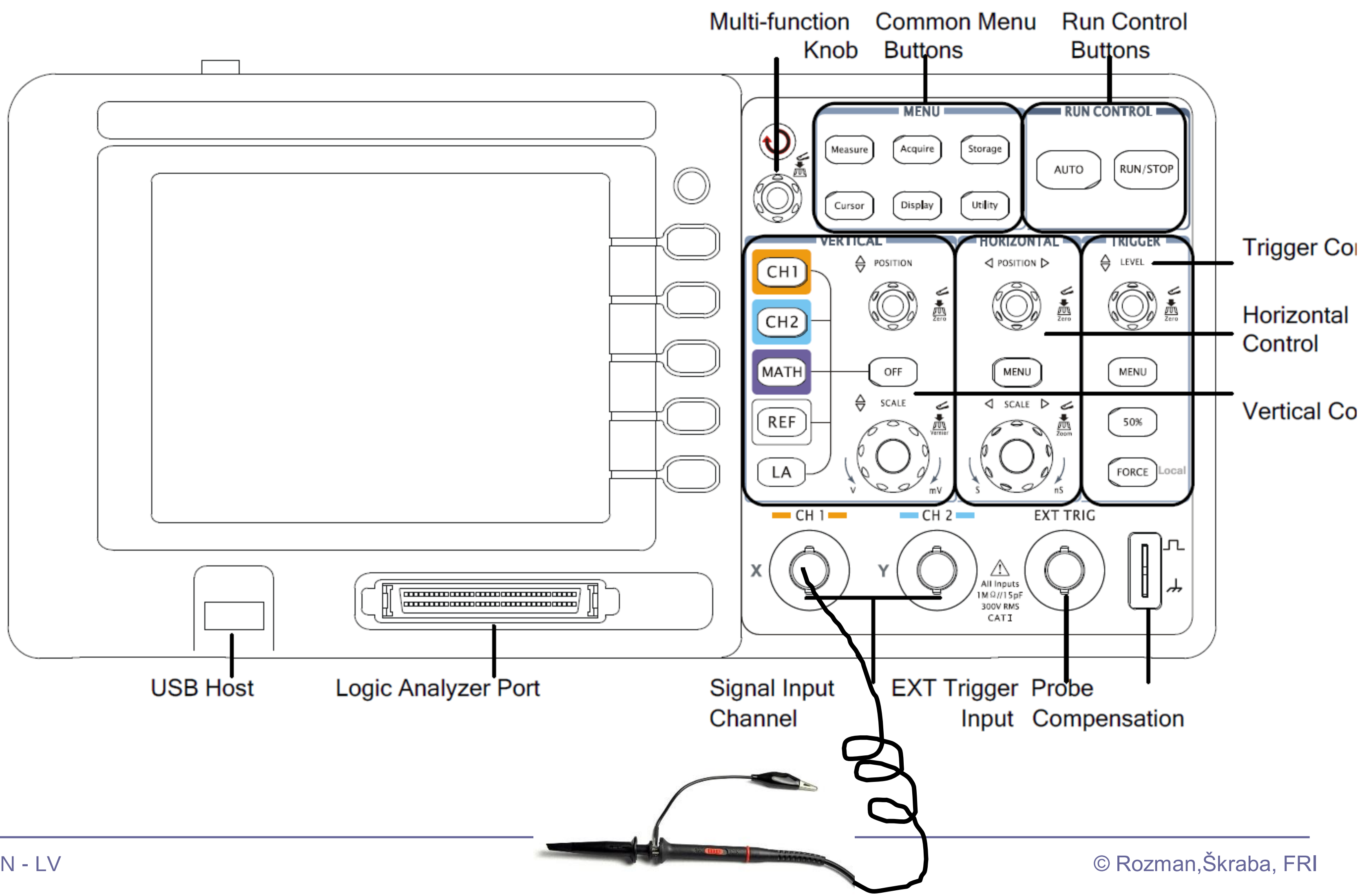


Linije

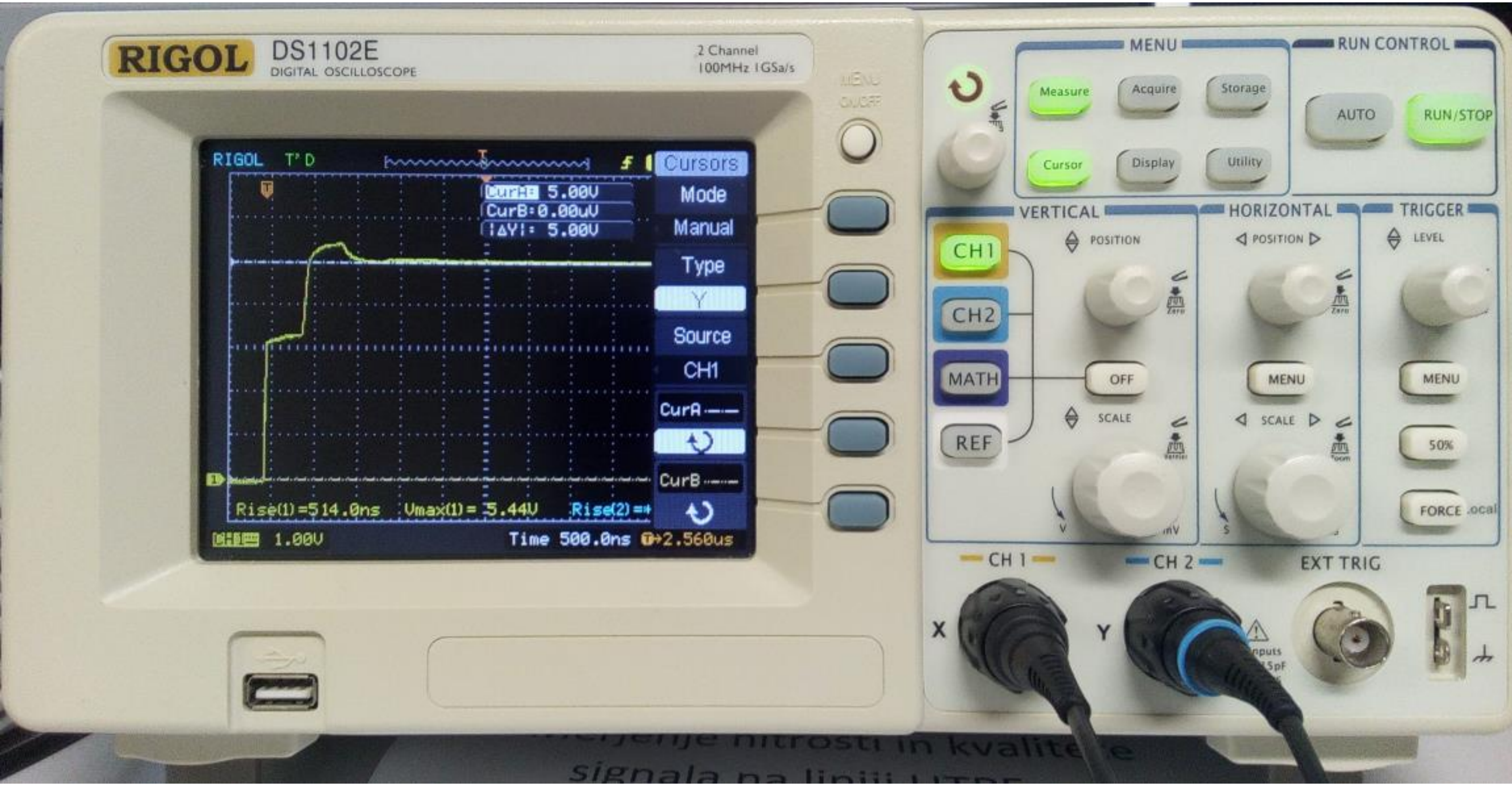
- Koaksialni kabel
- UTP Cat5e



Prednja stran osciloskopa - shema



Prednja stran osciloskopa - realna

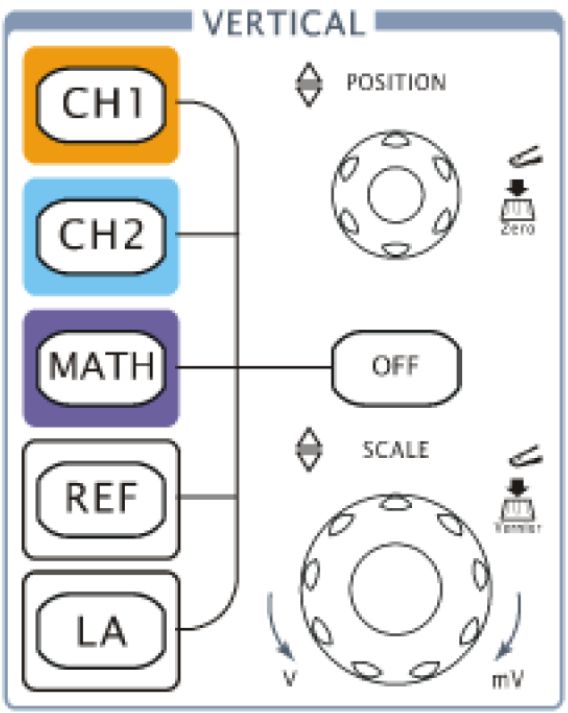


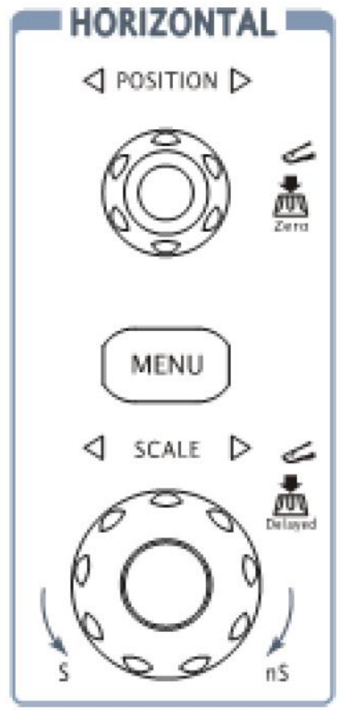
Prednja stran osciloskopa - kontrole

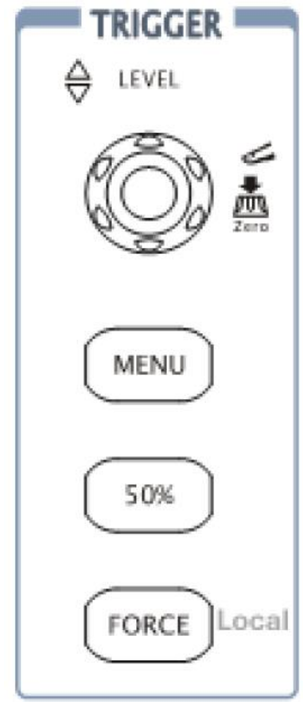
<u>Y-os (el. napetost)</u>
- **nastavitev merila [V/razdelek]**
- **pozicioniranje**

<u>X-os (čas)</u>
- **nastavitev merila [s/razdelek]**
- **pozicioniranje**

<u>Prožilnik</u>
- **začetek dogodka**
- **običajno 50%**



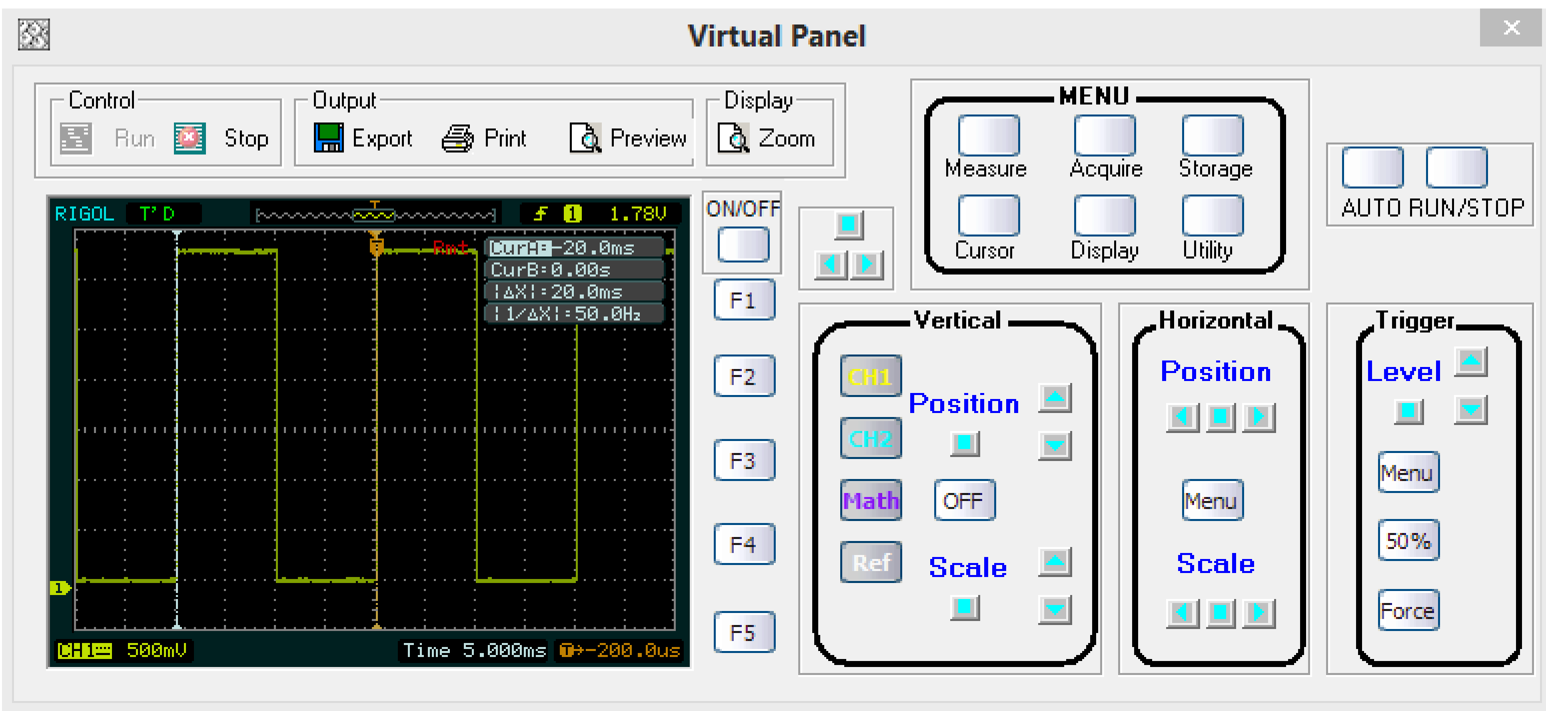




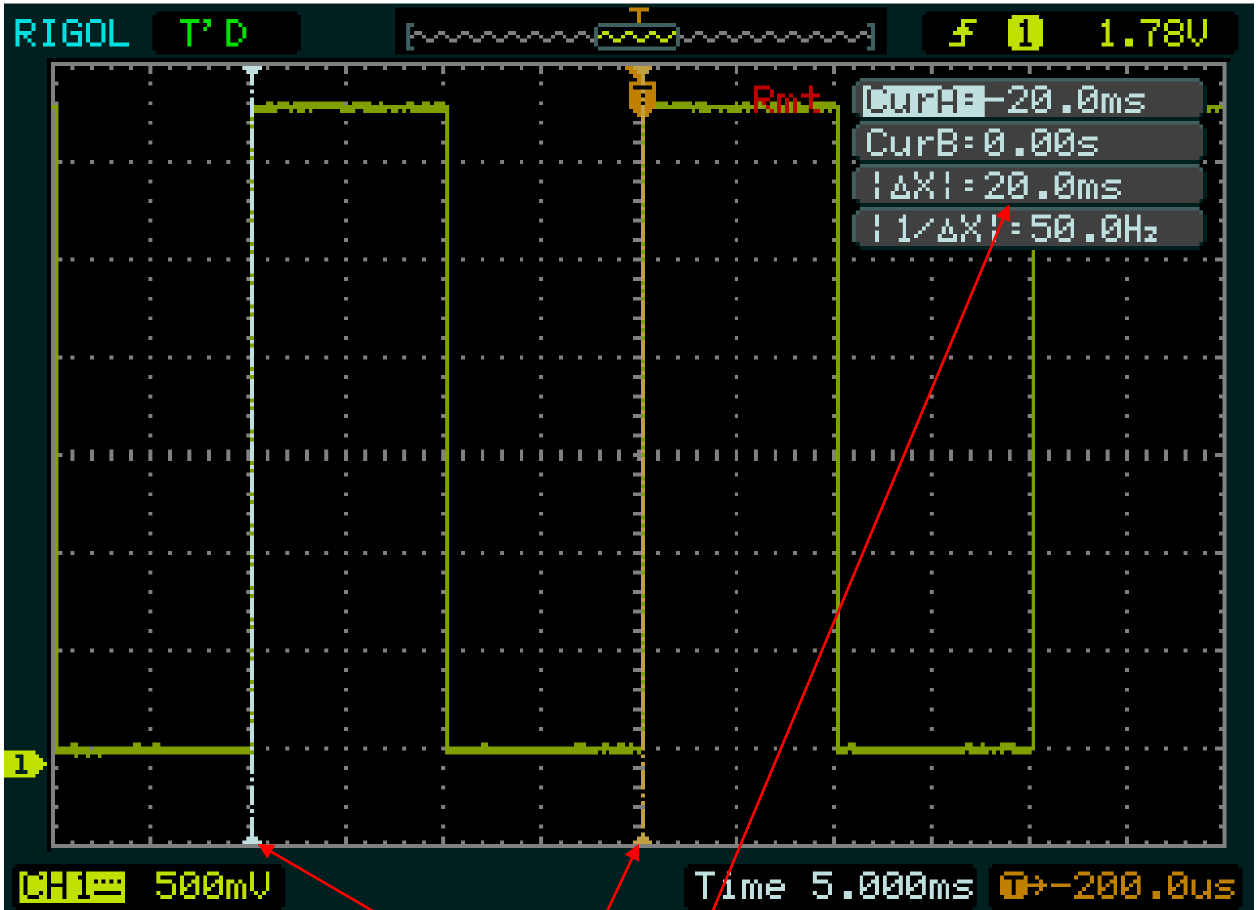
https://www.rigolna.com/products/digital-oscilloscopes/1000/
https://www.youtube.com/watch?v=TAQflYAa2VM

Spoznavanje merilne opreme…

PC aplikacija za osciloskop (USB povezava)



Zaslon osciloskopa – meritev periode



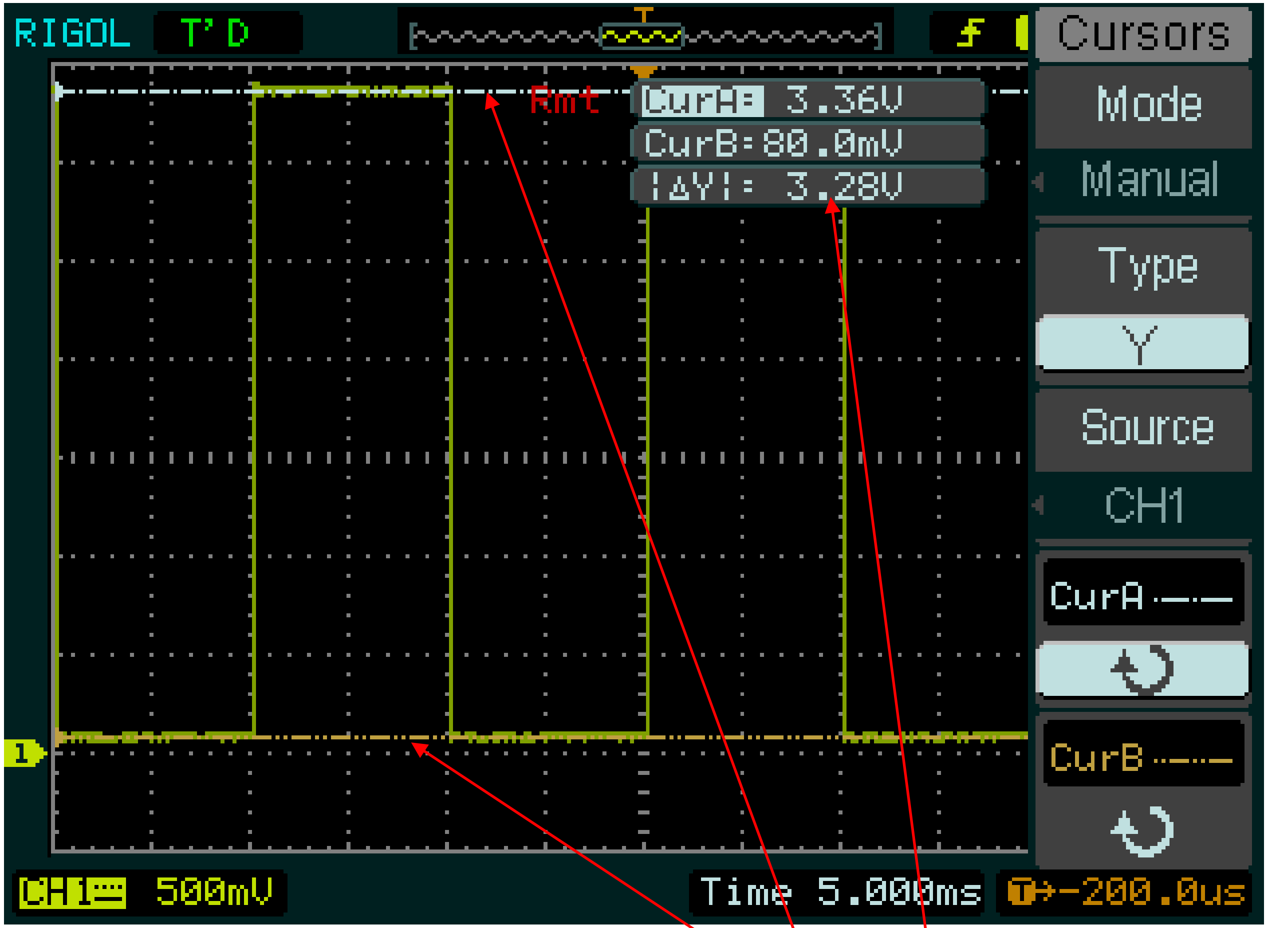
Programska nastavitev:

- **Delay 10ms**
- **Perioda 20ms**

Meritev periode signala:

- **20ms**

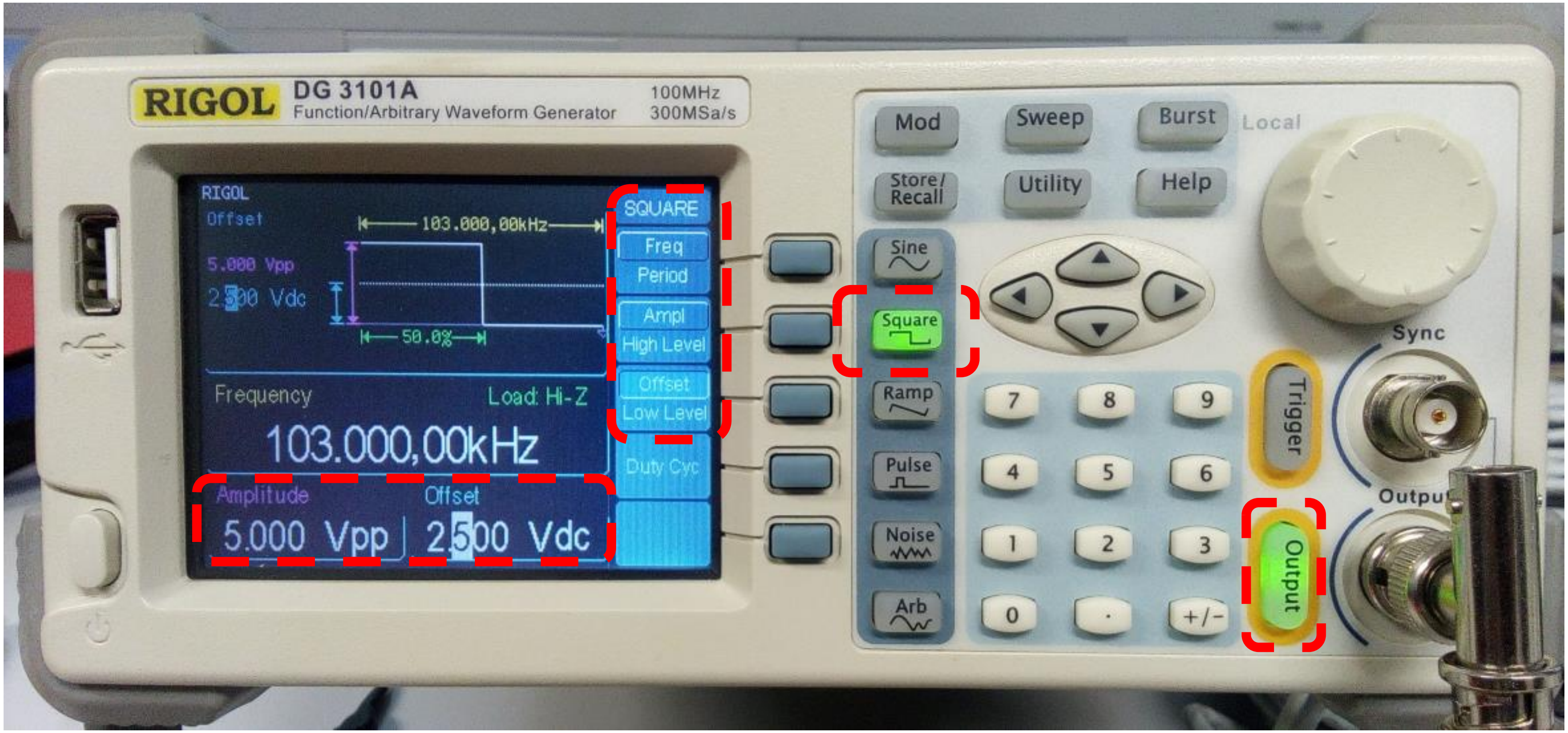
Zaslon osciloskopa – meritev amplitude



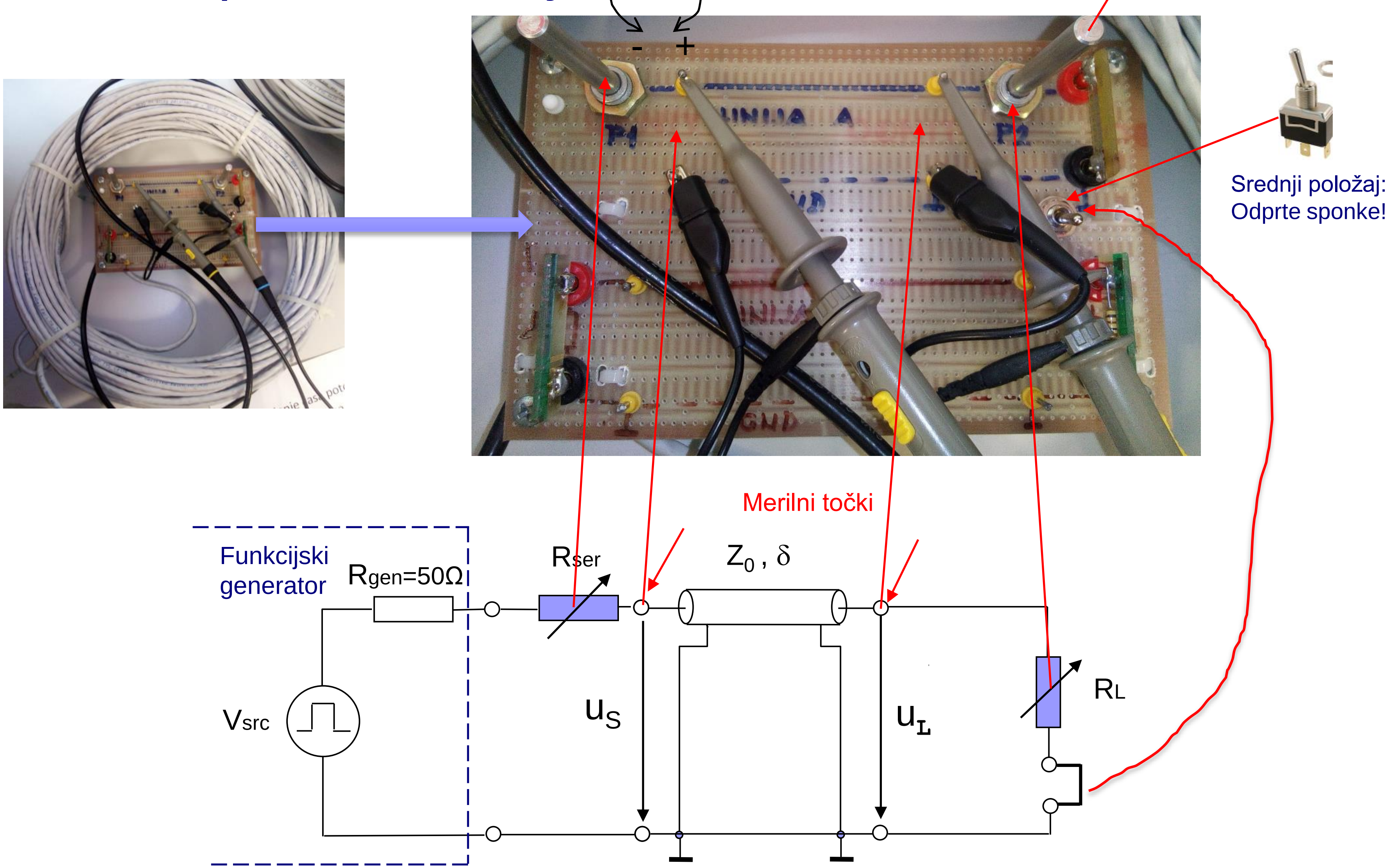
Meritev amplitude signala:

- **3.28V**

Generator signalov



Meritve prenosne linije



Laboratorijska vaja 7 - LV1

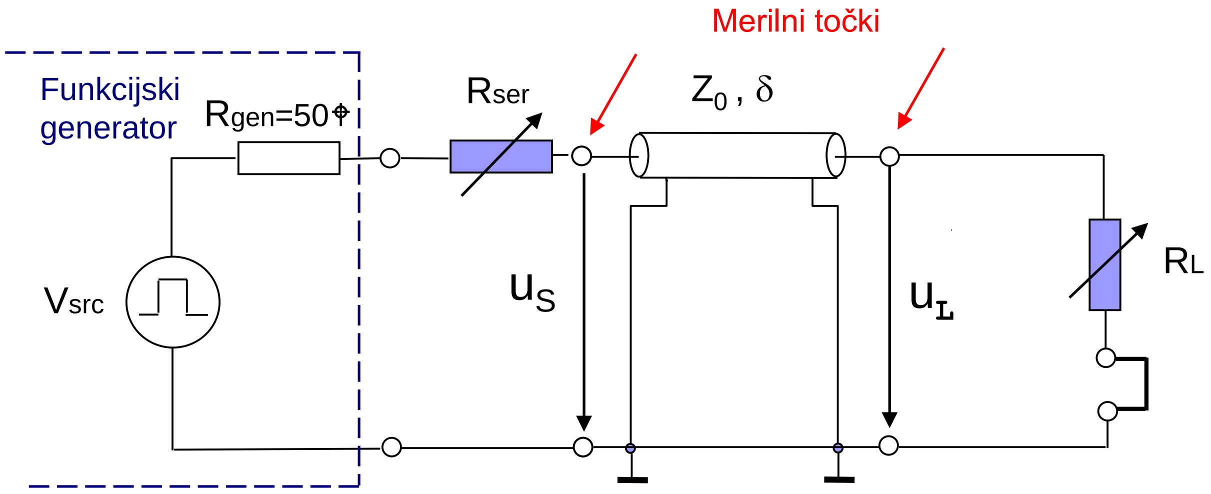
- 7.0: Uvod v meritve prenosnih linij
- 7.1: LV1-1: Meritev dolžine linije (l)
- 7.2: LV1-2: Meritev karakteristične upornosti linije (R_0)
- 7.3: LV1-3: Izziv - Meritev karakteristične upornosti linije drugače (R_0)

LV 1.1: Meritev dolžine prenosne linije

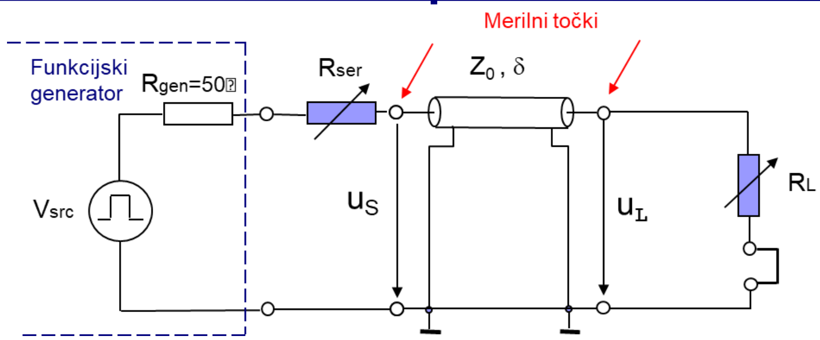
Impulzni generator uporabite kot izvor signala za napajanje linije, s pomočjo osciloskopa pa izmerite čas potovanja signala po liniji (τ). Razmislite ob kakšnih pogojih lahko najbolje opravite meritev ?

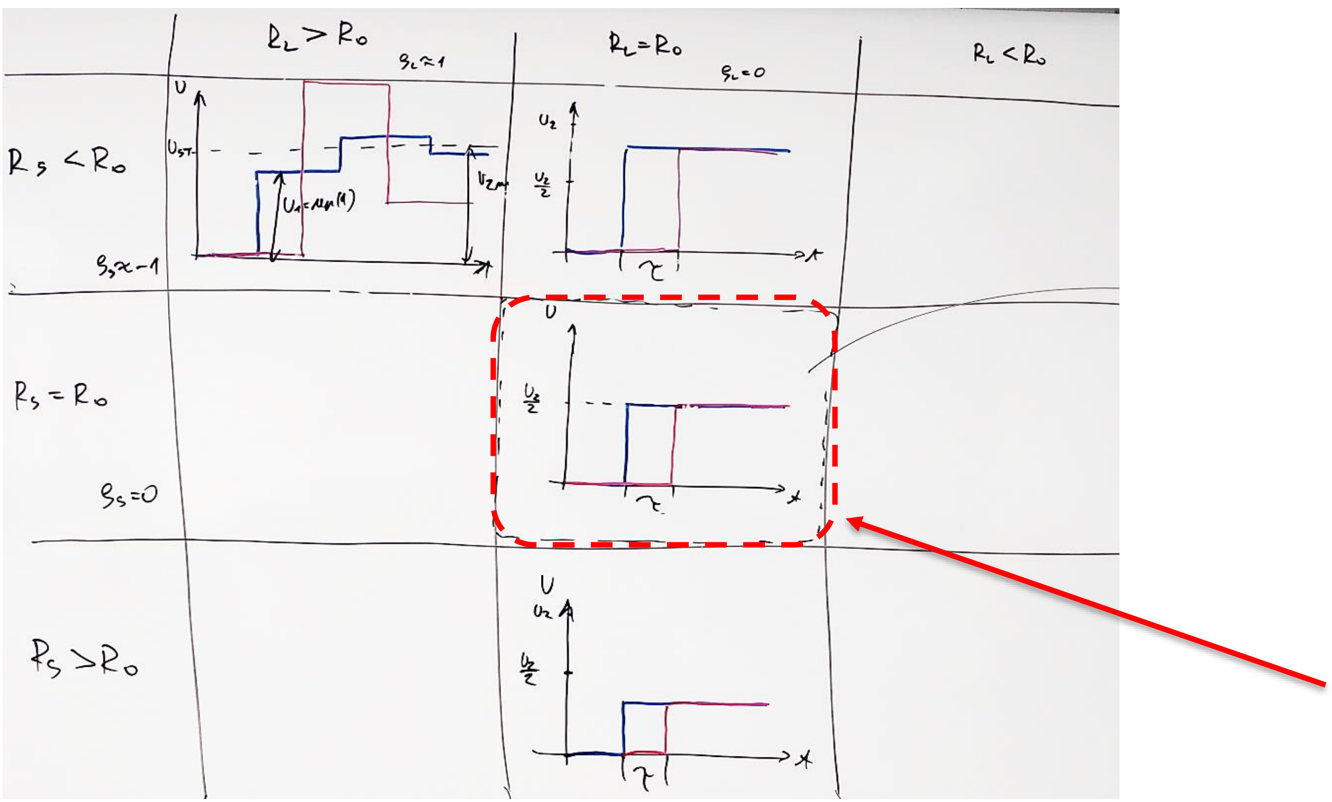
Izračunajte še dolžino prenosne linije, če poznate zakasnitev na enoto dolžine:

- Koaksialni kabel δ = 5,1ns/m (≈ 66% svetlobne hitrosti)
- Parica (UTP Cat 5e) δ = 4,8ns/m (≈ 69% svetlobne hitrosti)



LV 1.1: Meritev dolžine prenosne linije



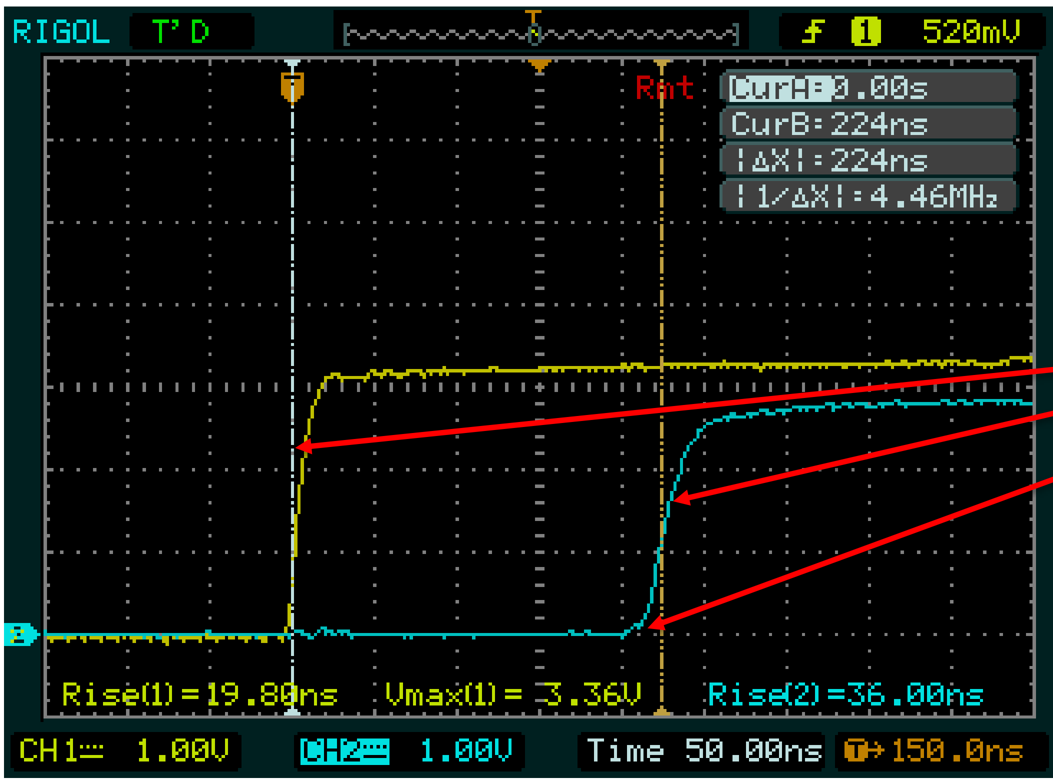


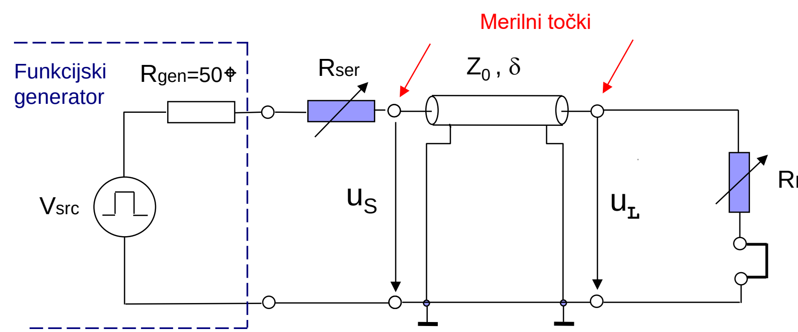
Izberemo kvadrant

LV 1.1: Meritev dolžine prenosne linije

Izračunajte še dolžino prenosne linije, če poznate zakasnitev na enoto dolžine:

- Koaksialni kabel δ = 5,1ns/m (≈ 66% svetlobne hitrosti)
- Parica (UTP Cat 5e) δ = 4,8ns/m (≈ 69% svetlobne hitrosti)





Strmini in točka meritve

Laboratorijska vaja 7 - LV1

- 7.0: Uvod v meritve prenosnih linij
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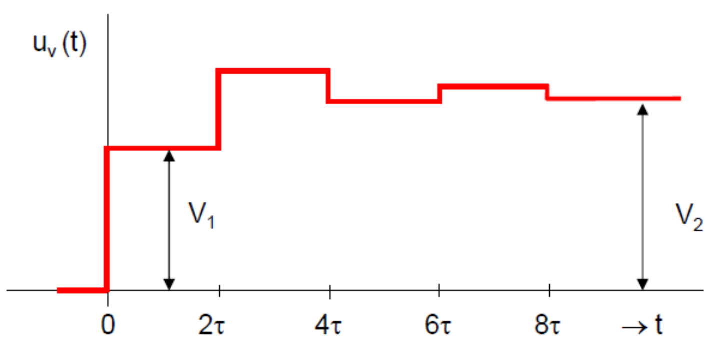
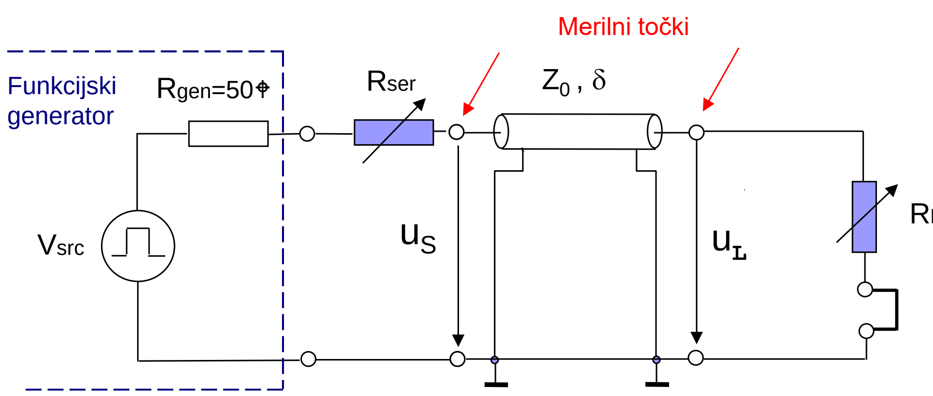
- 7.2: LV1-2: Meritev karakteristične upornosti linije (R_0)
- 7.3: LV1-3: Izziv - Meritev karakteristične upornosti linije drugače (R_0)

LV 1.2: Meritev karakteristične upornosti prenosne linije

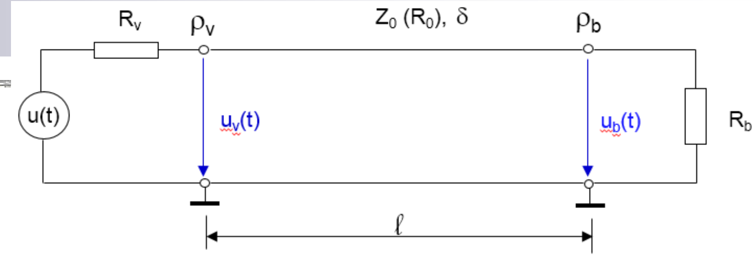
Izhodna upornost funkcijskega generatorja je R_{IZH}=50Ω, na izhodu linije pa pustite odprte sponke Rb= ∞.

S pomočjo osciloskopa izmerite napetost prvega vala V1 = u_V (0+) in napetost v stacionarnem stanju V2 = u_V (t>10 τ) na vhodu linije ter izračunajte karakteristično upornost linije R_0.

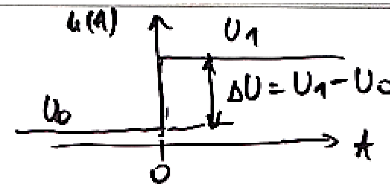




Recept analize odbojev



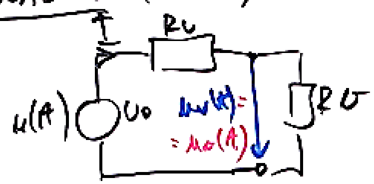
ODBOJI



FAZE:

① STACIONARNO ($t<0$, 0^-)

OHMOV ZAKON

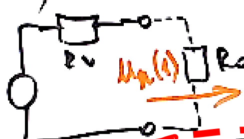


$$u_v(0^-) = u_b(0^-) = \frac{U_0}{R_v + R_b} \cdot R_b$$

② SPREMEMBA ΔU ($t=0$)

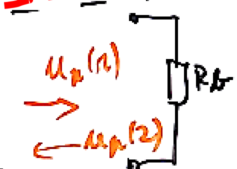
(PREM. POJAVI – ODBOJI) $\Delta U = U_1 - U_0$

$t = 0^+$:



$$u_v(0^+) = \underbrace{u_v(0^-)}_{\text{STAC.}} + \underbrace{\frac{\Delta U}{R_v + R_0} \cdot R_0}_{u_p(1)}$$

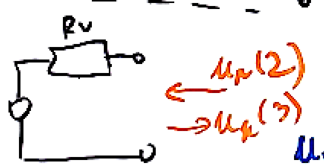
$t = \tau$:



$$u_b(\tau) = \underbrace{u_b(0^-)}_{\text{STAC.}} + \underbrace{u_p(1)}_{\text{PRIPOTUJE}} + \underbrace{u_p(1) \cdot \rho_b}_{\text{ODBOJ}}$$

$u_p(1) \cdot \rho_b = u_p(2)$

$t = 2\tau$:

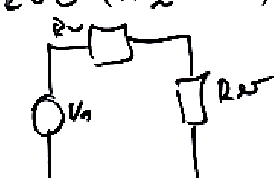


$$u_v(2\tau) = u_v(0^+) + \underbrace{u_p(2)}_{\text{PRIDE}} + \underbrace{u_p(2) \cdot \rho_v}_{\text{ODBOJ}}$$

$u_p(2) \cdot \rho_v = u_p(3)$

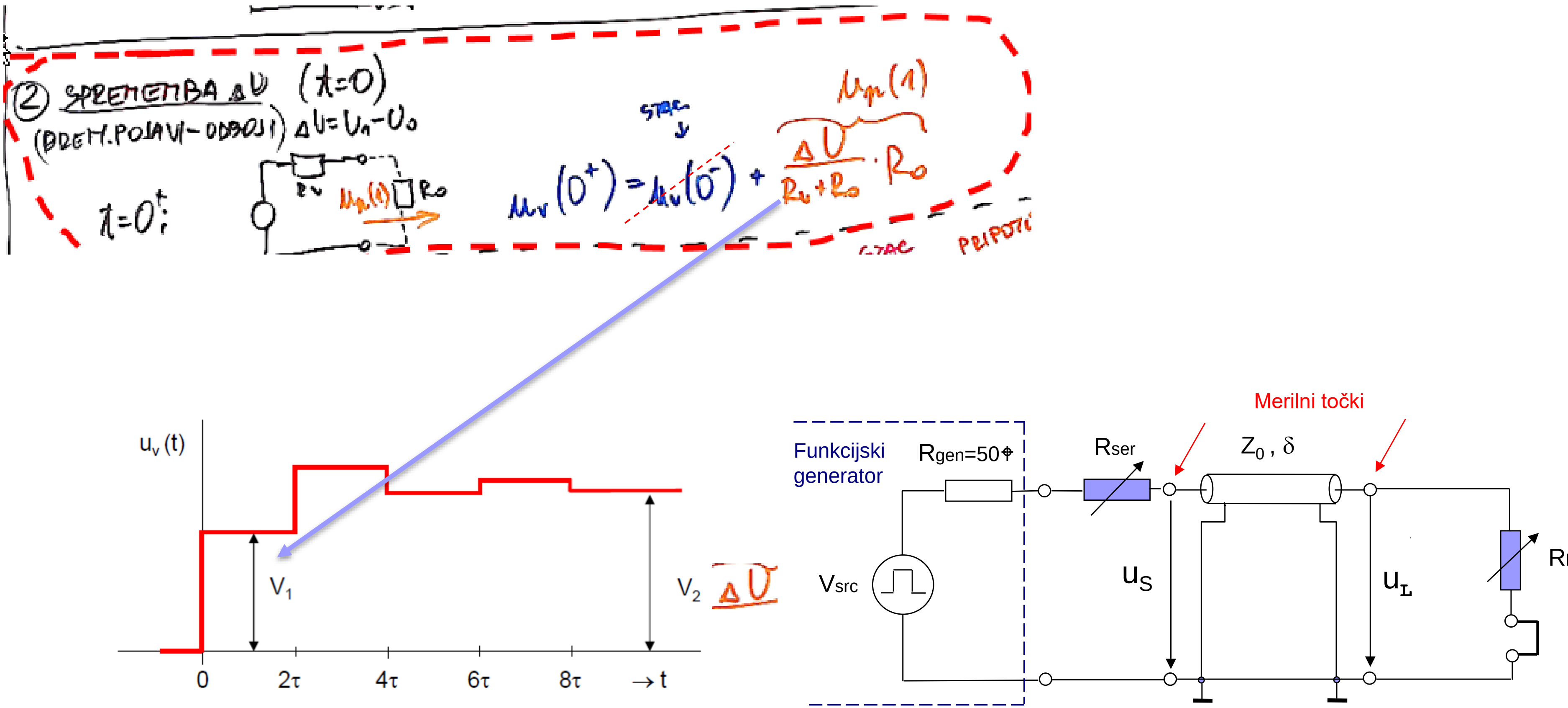
③ STACIONARNO ($t \gtrapprox 10\tau$)

OHMOV ZAKON

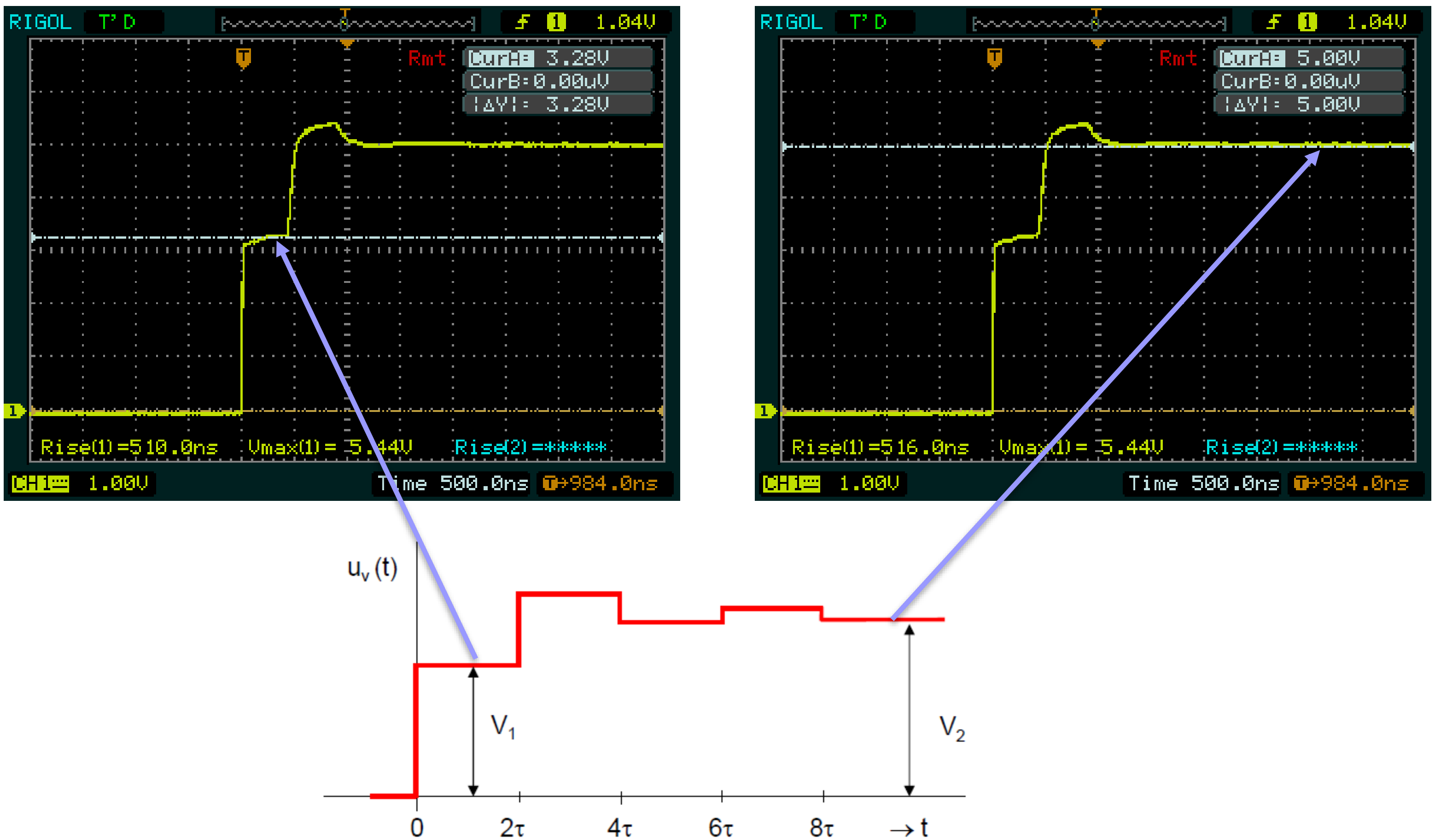


$$u_v(10\tau^+) = u_b(10\tau^+) = \frac{U_1}{R_v + R_b} \cdot R_b$$

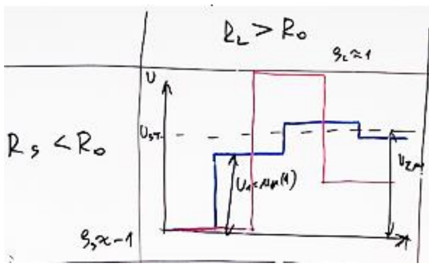
LV 1.2: Meritev karakteristične upornosti prenosne linije

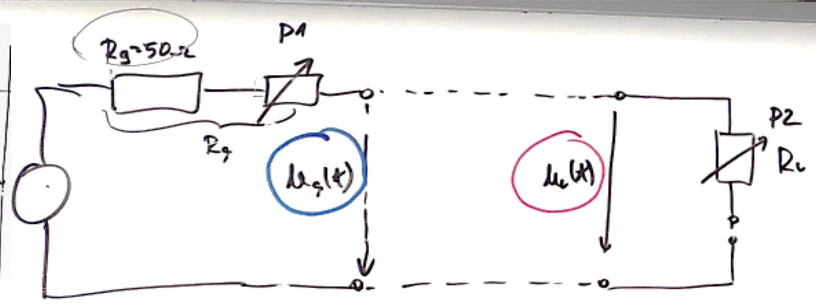


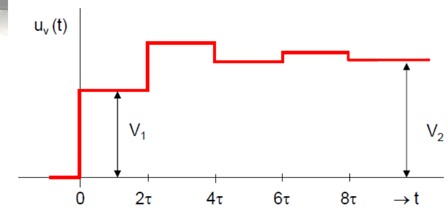
LV 1.2: Meritev karakteristične upornosti prenosne linije

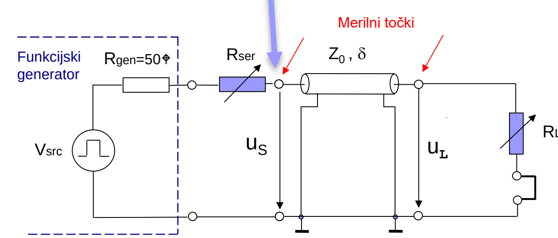


LV 1.2: Meritev karakteristične upornosti prenosne linije









$$\Delta U = U_2 - 0V \approx U_2$$

$$u_p(1) = \frac{\Delta U}{R_0 + R_s} \cdot R_0$$

$$U_1 = \frac{\Delta U}{R_0 + R_s} \cdot R_0 \quad / \cdot (R_0 + R_s)$$

$$u_s(0^-) = 0V$$

$$u_s(0^+) = u_p(1) = U_1$$

$$(R_0 + R_s) U_1 = \Delta U \cdot R_0$$

$$R_0 \cdot U_1 + R_s \cdot U_1 = \Delta U \cdot R_0$$

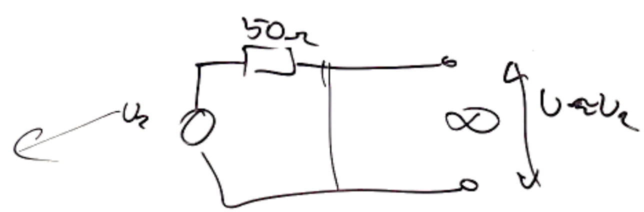
$$R_0 (U_1 - \Delta U) = - R_s \cdot U_1$$

$$R_0 (\Delta U - U_1) = R_s \cdot U_1$$

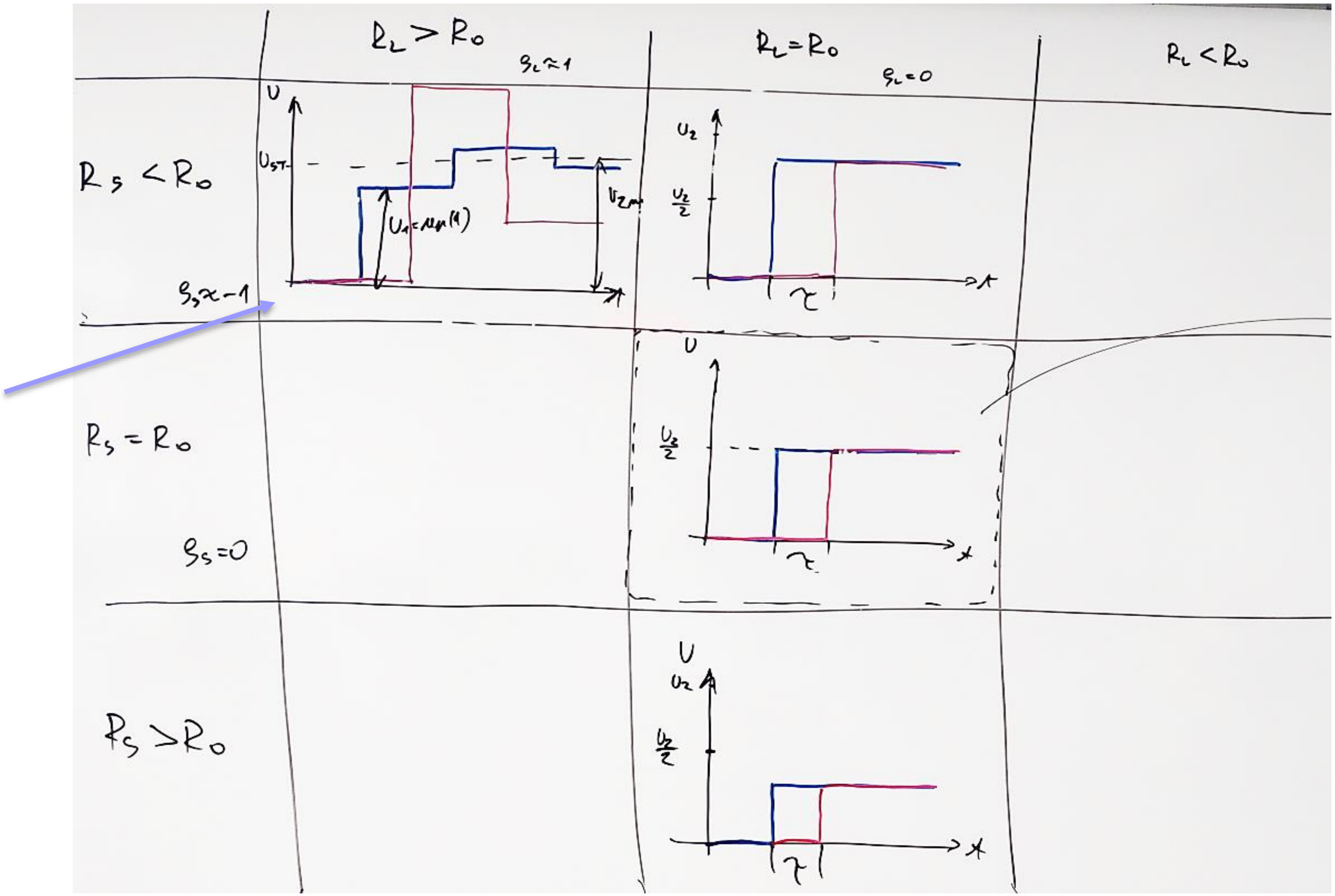
$$\boxed{R_0 = \frac{U_1 \cdot R_s}{\Delta U - U_1}}$$

$U_{2m} = U_2$ $\quad \Delta U = ?$

$R_L = \infty \Downarrow$ $\quad U_{2m} \approx U_2 = \Delta U$



LV 1.2: Meritev karakteristične upornosti prenosne linije



LV 1.2: Meritev karakteristične upornosti prenosne linije

Izhodna upornost funkcijskega generatorja je R_{IZH}=50Ω, na izhodu linije pa pustite odprte sponke Rb= ∞.

Nastavitev generatorja

Agilent 33120A
15 MHz Function /
Arbitrary Waveform Generator

User's Guide

Output Termination

Applies only to output amplitude and offset voltage. The function generator has a fixed output impedance of 50 ohms on the *OUTPUT* terminal. You can specify whether **you** are terminating the output into a 50 ohm load or an open circuit. Incorrect impedance matching between the function generator and your load will result in an amplitude or offset which does not match the specified signal level.

- Output termination: **50Ω** or High impedance. *The default is 50Ω.* See the table on page 59 for a list of amplitude limits for all functions.

- If you specify a 50 ohm termination but are actually terminating into an open circuit, the displayed output will be *twice* the value specified. For example, if you set the offset to 100 mVdc (and specify a 50 ohm termination) but are actually terminating the output into an open circuit, the actual displayed offset will be 200 mVdc.

Shift / Menu On/Off — **1 Turn on the menu.**

`A: MOD MENU`

> > > — **2 Move across to the SYS MENU choice on this level.** [1]

`D: SYS MENU`

∨ — **3 Move down a level to the OUT TERM command.**

`1: OUT TERM`

∨ > — **4 Move down a level and then across to the HIGH Z choice.** [1]

With the output termination set to "HIGH Z", the function generator allows you to set the unloaded (open circuit) output voltage.

`HIGH Z`

Enter — **5 Save the change and turn off the menu.**

LV 1.2: Meritev karakteristične upornosti prenosne linije

Izhodna upornost funkcijskega generatorja je R_{IZH}=50Ω, na izhodu linije pa pustite odprte sponke Rb= ∞.

Nastavitev generatorja

RIGOL

DG4000 Series

User's Guide **Function/Arbitrary Waveform Generator**

5. CH1 Output

BNC connector with 50Ω nominal output impedance.

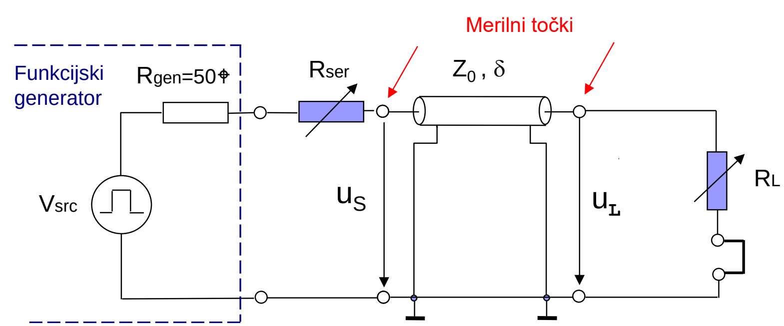
When **Output1** is enabled (the backlight turns on), this connector output waveform according to the current configuration of CH1.

RIGOL DG3000 Series Function/Arbitrary

User's Guide Waveform Generator

1. To Set the Output Load

For the [Output] Connector on the Front panel, the Generator has a built-in 50Ω series impendence. If the actual load does not match the set one, the displayed amplitude and offset are incorrect. This function is used to match the displayed voltage with the expected one.

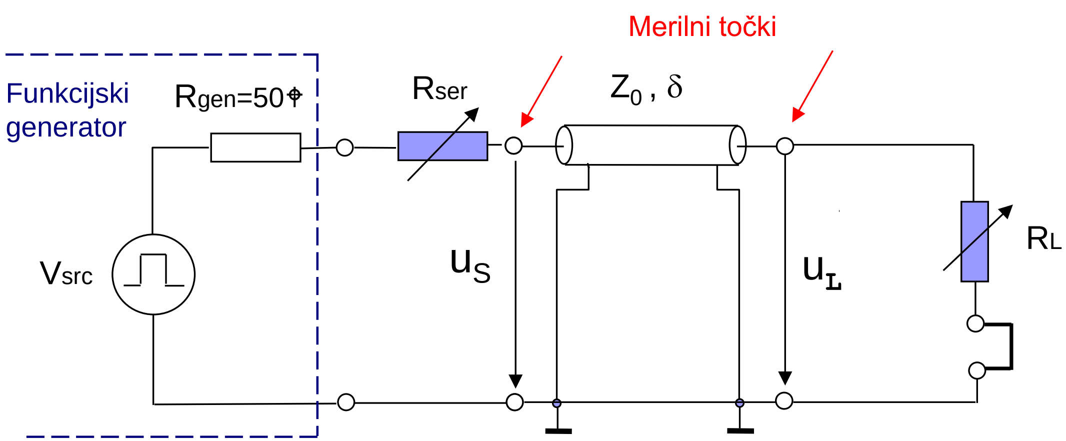


Laboratorijska vaja 7 - LV1

- 7.0: Uvod v meritve prenosnih linij
- 7.1: LV1-1: Meritev dolžine linije (l)
- 7.2: LV1-2: Meritev karakteristične upornosti linije (R_0)
- 7.3: LV1-3: Izziv - Meritev karakteristične upornosti linije drugače (R_0)

LV 1.3: Meritev karakteristične upornosti prenosne linije

Izziv: ali bi lahko še na kakšen drug način izmerili karakteristično upornost linije ?



LV1 - Meritve dolžine in karakteristične upornosti prenosne linije

1. Domača naloga

VHODNO – IZHODNE NAPRAVE

POROČILO Z LABORATORIJSKIH VAJ

LAB. VAJA LV1, LV2
Dolžina linije, karakteristična impedanca, odboji

PRIIMEK IN IME ______________________________

VPISNA ŠTEVILKA ______________

SKUPINA ŠT. ____

Vhodno izhodne naprave

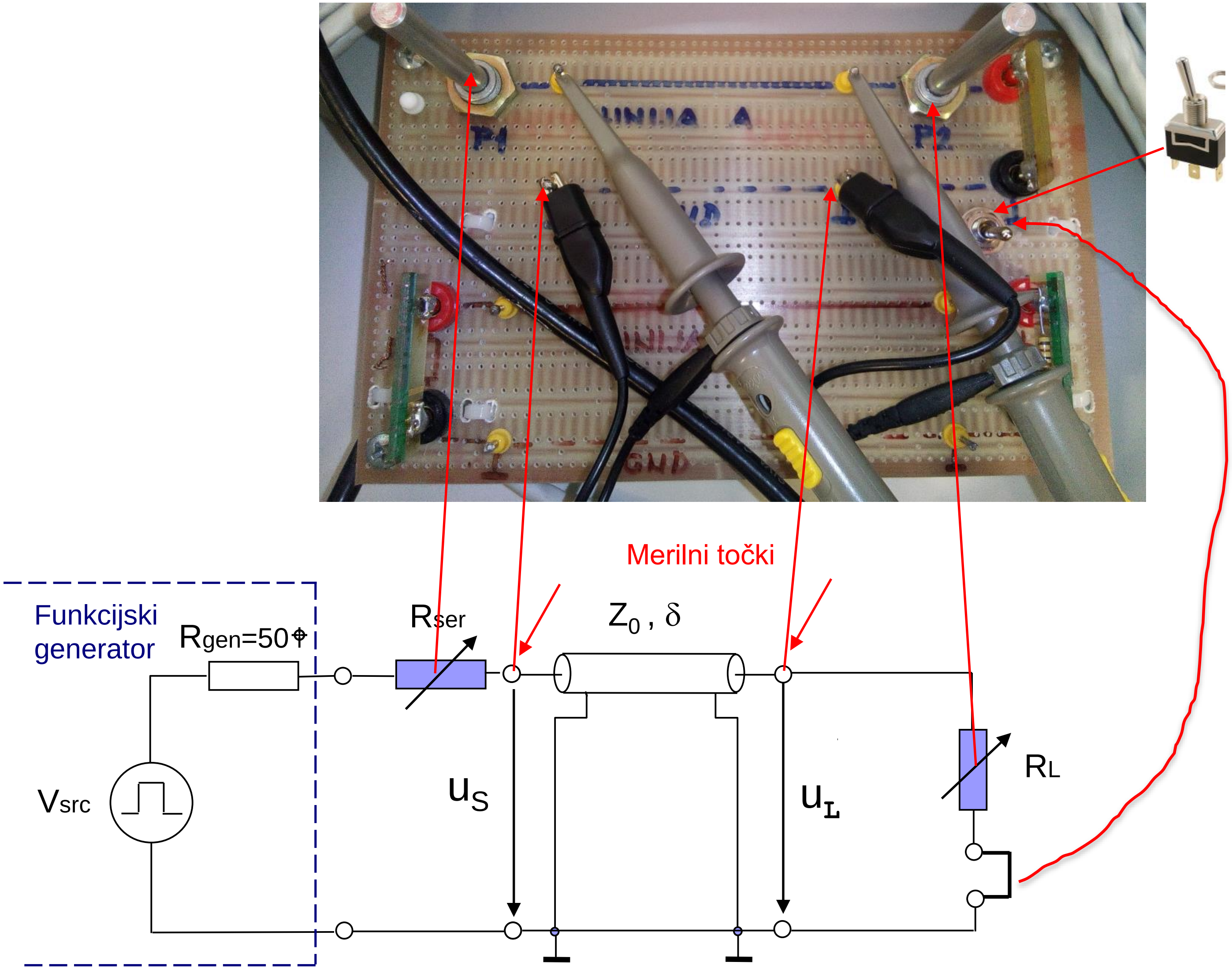
Laboratorijski vaja 8 - LV2

Meritve različnih situacij z odboji

Laboratorijska vaja 8 - LV2

- 8.1: LV2 : Meritve odbojev (razmerja Rv, Rb)
- 8.2: LV2 : Vpliv časa vzpona/padca – omejevanje odbojev
- 8.3: Odboji v praksi - omejevanje (zaključitve, „slew rate“)

Meritve prenosne linije



Stikala – položaji:

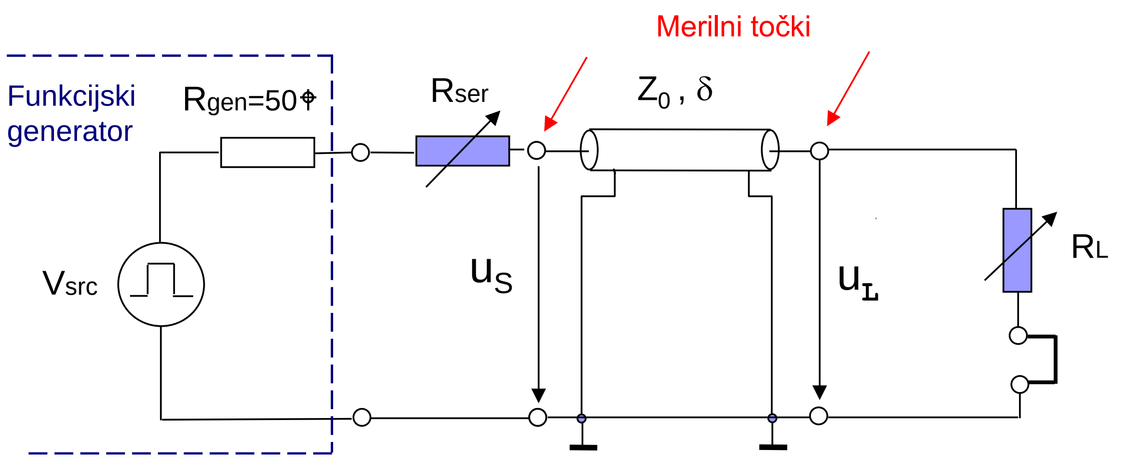
- 0 … RL= R(P2)
- Srednji položaj:
  odprte sponke (R_L=∞)
- 1 … RL= R(P2) + 22E

Potenciometri:

R(P1) = 0 … 500E
R(P2) = 0 … 500E

LV 2-1: Merjenje odbojev pri različnih odbojnih koeficientih na vhodu in izhodu linije

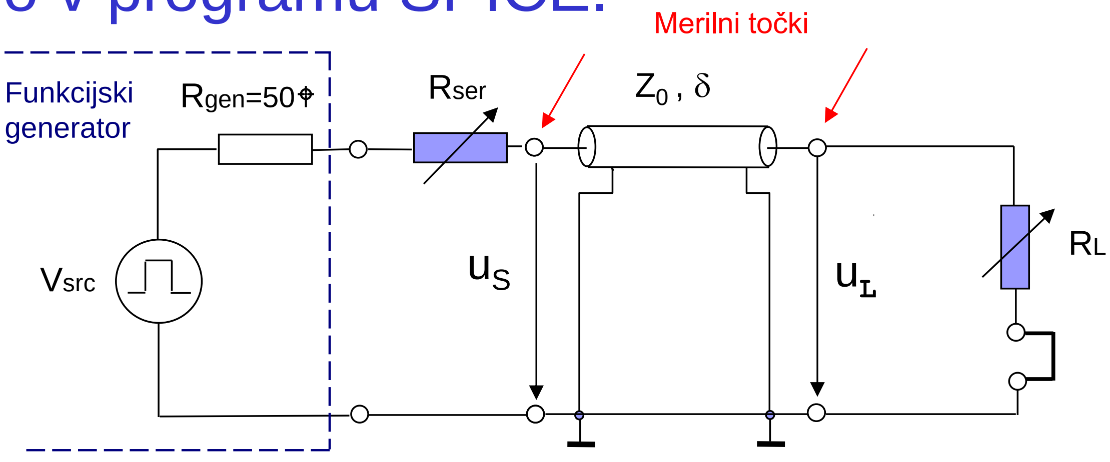
- Impulzni generator uporabite kot izvor signala za napajanje linije, z osciloskopom pa določite potek signala in izmerite napetostne nivoje na vhodu v linijo in na izhodu. Izhodna upornost impulznega generatorja je $R_{gen} = 50\Omega$.

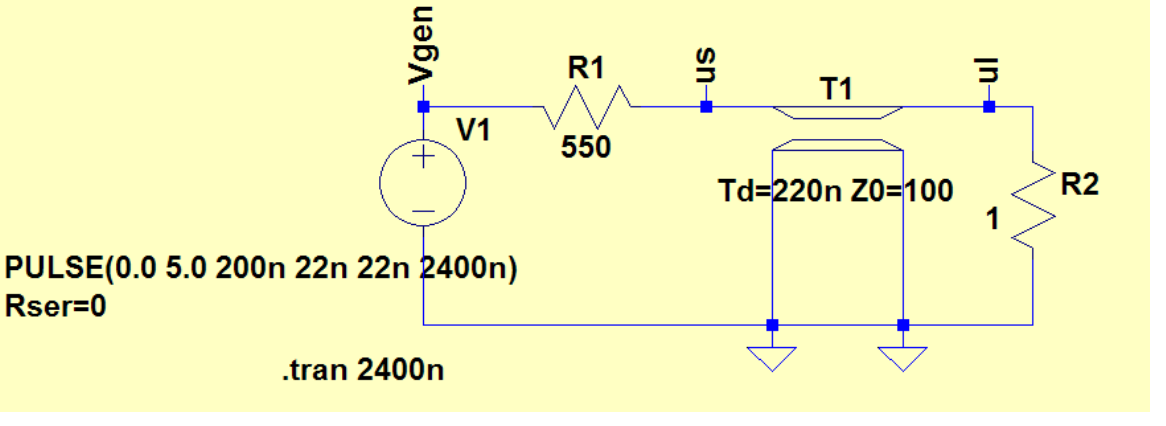


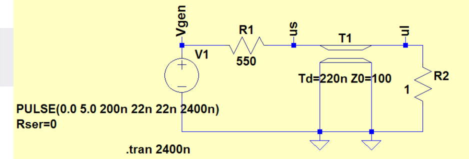
- Izmerite in narišite potek u_S (t) in u_L(t) za vseh devet kombinacij R_S in R_L. Vse to ponovite tudi s simulacijo v programu SPICE.

----	$R_L > R_0$	$R_L = R_0$	$R_L < R_0$
$R_S < R_0$			
$R_S = R_0$			
$R_S > R_0$			

Izmerite in narišite potek u_S (t) in u_L(t) za vseh devet kombinacij R_S in R_L. Vse to ponovite tudi s simulacijo v programu SPICE.



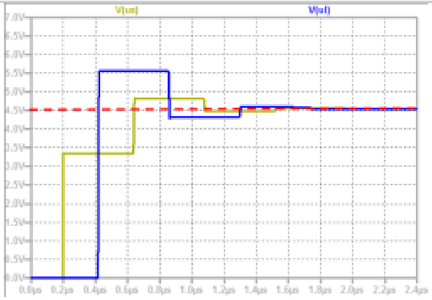
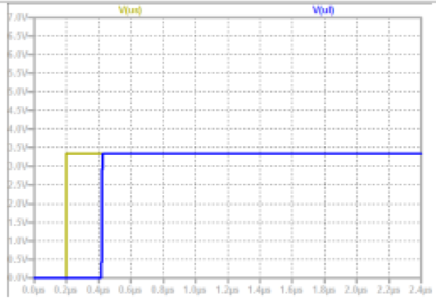
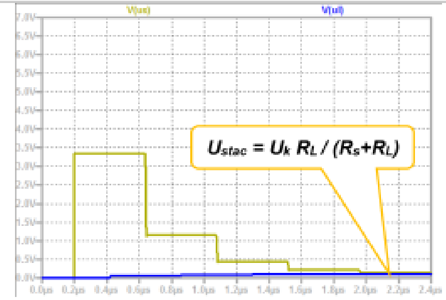
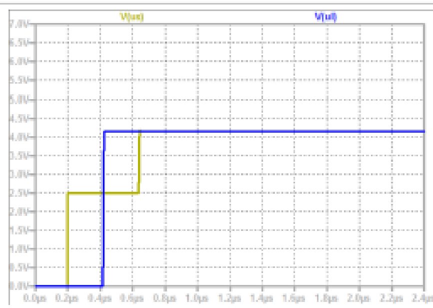
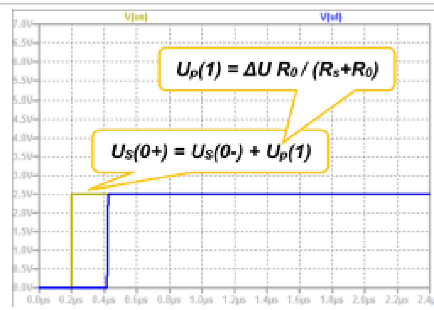
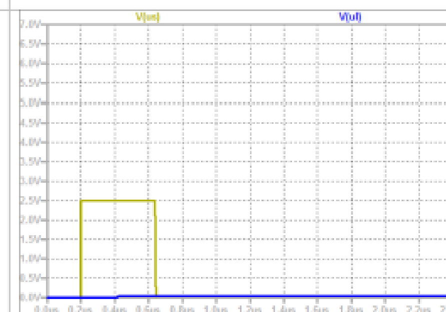
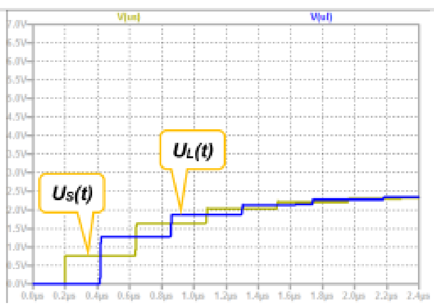
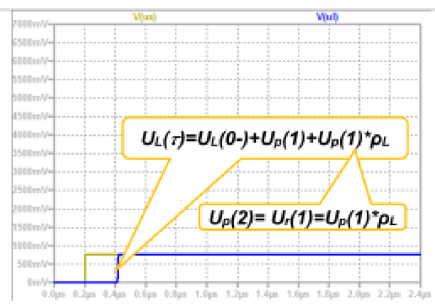
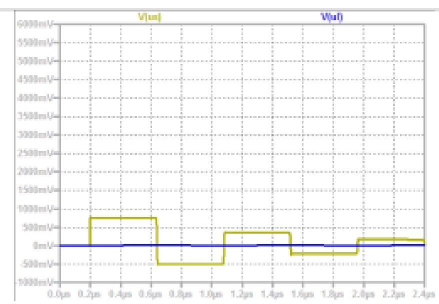




…Vse to ponovite tudi s simulacijo v programu SPICE.

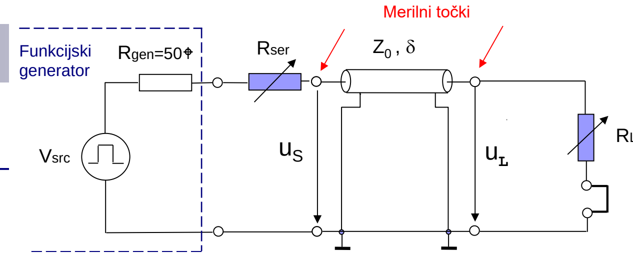
SPICE Simulacije slik iz osciloskopa: UTP kabel, R_S= 50..550 Ω , R_L = 1..500 Ω

Napetost se že pravilno porazdeli, z zakasnitvijo 1 τ se pojavi tudi na izhodu.

R_0=100Ω R_L,R_S=0,50,500Ω	$R_L > R_0$, R_L=500Ω ρ_L=0.666 (poz. odboj)	$R_L = R_0$ ρ_L=0 (ni odboja)	$R_L < R_0$, R_L=1Ω ρ_L=-0.98 (neg. odboj)
Višje potujoče napetosti $R_S < R_0$ R_S=50 Ω ρ_S=-0.333 [0.5V/razdelek]			
$R_S = R_0$ ρ_S=0 [0.5V/razdelek]			
Nizke potujoče napetosti $R_S > R_0$ R_S=550 Ω ρ_S=0.692 [0.5V/razdelek]			

(LV2) - Merjenje odbojev na liniji

…še s praktičnimi meritvami.



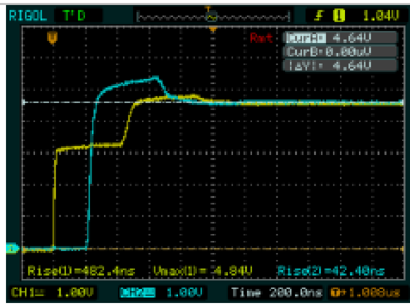
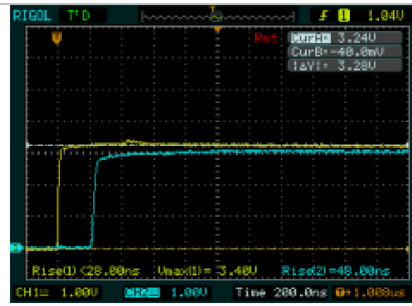
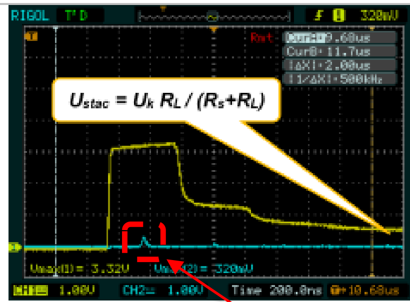
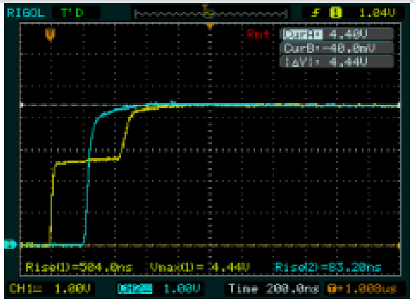
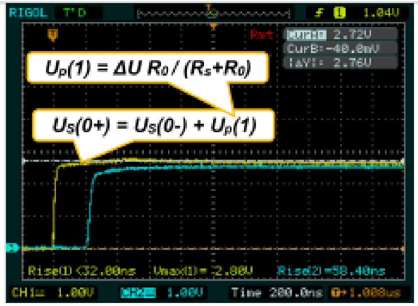
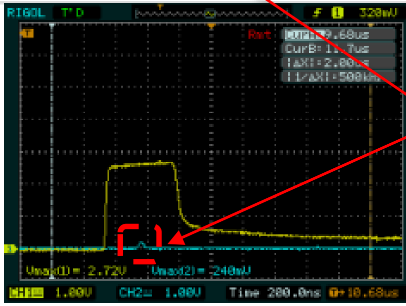
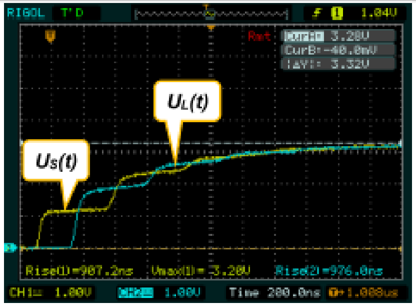
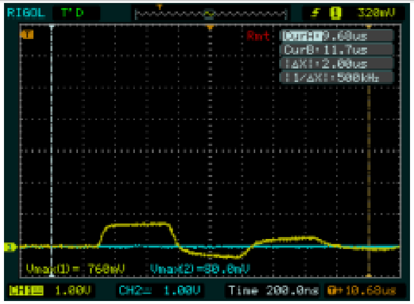
Stikala – položaji:
- 0 … RL= R(P2)
- Srednji položaj: odprte sponke (R_L=∞)
- 1 … RL= R(P2) + 22E

Potenciometri:

R(P1) = 0 … 500E
R(P2) = 0 … 500E

Slike osciloskopa: UTP kabel, R_S= 50..550 Ω , R_L = 1..500 Ω (R_{gen}=50 Ω) UTP

Napetost se že pravilno porazdeli, z zakasnitvijo 1τ se pojavi tudi na izhodu.

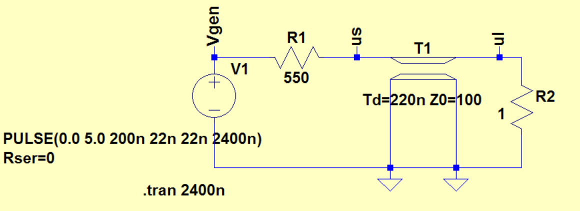
R_0=100Ω R_L,R_S=0,50,500Ω	$R_L > R_0$, R_L=500Ω ρ_L=0.666 (poz. odboj)	$R_L = R_0$ ρ_L=0 (ni odboja)	$R_L < R_0$, R_L=1Ω ρ_L=-0.98 (neg. odboj)
$R_S < R_0$ R_S=50 Ω ρ_S=-0.333 [1V/razdelek]			
$R_S = R_0$ ρ_S=0 [1V/razdelek]			
$R_S > R_0$ R_S=550 Ω ρ_S=0.692 [1V/razdelek]			

Višje potujoče napetosti

Nizke potujoče napetosti

Odboj
ρ ≈ -1

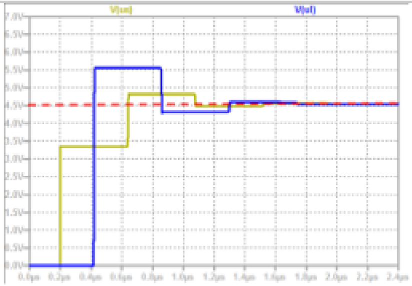
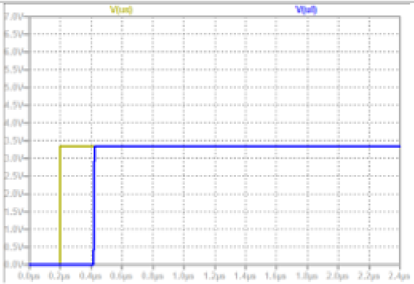
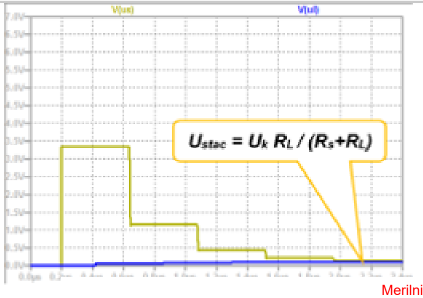
Primerjava: Simulacija - Meritve.

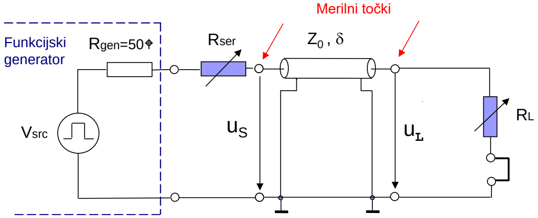


SPICE Simulacije slik iz osciloskopa: UTP kabel, R_S= 50..550 Ω , R_L = 1..500 Ω

Napetost se že pravilno porazdeli, z zakasnitvijo 1τ se pojavi tudi na izhodu.

Višje potujoče napetosti

R_0=100Ω R_L,R_S=0,50,500Ω	$R_L > R_0$, R_L=500Ω ρ_L=0.666 (poz. odboj)	$R_L = R_0$ ρ_L=0 (ni odboja)	$R_L < R_0$, R_L=1Ω ρ_L=-0.98 (neg. odboj)
$R_S < R_0$ R_S=50 Ω ρ_S=-0.333 [0.5V/razdelek]			



Slike osciloskopa: UTP kabel, R_S= 50..550 Ω , R_L = 1..500 Ω (R_{gen}=50 Ω) UTP

Napetost se že pravilno porazdeli, z zakasnitvijo 1τ se pojavi tudi na izhodu.

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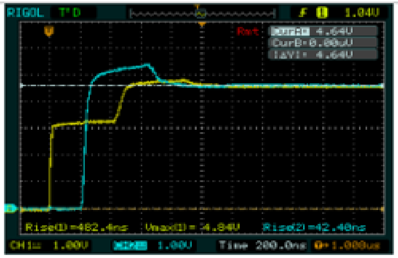
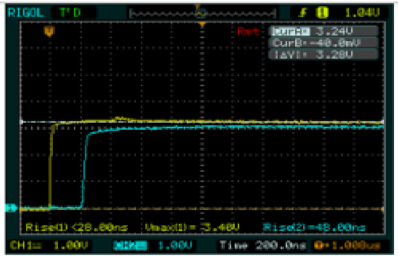
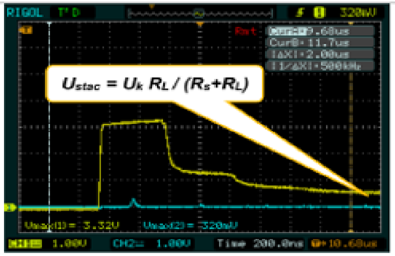
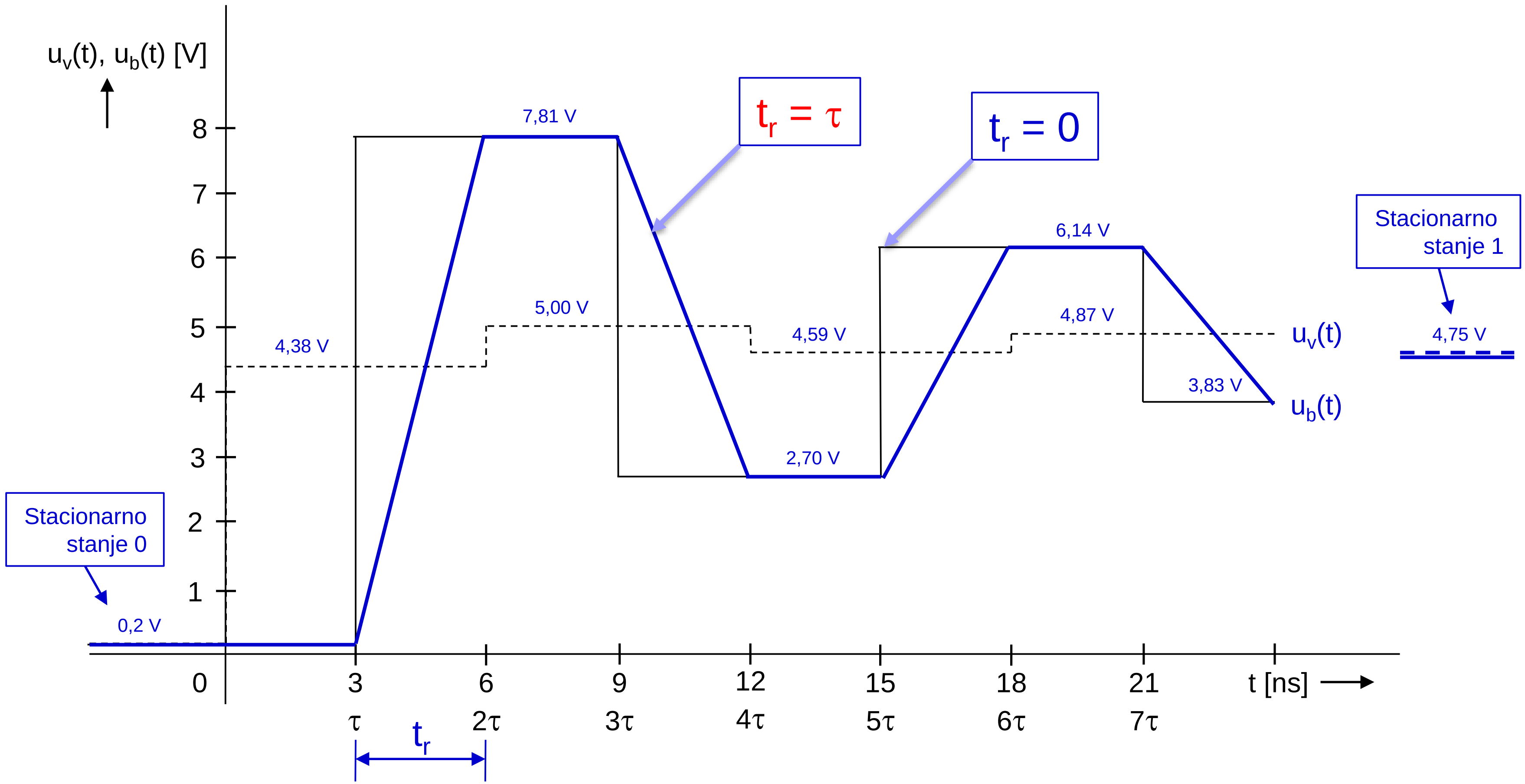
R_0=100Ω R_L,R_S=0,50,500Ω	$R_L > R_0$, R_L=500Ω ρ_L=0.666 (poz. odboj)	$R_L = R_0$ ρ_L=0 (ni odboja)	$R_L < R_0$, R_L=1Ω ρ_L=-0.98 (neg. odboj)
$R_S < R_0$ R_S=50 Ω ρ_S=-0.333 [1V/razdelek]			

Laboratorijska vaja 8 - LV2

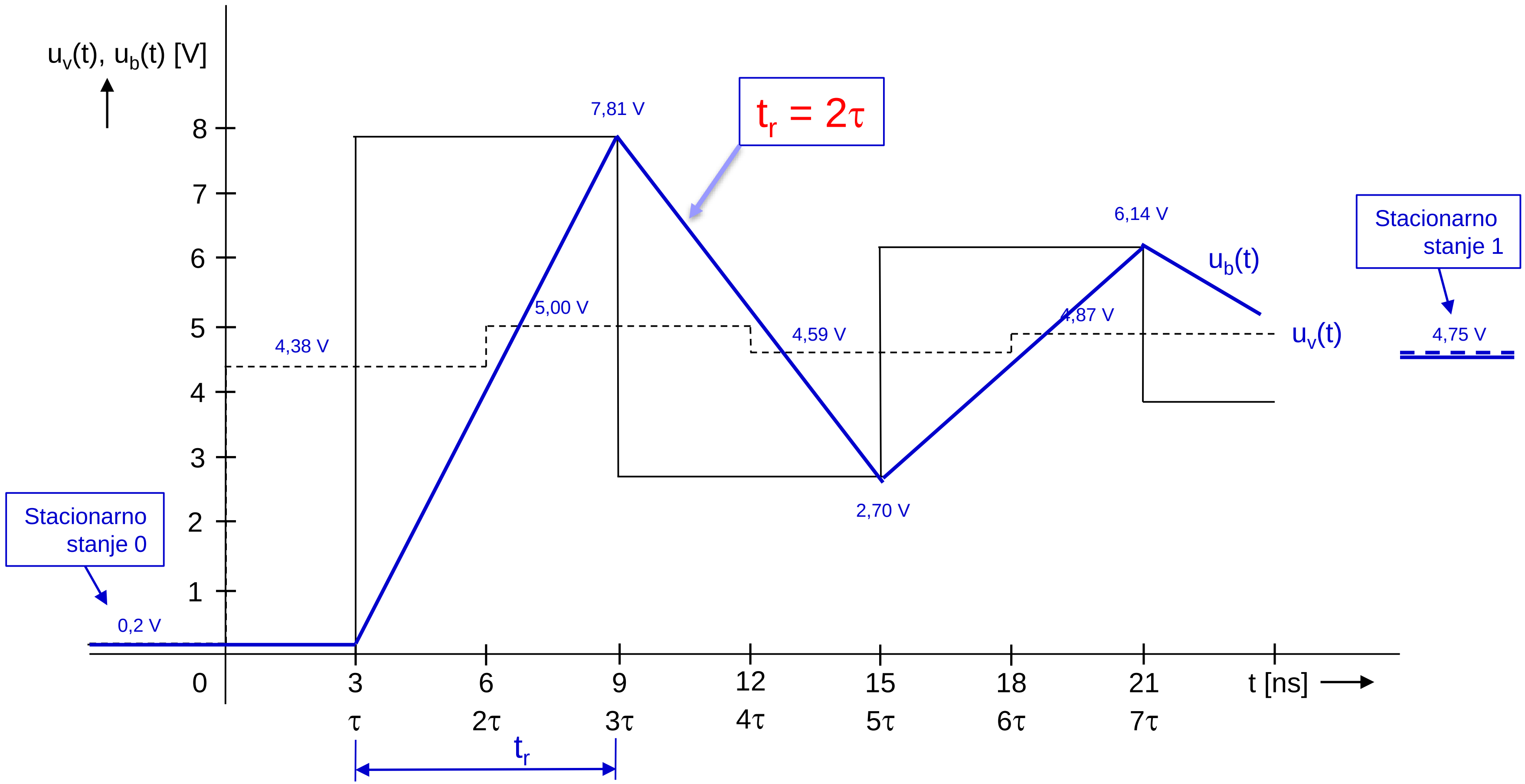
- 8.1: LV2 : Meritve odbojev (razmerja Rv, Rb)
- 8.2: LV2 : Vpliv časa vzpona/padca – omejevanje odbojev
- 8.3: Odboji v praksi - omejevanje (zaključitve, „slew rate“)

Ponovitev – predavanja

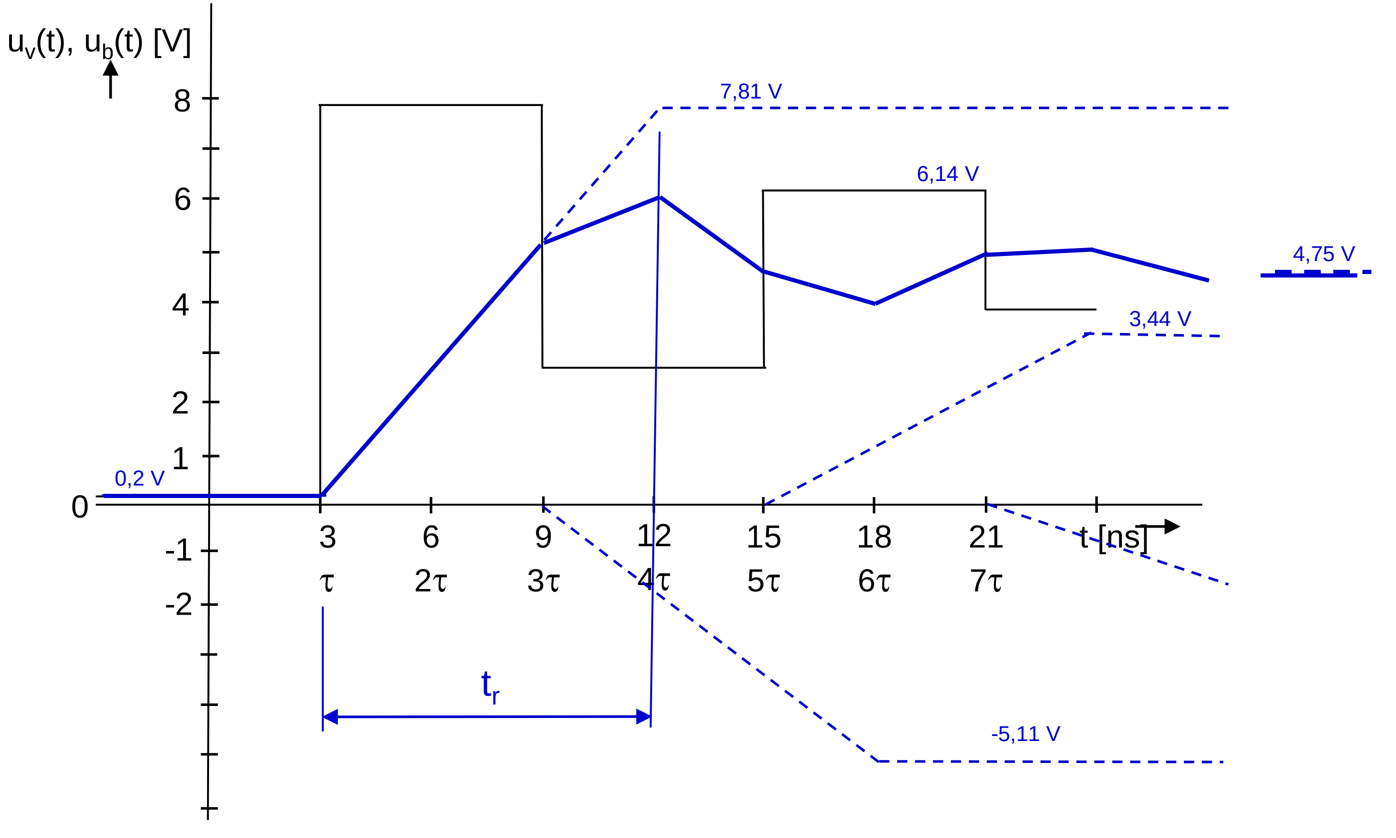
Časovni diagram poteka napetosti na izhodu iz linije do časa t =7τ, če je čas vzpona signala enak času potovanja signala po liniji $t_r = \tau$.



Časovni diagram poteka napetosti izhodu iz linije do časa t =7τ, če je čas vzpona signala enak času potovanja signala po liniji $t_r = 2\tau$

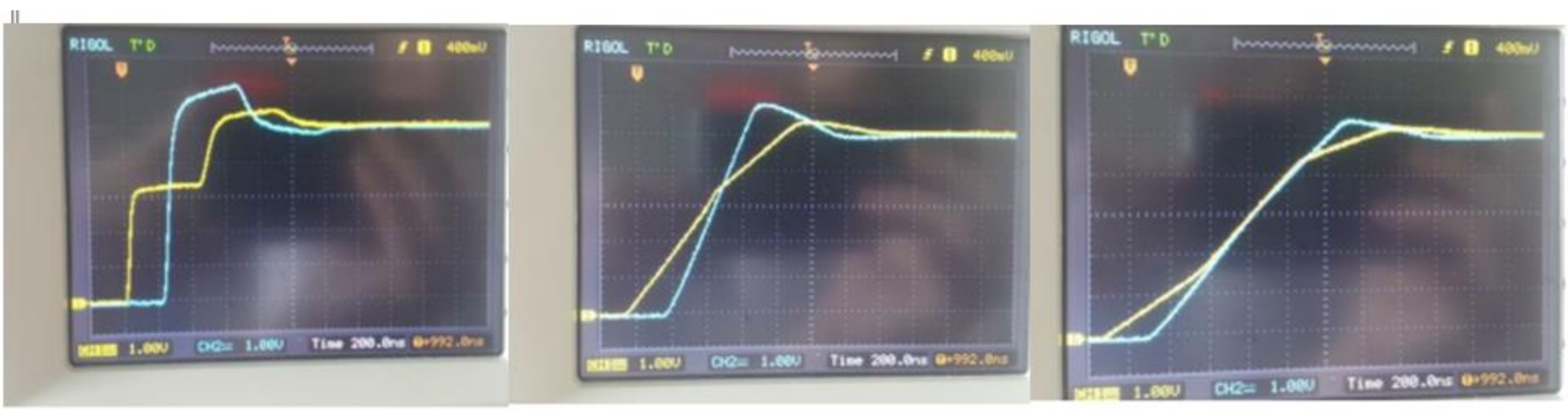


Časovni diagram poteka napetosti izhodu iz linije do časa t =7τ, če je čas vzpona signala enak času potovanja signala po liniji $t_r = 3\tau$ ($t_r > 2\tau$)



- Na impulznem generatorju spreminjajte čas vzpona signala t_r in opazujte vpliv na odboje.
- Pri kateri vrednosti t_r se odboji začnejo manjšati?

- Na impulznem generatorju spreminjajte čas vzpona signala t_r in opazujte vpliv na odboje.
- Pri kateri vrednosti t_r se odboji začnejo manjšati?
- Prikaz meritev :



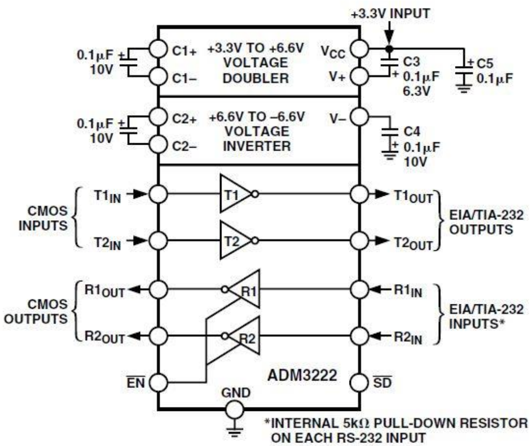
$0.2\ \tau$ 2τ 4τ

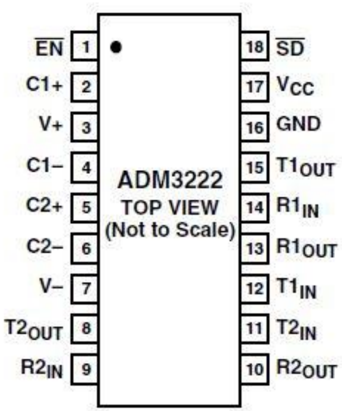
Laboratorijska vaja 8 - LV2

- 8.1: LV2 : Meritve odbojev (razmerja Rv, Rb)
- 8.2: LV2 : Vpliv časa vzpona/padca – omejevanje odbojev
- 8.3: Odboji v praksi - omejevanje (zaključitve, „slew rate“)

Primer omejitve časa vzpona/padca – RS232

RS-232 oddajnik/sprejemnik - ADM 3222





ADM3202/ADM3222/ADM1385–SPECIFICATIONS

(V_{CC} = +3.3 V ± 0.3 V, C1–C4 = 0.1 µF. All specifications T_{MIN} to T_{MAX} unless otherwise noted.)

Parameter	Min	Typ	Max	Unit	Test Conditions/Comments
DC CHARACTERISTICS					
Operating Voltage Range	3.0	3.3	5.5	V	
V_{CC} Power Supply Current		1.3	2.1	mA	No Load
		8	10	mA	R_L = 3 kΩ to GND
Shutdown Supply Current		0.01	0.5	µA	
LOGIC					
Input Logic Threshold Low, V_{INL}			0.8	V	T_{IN}
Input Logic Threshold High, V_{INH}	2.0			V	T_{IN}
CMOS Output Voltage Low, V_{OL}			0.4	V	I_{OUT} = 1.6 mA
CMOS Output Voltage High, V_{OH}	V_{CC} – 0.6			V	I_{OUT} = –1 mA
Input Leakage Current		0.01	±1	µA	T_{IN} = GND to V_{CC}*
Output Leakage Current			±10	µA	Receivers Disabled
RS-232 RECEIVER					
EIA-232 Input Voltage Range	–30		+30	V	
EIA-232 Input Threshold Low	0.6	1.2		V	
EIA-232 Input Threshold High		1.6	2.4	V	
EIA-232 Input Hysteresis		0.4		V	
EIA-232 Input Resistance	3	5	7	kΩ	
RS-232 TRANSMITTER					
Output Voltage Swing (RS-232)	±5.0	±5.2		V	V_{CC} = 3.3 V. All Transmitter Outputs Loaded with 3 kΩ to Ground
Output Voltage Swing (RS-562)	±3.7			V	V_{CC} = 3.0 V
Transmitter Output Resistance	300			Ω	V_{CC} = 0 V, V_{OUT} = ±2 V
RS-232 Output Short Circuit Current		±15		mA	
Output Leakage Current			±25	µA	SD = Low, V_{OUT} = 12 V
TIMING CHARACTERISTICS					
Maximum Data Rate	460			kbps	V_{CC} = 3.3 V, R_L = 3 kΩ to 7 kΩ, C_L = 50 pF to 1000 pF. One Tx Switching
Receiver Propagation Delay					
TPHL		0.4	1	µs	
TPLH		0.4	1	µs	
Transmitter Propagation Delay		300	750	ns	R_L = 3 kΩ, C_L = 1000 pF
Receiver Output Enable Time		200		ns	
Receiver Output Disable Time		200		ns	
Transmitter Skew		30		ns	
Receiver Skew		300		ns	
Transition Region Slew Rate					Measured from +3 V to –3 V or –3 V to +3 V, V_{CC} = +3.3 V
	6	10	30	V/µs	R_L = 3 kΩ, C_L = 1000 pF, T_A = +25°C
	4	10	30	V/µs	R_L = 3 kΩ, C_L = 2500 pF, T_A = +25°C

*ADM1385: Input leakage current typically –10 µA when T_{IN} = GND.
Specifications subject to change without notice.

Slew Rate: max 30V/us

ADM3202/ADM3222/ADM1385–SPECIFICATIONS

(V_{CC} = +3.3 V ± 0.3 V, C1–C4 = 0.1 µF. All specifications T_{MIN} to T_{MAX} unless otherwise noted.)

Parameter	Min	Typ	Max	Unit	Test Conditions/Comments
DC CHARACTERISTICS					
Operating Voltage Range	3.0	3.3	5.5	V	
V_{CC} Power Supply Current		1.3	2.1	mA	No Load
		8	10	mA	R_L = 3 kΩ to GND
Shutdown Supply Current		0.01	0.5	µA	
LOGIC					
Input Logic Threshold Low, V_{INL}			0.8	V	T_{IN}
Input Logic Threshold High, V_{INH}	2.0			V	T_{IN}
CMOS Output Voltage Low, V_{OL}			0.4	V	I_{OUT} = 1.6 mA
CMOS Output Voltage High, V_{OH}	V_{CC} – 0.6			V	I_{OUT} = –1 mA
Input Leakage Current		0.01	±1	µA	T_{IN} = GND to V_{CC}*
Output Leakage Current			±10	µA	Receivers Disabled
RS-232 RECEIVER					
EIA-232 Input Voltage Range	–30		+30	V	
EIA-232 Input Threshold Low	0.6	1.2		V	
EIA-232 Input Threshold High		1.6	2.4	V	
EIA-232 Input Hysteresis		0.4		V	
EIA-232 Input Resistance	3	5	7	kΩ	
RS-232 TRANSMITTER					
Output Voltage Swing (RS-232)	±5.0	±5.2		V	V_{CC} = 3.3 V. All Transmitter Outputs Loaded with 3 kΩ to Ground
Output Voltage Swing (RS-562)	±3.7			V	V_{CC} = 3.0 V
Transmitter Output Resistance	300			Ω	V_{CC} = 0 V, V_{OUT} = ±2 V
RS-232 Output Short Circuit Current		±15		mA	
Output Leakage Current			±25	µA	SD = Low, V_{OUT} = 12 V
TIMING CHARACTERISTICS					
Maximum Data Rate	460			kbps	V_{CC} = 3.3 V, R_L = 3 kΩ to 7 kΩ, C_L = 50 pF to 1000 pF. One Tx Switching
Receiver Propagation Delay					
TPHL		0.4	1	µs	
TPLH		0.4	1	µs	
Transmitter Propagation Delay		300	750	ns	R_L = 3 kΩ, C_L = 1000 pF
Receiver Output Enable Time		200		ns	
Receiver Output Disable Time		200		ns	
Transmitter Skew		30		ns	
Receiver Skew		300		ns	
Transition Region Slew Rate					Measured from +3 V to –3 V or –3 V to +3 V, V_{CC} = +3.3 V
	6	10	30	V/µs	R_L = 3 kΩ, C_L = 1000 pF, T_A = +25°C
	4	10	30	V/µs	R_L = 3 kΩ, C_L = 2500 pF, T_A = +25°C

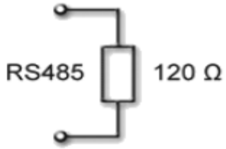
*ADM1385: Input leakage current typically –10 µA when T_{IN} = GND.

Specifications subject to change without notice.

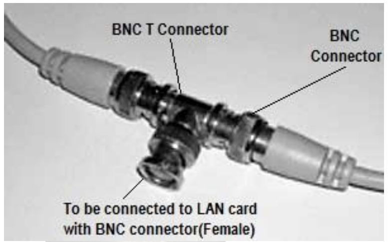
Primeri zaključevanj linij:

- SCSI
  - Aktivni - vgrajen regulator napetosti

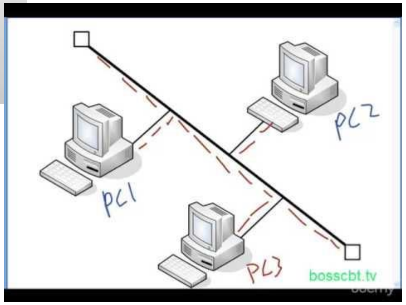
- CAN - Controller Area Network
- RS485
  - Pasivni - upor 120 ohm

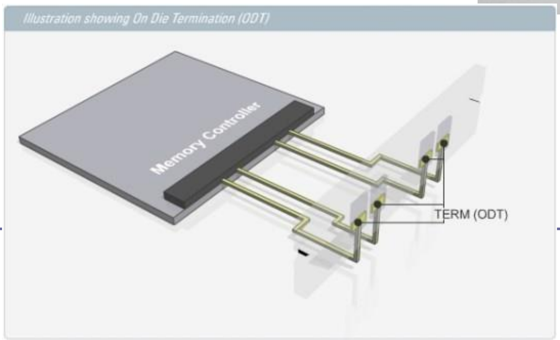


- Ethernet coaxial 10BASE2
  - Pasivni - upor 50 ohm (BNC terminator)



- Antenski kabel
  - Pasivni - upor 75 ohm
- Unibus, MIL-STD-1553
- CPE-SDRAM povezave ->

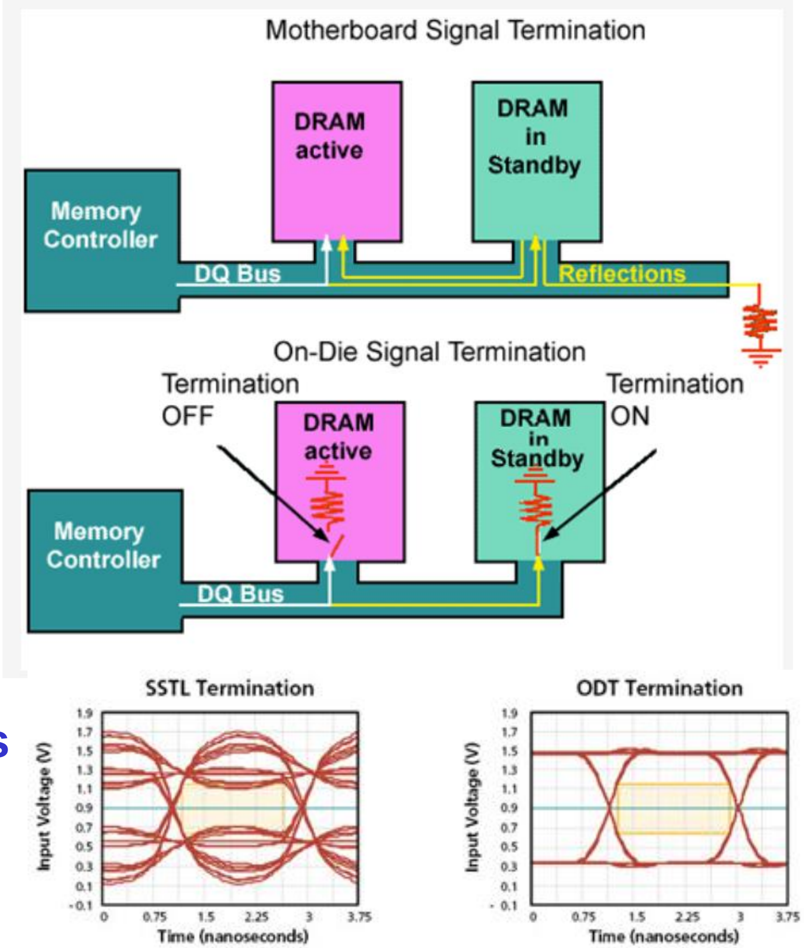




Dodatek: CPE-SDRAM (zmogljiva povezava)

DRAM Termination

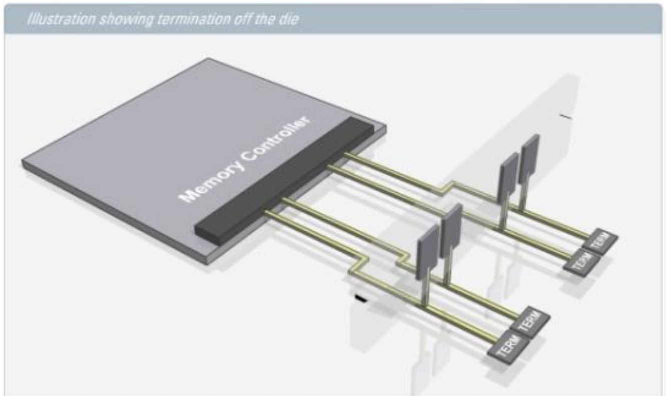
- **DDR (SSTL - mat. plošča)**
- **DDR2,3 (ODT – moduli):**
  - 50, 75, 150 Ohms (DDR2)
  - 40, 60, 120 Ohms (DDR3)

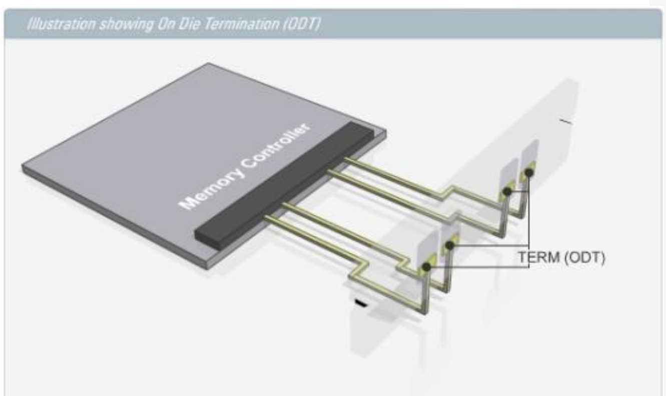


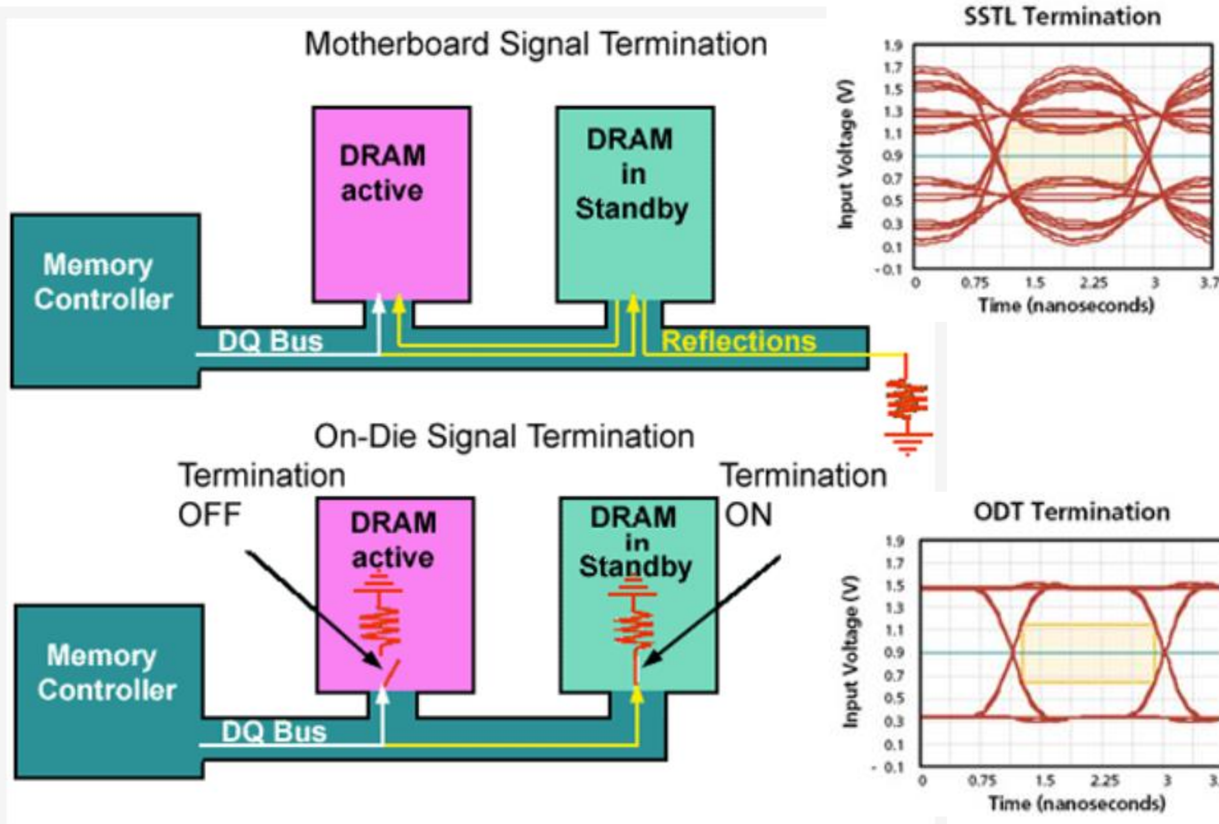
Priporočila Samsung (DDR2):

- Single memory module / channel : **150 ohms**
- Two memory modules / channels
  - DDR2-400 / 533 memory : **75 ohms**
  - DDR2-667 / 800 memory : **50 ohms**

Dodatek: CPE-SDRAM (zmogljiva povezava)

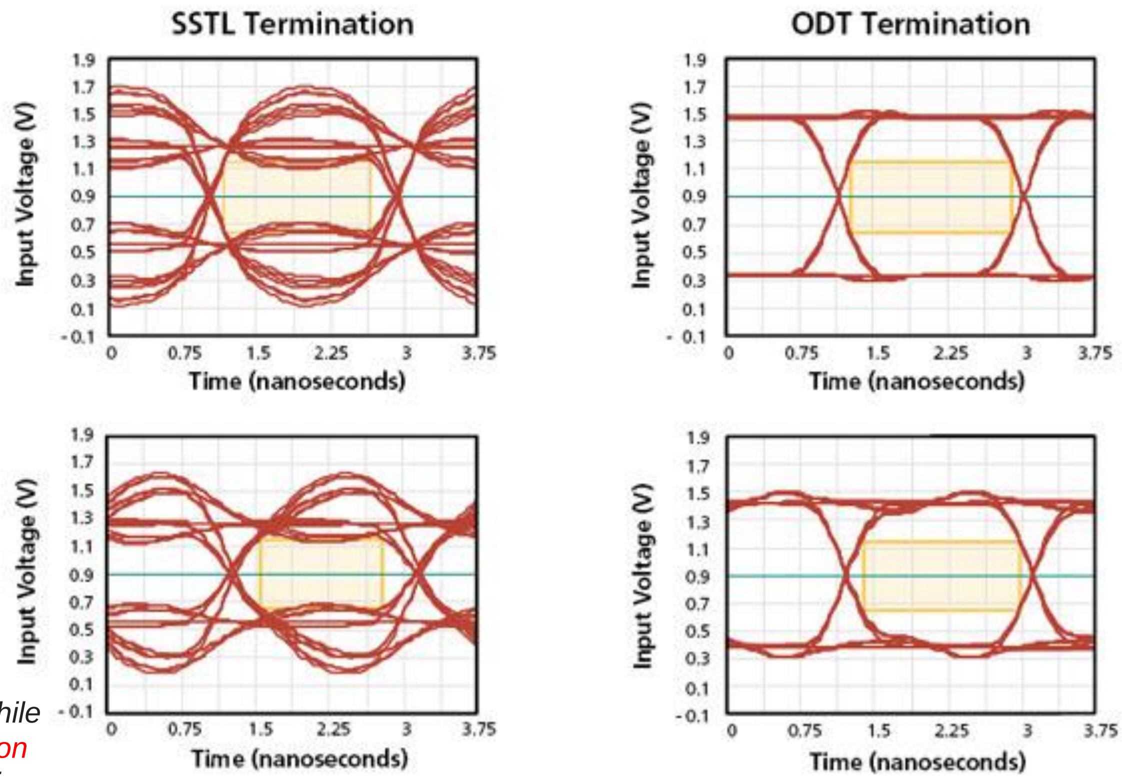






Dodatek: Zaključevanje v praksi

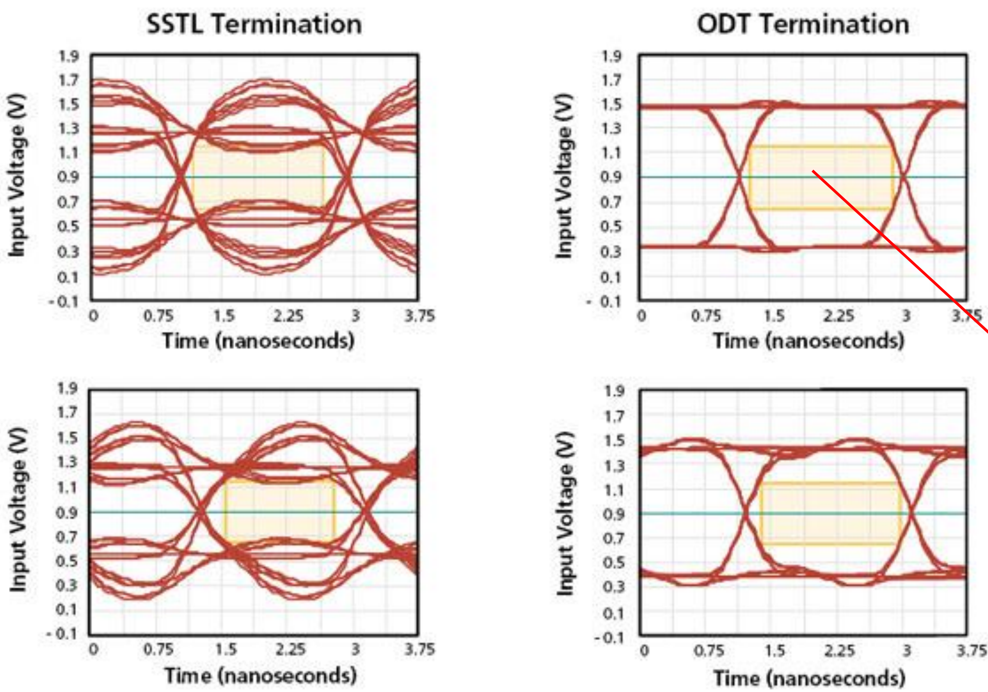
- Razlike v izvedbi (matična pl. vs. On-Die-Termination)

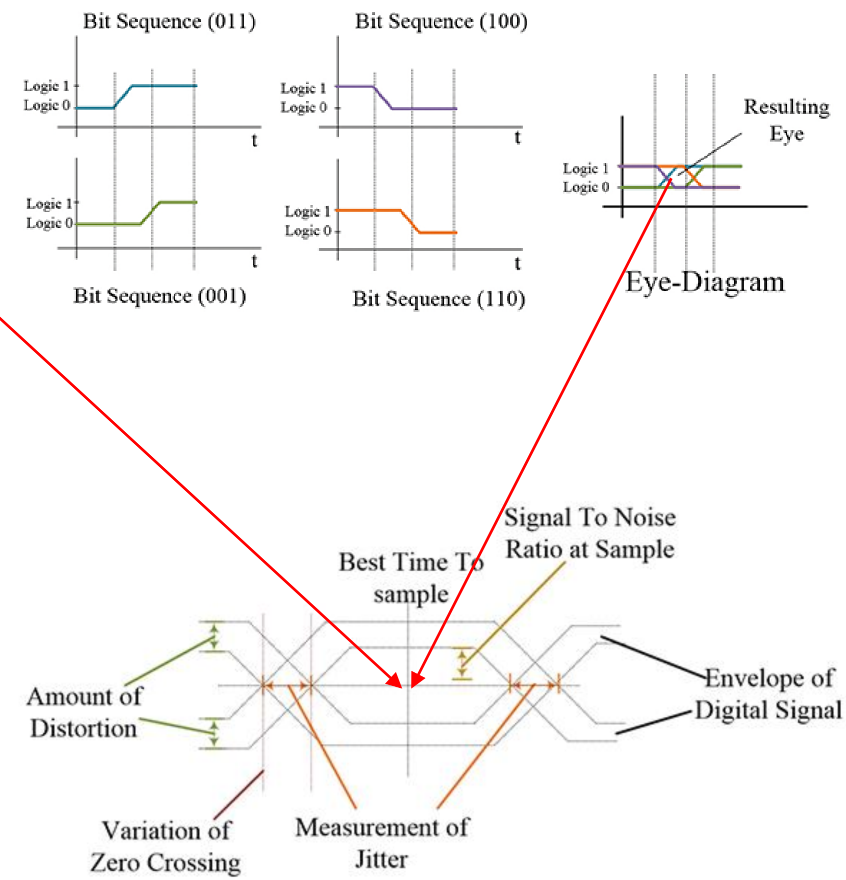


Resistive Termination
On DDR memories, the necessary resistive termination is located on the motherboard, while on DDR2 and DDR3 memories this termination is located inside the memory chips – a technique called ODT (On-Die Termination).

Vir: https://www.hardwaresecrets.com/everything-you-need-to-know-about-ddr-ddr2-and-ddr3-memories/6/

- # Razlike v izvedbi (matična pl. vs. On-Die-Termination)





Primeri očesnih vzorcev (bomo še obravnavali, merili) …

Vir: https://incompliancemag.com/article/an-overview-of-transmission-lines-in-electronic-systems/

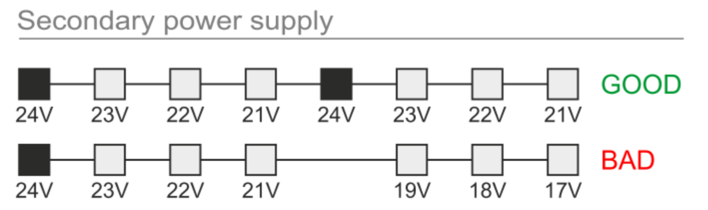
Dodatek: Praktični primer CANBUS vodila

INTEGRA BM SYSTEM **Bus length**

Regarding bus length, two points must be considered:

1. Voltage drop

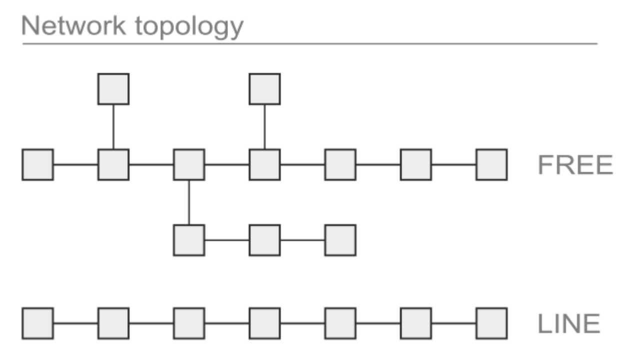
Wire resistance cause voltage drop, which depends of cable length, wire diameter and power consumption. Cable must be selected to ensure each module have at least the minimum specified voltage.



2. Signal delay

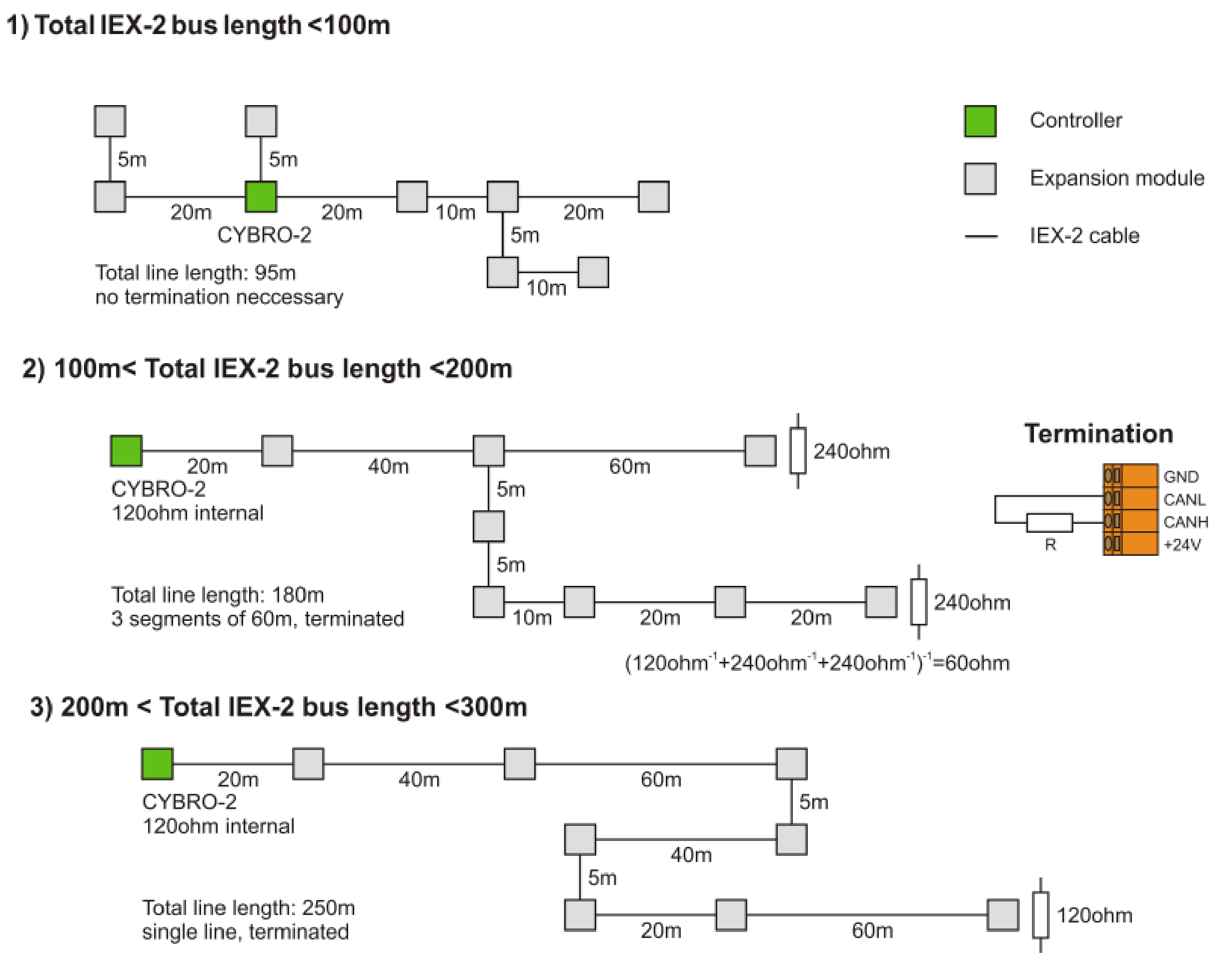
Communication speed is limited with propagation time and bus topology. With default 100kbps baudrate, 100m is safe without restrictions. For a longer distance, cable must be connected in a line (without trunks) and properly terminated.

Speed\Topology	FREE	LINE
100kbps	100m	300m
50kbps	200m	500m
20kbps	500m	1000m



Dodatek: Praktični primer CANBUS vodila

INTEGRA BM SYSTEM **Cabling topology & Termination**

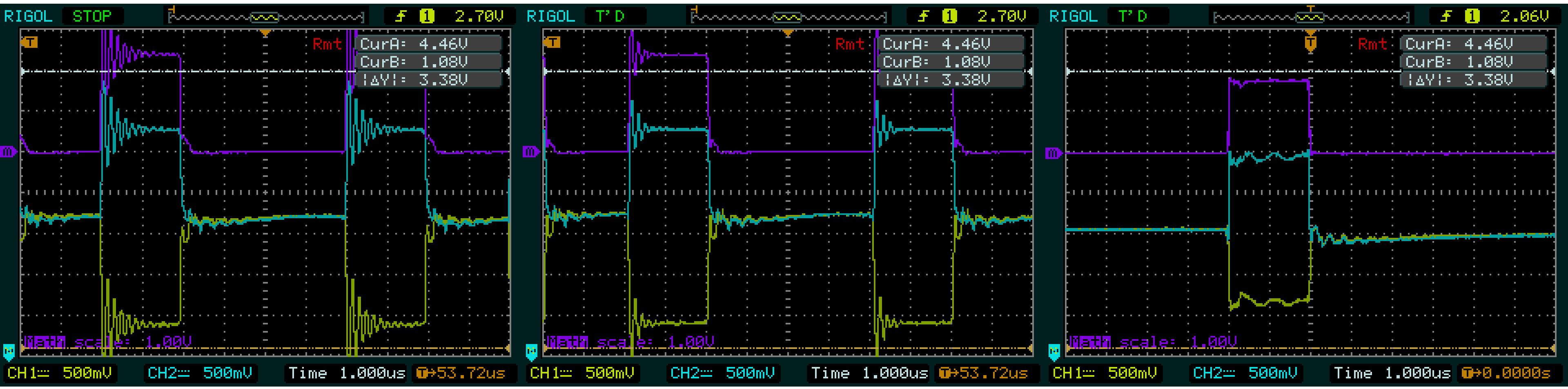


Dodatek: Praktični primer CANBUS vodila

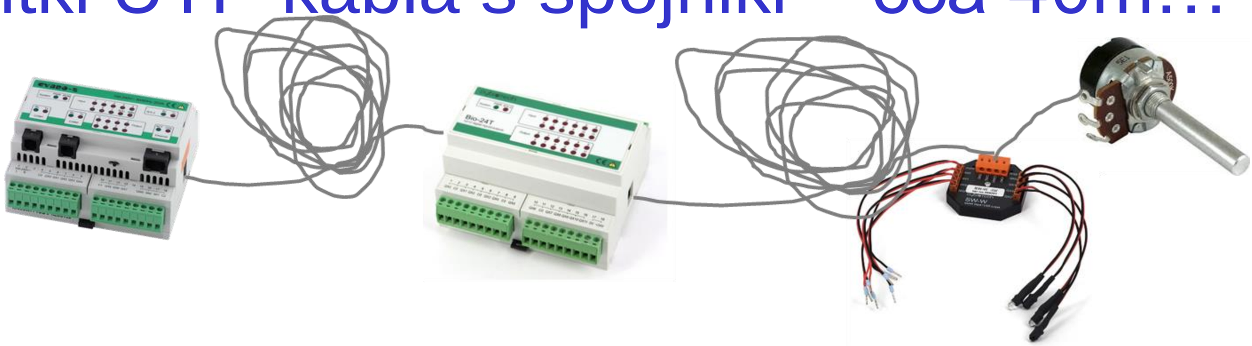
Lab. vaja CANBUS – meritve

500kb/s:

Odprte sponke 500ohm 107ohm



3 zavitki UTP kabla s spojniki – cca 40m…

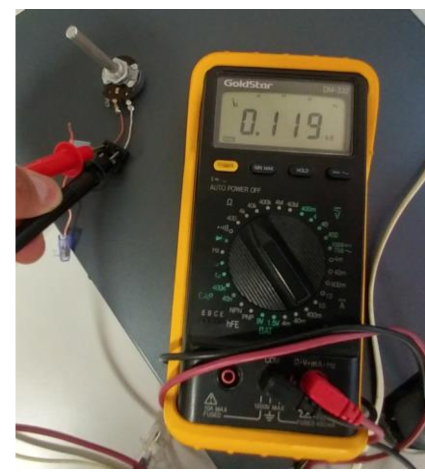


Dodatek: Praktični primer CANBUS vodila

Lab. vaja CANBUS - meritve

Nezaključena linija

Zaključena linija



Dodatek: Praktični primer CANBUS vodila

Nastavitev časa vzpona/padca (CAN Phy)

Please use MCP2561

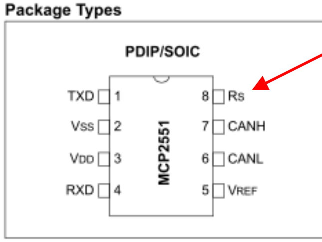
MICROCHIP **MCP2551**

High-Speed CAN Transceiver

Features

- Supports 1 Mb/s operation
- Implements ISO-11898 standard physical layer requirements
- Suitable for 12V and 24V systems
- Externally-controlled slope for reduced RFI emissions
- Detection of ground fault (permanent Dominant) on TXD input
- Power-on Reset and voltage brown-out protection
- An unpowered node or brown-out event will not disturb the CAN bus
- Low current standby operation
- Protection against damage due to short-circuit conditions (positive or negative battery voltage)
- Protection against high-voltage transients
- Automatic thermal shutdown protection
- Up to 112 nodes can be connected
- High-noise immunity due to differential bus implementation
- Temperature ranges:
  - Industrial (I): -40°C to +85°C
  - Extended (E): -40°C to +125°C

Package Types

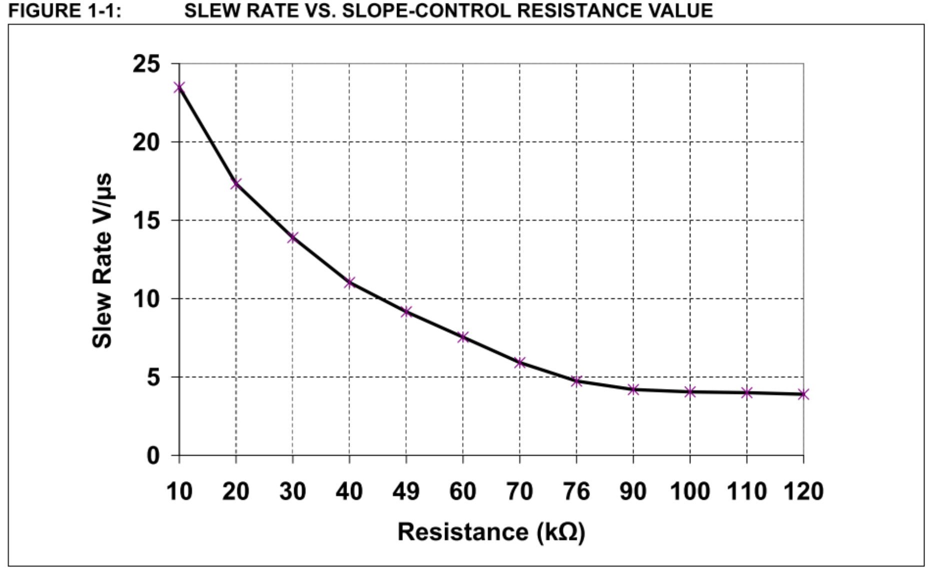


1.4.2 SLOPE-CONTROL

Slope-Control mode further reduces EMI by limiting the rise and fall times of CANH and CANL. The slope, or slew rate (SR), is controlled by connecting an external resistor (REXT) between RS and VOL (usually ground). The slope is proportional to the current output at the RS pin. Since the current is primarily determined by the slope-control resistance value REXT, a certain slew rate is achieved by applying a specific resistance. Figure 1-1 illustrates typical slew rate values as a function of the slope-control resistance value.

Rs vs. Slew rate

FIGURE 1-1: SLEW RATE VS. SLOPE-CONTROL RESISTANCE VALUE



Dodatek: Zaključevanje v praksi - Viri

Viri :

- https://incompliancemag.com/article/an-overview-of-transmission-lines-in-electronic-systems/
- https://m.blog.naver.com/framkang/220456911948
- https://www.techarp.com/bios-guide/dram-termination/
- https://www.hardwaresecrets.com/everything-you-need-to-know-about-ddr-ddr2-and-ddr3-memories/6/

