# **Vill.** <u>**Laboratórium 1.**</u> tárgy
## *(őszi félév)*

- **a Tárgy**

  *... **követelmények** és számonkérés*

- *Mérések / mérőcsoport (**2 fő**)*

  *... saját **időtábla***

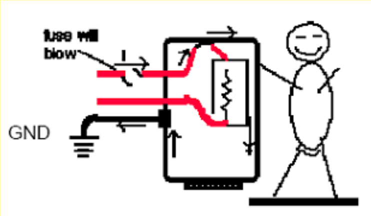
- **a Munkahely**

  *... szakszerűség, **biztonság** (**! aláírás !**)*


<u>1.sz. mérés</u>: **Műszerkezelés**

*... **alap**eszközök (minden mérőhelyen)*

# Balesetmegelőzési és tűzvédelmi rendszabályok <u>betartása</u>

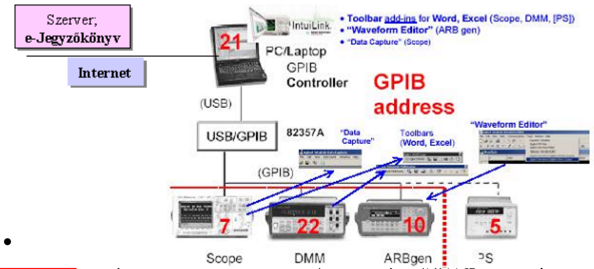



lásd: <u>Időtábla</u> hátoldal, Mérési <u>útmutató</u>,
**Hírdetőtábla**
**! aláírás !**

Hálózati **főkapcsoló** (csak mérésvezető), **tanári gép ...** csak <u>ezután</u>

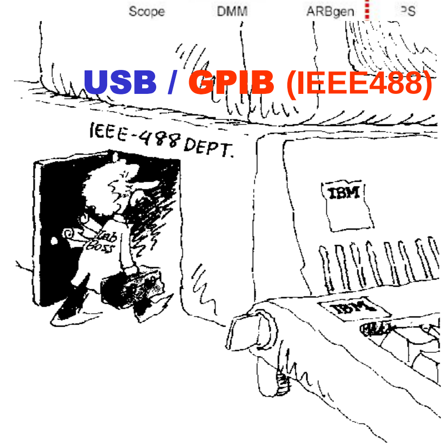
**Mérőhely** **<u>táp-elosztó</u>** bekapcsolás,
<u>számítógép</u> **be(!)** … **és várakozás(!),**
<u>műszer(ek)</u> **be/ki** kapcsolás

# Mérőhely bekapcsolás




1. **Mérőhely táp-elosztó** – *BE*kapcs.
2. **Számítógép** – *BE*

   ... és **„magára hagyjuk" (!)**, amíg az *aut.* konfigurálás lefut **( „fekete ablak" )** (→ alaphelyzet!)




3. **Műszer(ek)** – *BE* / **ki**

MOST: a műszereket **a bemutatás sorrendjében** kapcsoljuk be („ütemezett" műszerkezelés)

Ellenőrzés: a mérőhely *rendben* ...

**a <u>Tárgy</u>** → Mérnöki/gyakorlati munka

*„ Ha én mérnök volnék, mér'ne sokat mérnék ...”*

# **Jegyzet:** Mérési ut., Műszerismertető

- <u>Hallgatói segédlet</u> a **Laboratórium I. c. tárgy** méréseihez, BME VIK, Vill.m. Szak
- <u>”Műszerismertető" segédlet</u> a **Laboratórium I. c. tárgy** méréseihez, BME VIK, Vill.m. Szak

## **WEB lap:**

http://www.mit.bme.hu/oktatas/targyak/vimia304/

**Öt** <u>helyszín</u>: I**B**413, I**E**226, IL107, **V2**/405 a,b
**4 (5)** időpont (kurzus) ...

# *Követelmények:*

**11** mérés, **1** ellenörző mérés ( **időtábla** )
• **Minden mérést el kell végezni!** •

**Gondos** munka
(és a mérőhelyek eszközeinek száma csak **nő**het!)

Józan, de **szigorú** labor szabályok
( legfontosabb a BIZTONSÁG;
hetenként *több mint 150 ember* dolgozik a laborban)

**3K** szabály („főbenjáró bűnök"):

• **K**ésés ( hiányzás?? )
• **K**észületlenség
• sza**K**szerűtlenség

→ **Pótmérés** ( **max 1+1 !**)

# *Számonkérés:*

**1-3. mérés: nincs osztályzat**

**4-11.** mérés: **egyéni Házi feladat WEB lapról**
***közös* e-Jegyzőkönyv ( magyar ! )**
**külön-külön** (!) osztályzat

**Ellenörző mérés:** gyakorlati – ***egyedül***
írásbeli – ***egyedül***

Nincs „szivatás",
de „Róbert bácsik" sem vagyunk ...

A mérésvezető **egyénenként** ad osztályzatot
- a **felkészülés** ellenörzése (!),
- az otthon *egyedül (!)* elkészített **Házi feladat** megoldása,
- a **labormunka** és
- a *közös* **e-Jegyzőkönyv** alapján

# *Mérés pótlás:* **max** **1+1**

**1 – 3.:** **1 mérés** pótolható, csak ennek pótlása után (!!) lehet folytatni (4-11.) a labor munkát

• *külön* időpont • → **Hirdetőtábla**

4 – 11.: **1 mérés** pótolható

***személyes*** jelentkezéssel

• pótmérési időpontban •

# ***Mérések / <u>mérőcsoport</u> (2 fő)***

- Mérések:

  1-3.: <u>mindenki</u> <u>*ugyanazt*</u> méri ( „előkészítő" jelleg)
  **4-11. és Ell. mérés**: <u>***időtábla* szerint**</u>

- <u>Mérő-csoport</u> beosztás •

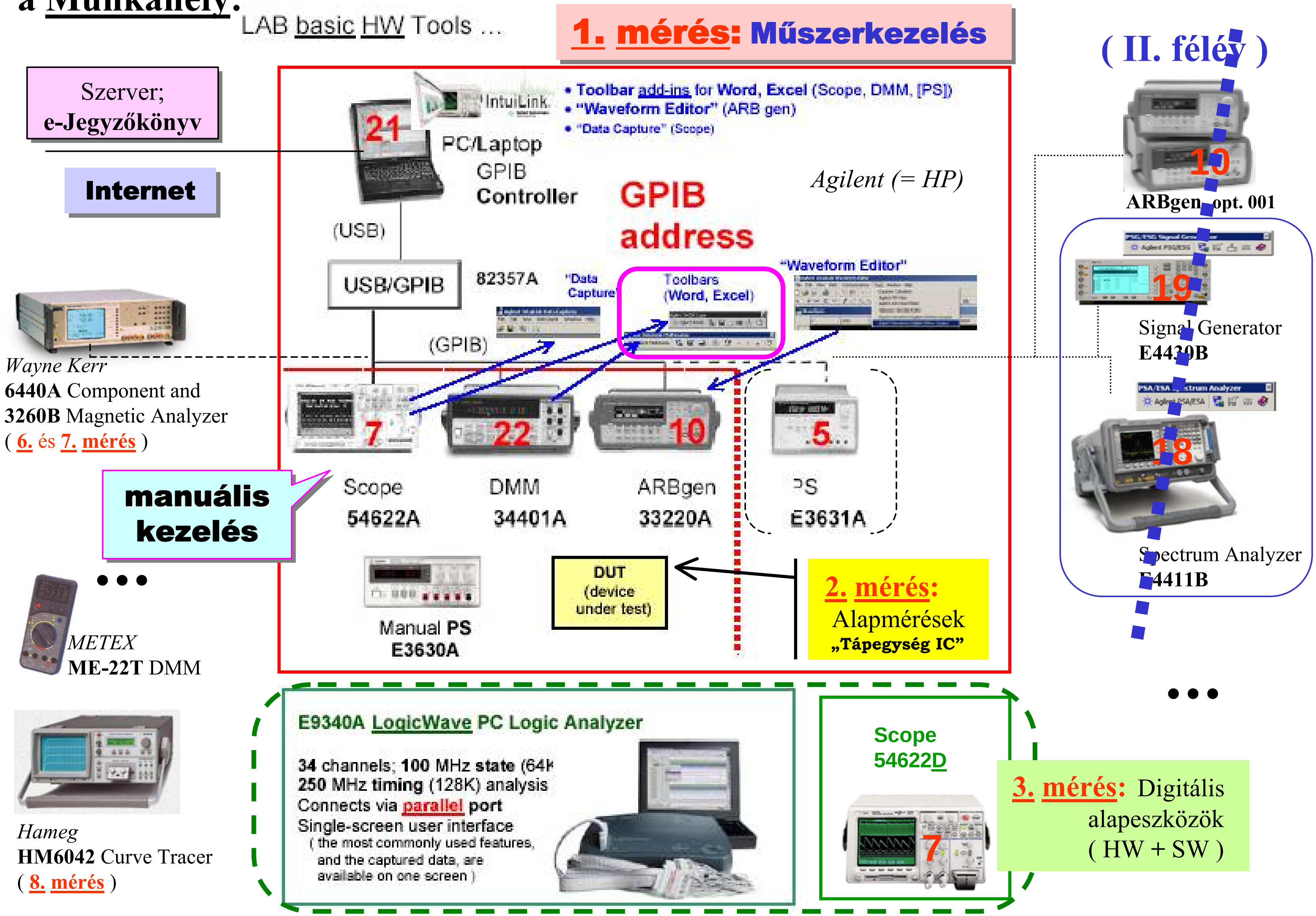
  minden csoportnak <u>saját</u> időtábla

- **Mérés NEM marad el**, minden mérést el kell végezni

- **Fel kell készülni** a mérésre
- Meg kell oldani a **Házi feladat**ot (a Tárgy WEB lapról)

- A mérés **4 óra**, a szüneteket *dinamikusan* kezeljük

# a Munkahely:




http://www.hit.bme.hu/people/papay/edu/Lab/Tools.htm

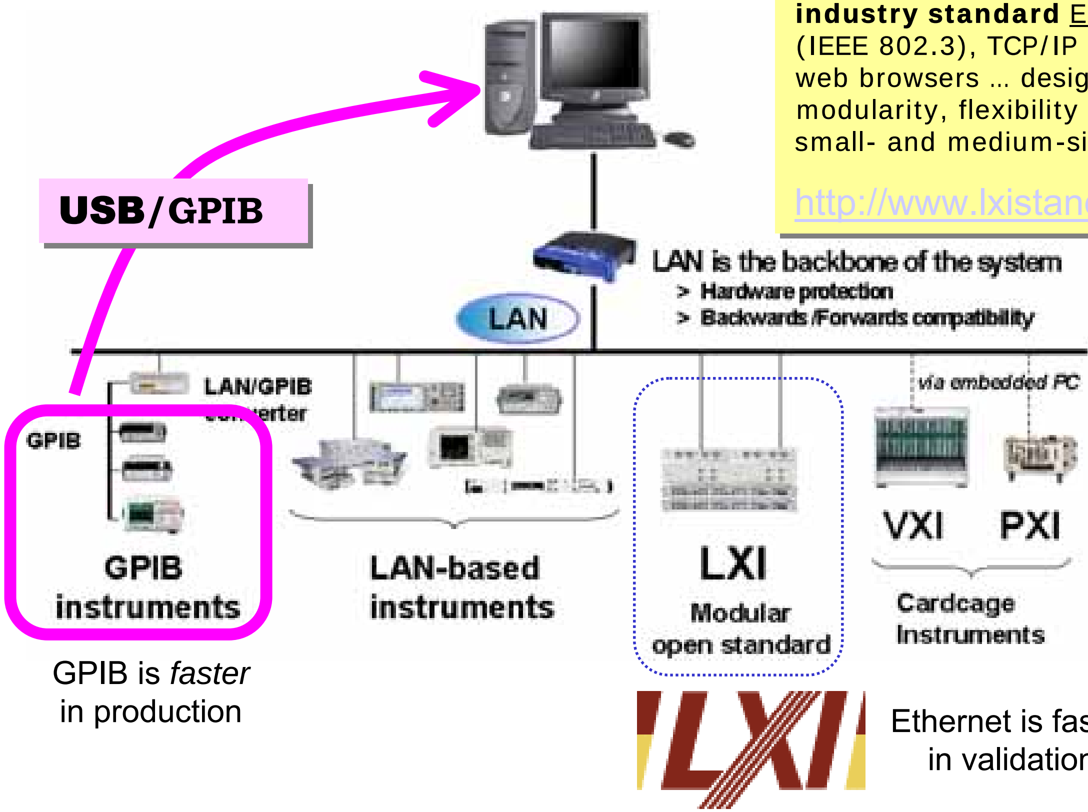
# *GPIB* = **G**eneral **P**urpose **Interface** (**I**nstrument) **B**us

***NEW (2004): LXI*** = **L**AN e**X**tensions for **I**nstrumentation

LXI is an instrumentation platform based on **industry standard** Ethernet technology (IEEE 802.3), TCP/IP protocols, LAN cables, web browsers … designed to provide modularity, flexibility and performance to small- and medium-sized systems.

http://www.lxistandard.org/home

**Vill. LAB**



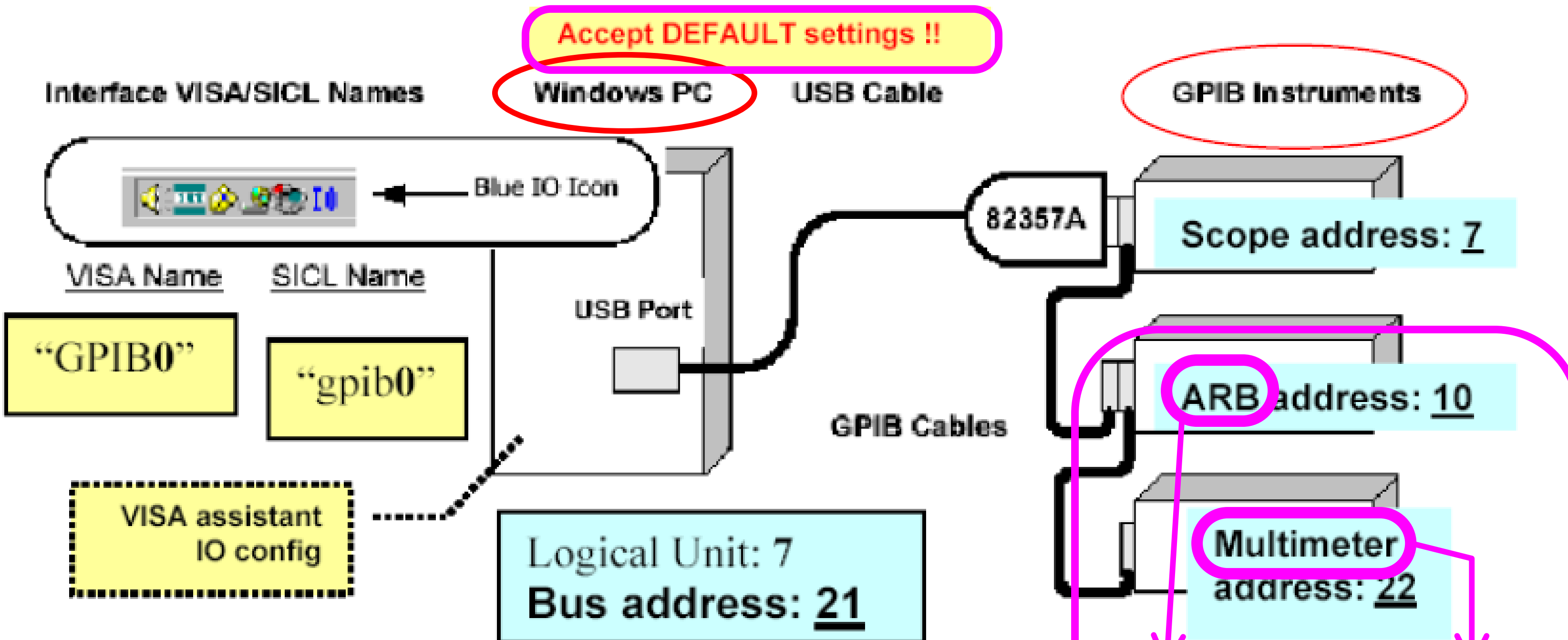

**The *optimal* bus is use-case-specific**

GPIB is *faster* in production

Ethernet is faster in validation

# I/O interface: **USB/GPIB**

**Plug-and-Play (*PnP*)**; <u>Transparent</u> interface

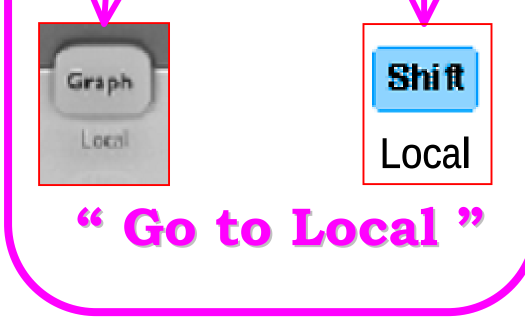



Note: **VISA** = Virtual Instrumentation Software Architecture
**SICL** = Standard Instrument Control Library

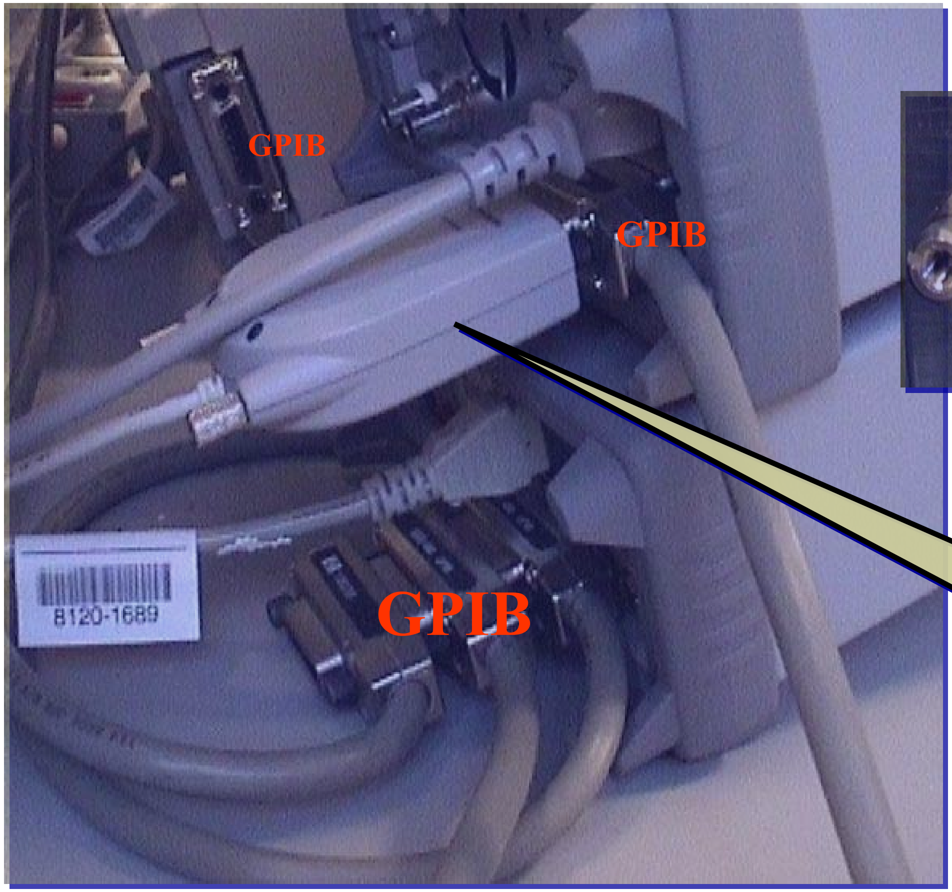
**USB** = **U**niversal **S**erial **B**us

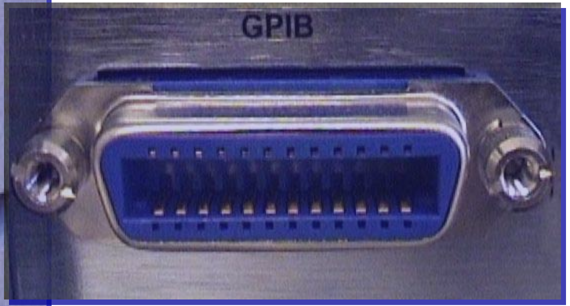
**GPIB** = **G**eneral **P**urpose **I**nterface (**I**nstrument) **B**us

**HP-IB = IEEE488 = IEC625**



# I/O interface: **USB/GPIB**

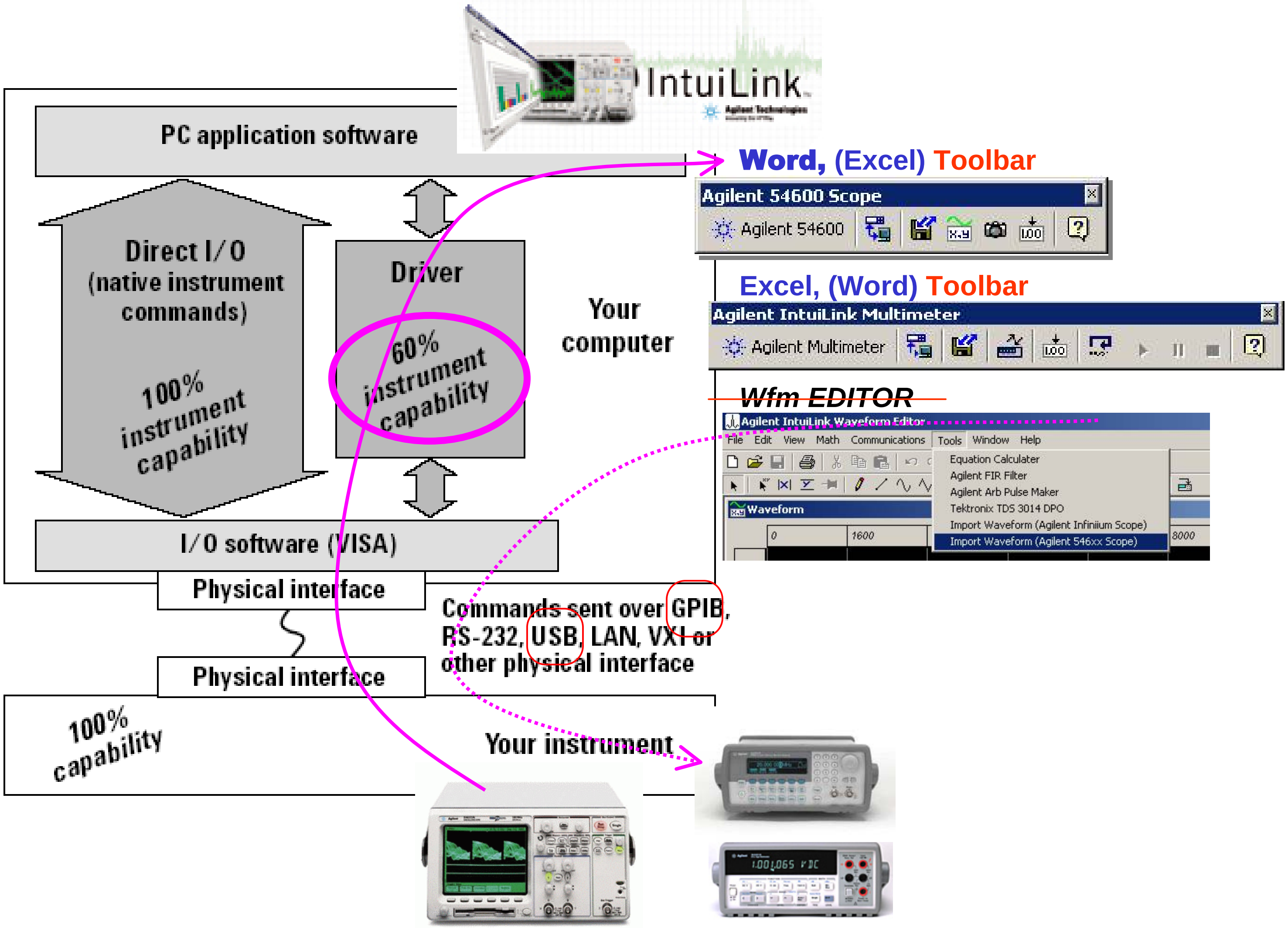



USB ⇔ GPIB
átalakító
82357A

# IntuiLink connectivity SW

***Word***, *Excel* **Toolbars**; ~~*stand-alone* **SW tools**~~



# *e* – Jegyzőkönyv / WORD /

(**váz** ← G: drive, szerver)

**A jegyzőkönyv <u>ékezetes</u> <u>betűkkel</u> készül!**

**Jegyzőkönyv írás előtt <u>ellenőrizzük</u> a hálózatot!**

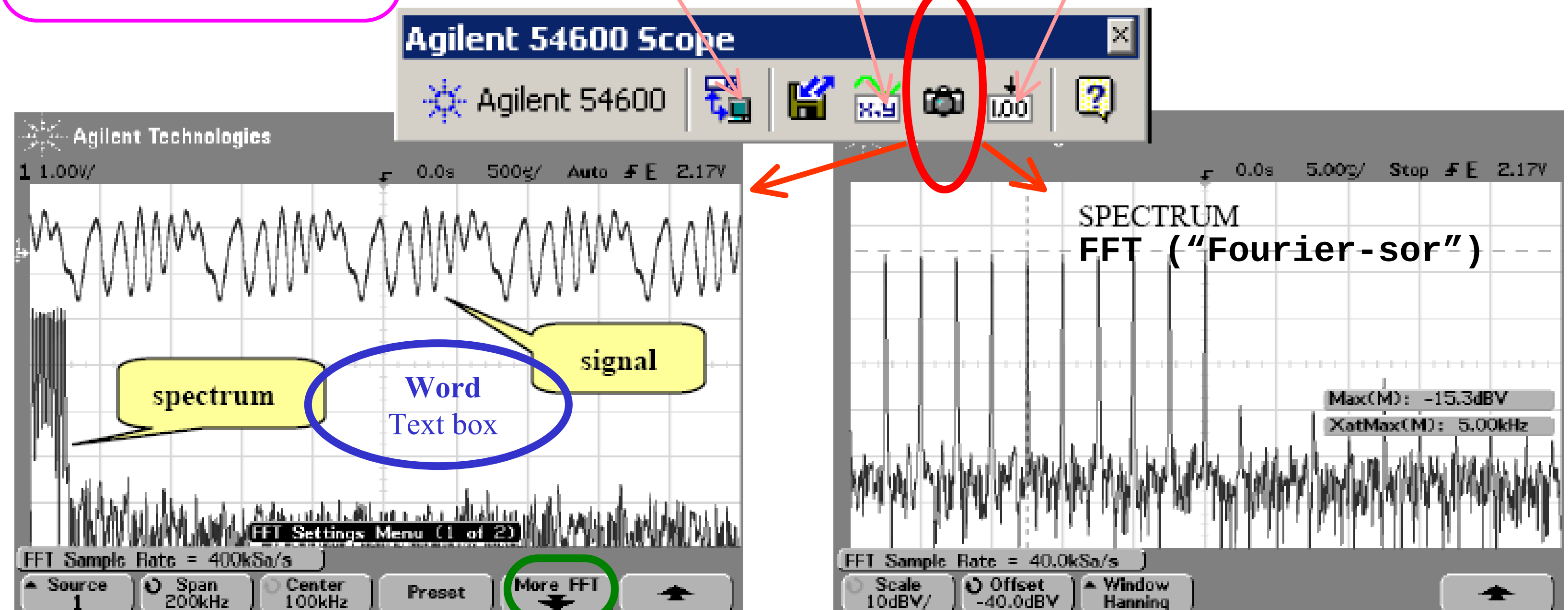
**connect** to Scope

data & **graph**

**Screen image**

meas

WORD / **IntuiLink** Toolbar:




(press **Math / FFT**)

(press **More FFT**)

*e-Jegyzőkönyv*: **kód .** doc **Word** file

**3**: **IL107 Lab**

**V**: **Vill.**

NAP: **h, k, s, c, p**

**de**: délelőtt, **du**: délután

**kód** - file név - konvenció: **V 3 s du 2 *01*** .doc

Save as …**G: drive**

*MÉRÉS*: ***01, 02, … 11***

MérőCSOPORT: **1, 2, … 8**

*e*-Jegyzőkönyv **váz**: *szerveren*

1.mérés: — *(gyakorlás)*

**2.mérés:** max. **5** old. , csak ez **nyomtatva is …**

3.mérés: — *(gyakorlás)*

**4-11. mérések: osztályozva**

**a jegyzőkönyv ékezetes betűkkel készül!**

***Működő*** *mérőhely – ezt várjuk el, ilyet is hagyjunk ott!*

- *kombinált (!)* **Vill.** és **Info** mérőhely(ek)
  - **alapműszerek** (*tápegység, jelgenerátor; oszcilloszkóp, multiméter*)
    - mérendő objektumok és kiegészítők
    - *speciális* mérőeszközök, *egyéb* mérőműszerek (!!)
    - **mérőkábelek, lezárók**, IC-k **...**
  - **Win2K** op. rendszer, MSOffice: **WORD**, *Excel*
    - *speciális* SW-ek, *Matlab*, **...**
    - **Internet**
- *e*-Jegyzőkönyv: **WORD** (← IntuiLink *Toolbar*)
    - **jegyzőkönyvet NEM nyomtatunk a Labor-ban**

**→ e-mail, floppy** … **pendrive (USB)**


- **más jegyzőkönyvét NEM használhatjuk** a Labor nem zártosztály

**Mottó:** **„Bolondbiztos rendszert csak a bolondok használnak”**
Folyománya:

- **a HW elrontható → a műszer NEM klaviatúra (!!)**
  **→ a számítógép NEM játék-konzol (!!)**
- *nem igaz*, hogy „bármit működésbe lehet hozni, ha elég sokáig babrálod”
- *téveszme* az, hogy „ha valami bedugható, akkor azt dugd is be”

**Műszer** kezelés**:** SZAKSZERŰSÉG és BIZTONSÁG

Ez súlyos fegyelmi vétség ...

- csak a **saját** eszközök használhatók (**más mérőhelye *tabu***)
- *kétszer* is gondoljuk át a **vezetékezés**t
- a méréshez szükséges műszer-**üzemmód**okat állítsuk be (!),
  a műszer-**alap**beállítást (**I/O kapcsolat**, nyelv, **...** stb) **NE** módosítsuk,
  CALibrálást **NE** kezdeményezzünk **...** ( óvatosan a *menü* választékkal !)

**Számítógép** használat**:** MŰSZER-KAPCSOLAT és e-Jegyzőkönyv

- **manuálisan** kell beállítani a műszereket**:** az *IntuiLink* SW „adat **copy(move)**”
  és nem soft-panel (csak *néhány* funkció távvezérelhető **...**)
- a **számítógép**et **NE** mozgassuk, benne **NE** turkáljunk (TILOS az **átkonfig**.,
  új program betöltése, program törlés, zene-file letöltés **...** stb.)

# Méréstechnika ...

**Analóg jel** (time domain):

+ 6 V, ± 20 V

forma: **Sine, Square, Ramp, Pulse, Noise, ARB, (DC)**

- Tápegység (**PS**) [1]
- Jelgenerátor (**ARBgen**) [2]

$$v(t) = V_{DC} + V_{AC}(t) = V_{offset} + A \cdot u(t)$$

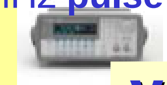
- Oszcilloszkóp (**Scope**) [3]
- Multiméter (**DMM**) [4]

$u(t+T) = u(t)$, min $u(t)$ = **-1**, max $u(t)$ = **+1**

T =1/**F**

$A = V_{pp}/2 = CF \cdot V_{rms}$ , CF : crest factor

**20 MHz sine, square**
5 MHz pulse ...



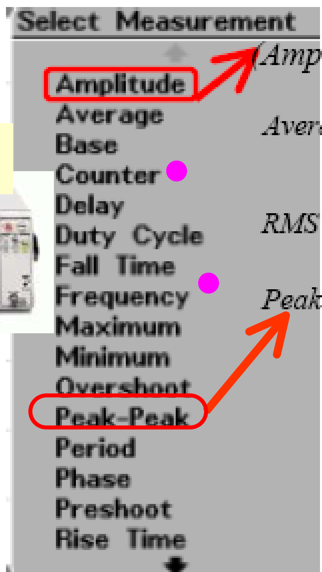
$V_{OUT}$

**"DMM: The Swiss Army knife of test"**

**Paraméter mérés**: Oszcilloszkóp *kontra* Multiméter

*DC* vagy *AC* csatolás **AC/DC quiz**

**Scope:** Ch1, Ch2, Math (source)

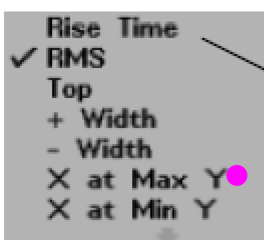



$(Ampl = Top - Base)$!!

$$Average = \frac{\sum x_i}{n}$$

$$RMS(dc) = \sqrt{\frac{\sum (x_i)^2}{n}}$$

$$Peak - Peak = V_{pp} = Max - Min$$




$V_{INPUT}$

**100 MHz;**
**8 bit / 200 MSPS**

**Math:** 1-2( **diff** ),
... **2K FFT**

direkt *kontra* differenciális (Math: **1- 2**) mérés

**DMM:** „dual slope" (analóg integrálás)

**21 bit**
**(6 1/2 digit)**

- $V_{DC}$
- $V_{AC}$ - *AC* coupled **true** $V_{rms}$
- **F**
- T } reciprocal Counter

...

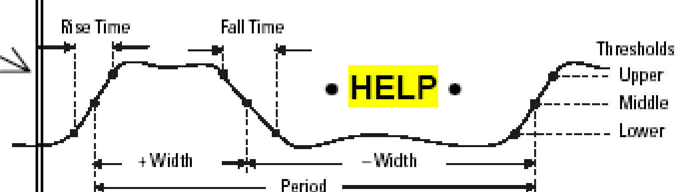
0.1V – 1KV
**(dc, ac: 300KHz)**

áram ($I_{DC}$, $I_{AC}$ - *AC* coupled **true** RMS)

ellenállás (Ω 2W, 4W)

...

**Math:** Null, **dB**

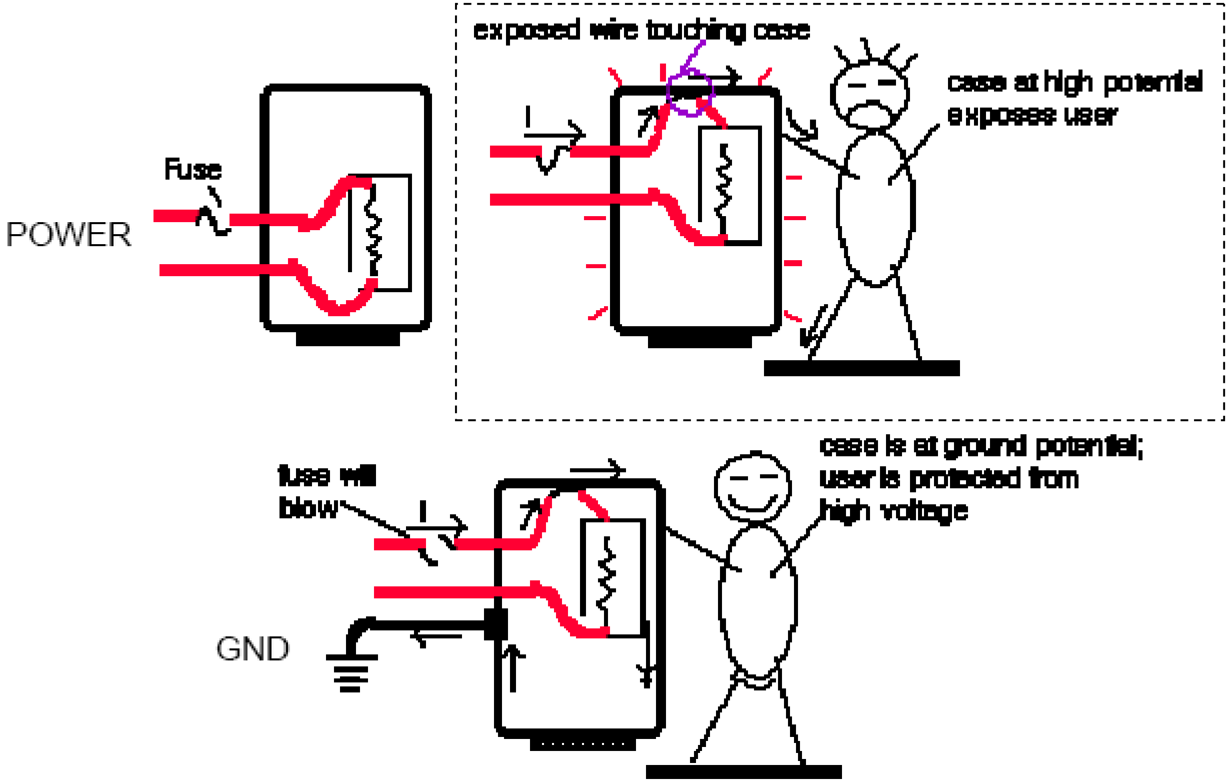



• **HELP** •

**"Scope: The eye of the engineer"**

# Hi / Lo (= COM), GND

Minden mérőkészülék háza (biztonsági okból) az érintésvédelmi földre van kötve:




Ha a jelföld nincs hozzákötve az életvédelmi földhöz, akkor a készülék „lebeg" (a jelföld eltérő potenciálú az „igazi" föld-höz képest). Összekötés (COM ≡ GND) esetén a készülék „*nem* lebeg".

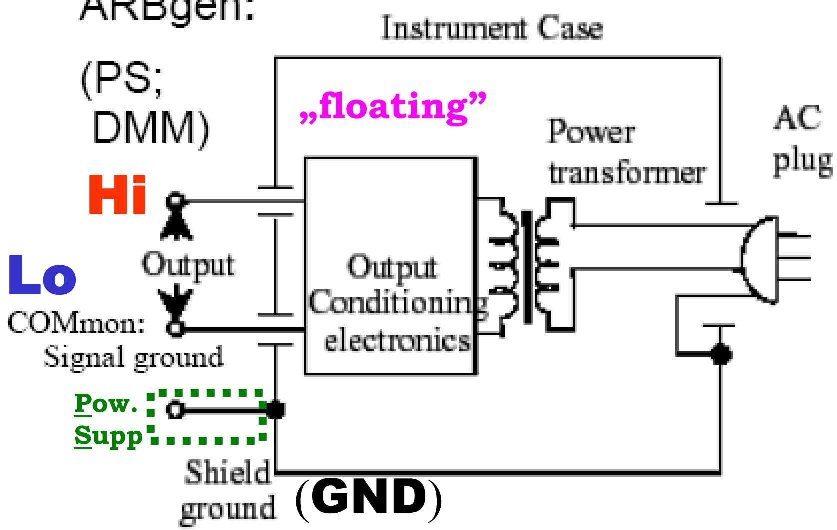
- Csak az *oszcilloszkóp*, lévén nagyfrekvenciás eszköz, „*nem* lebeg".

# Hi / Lo (= COM), GND

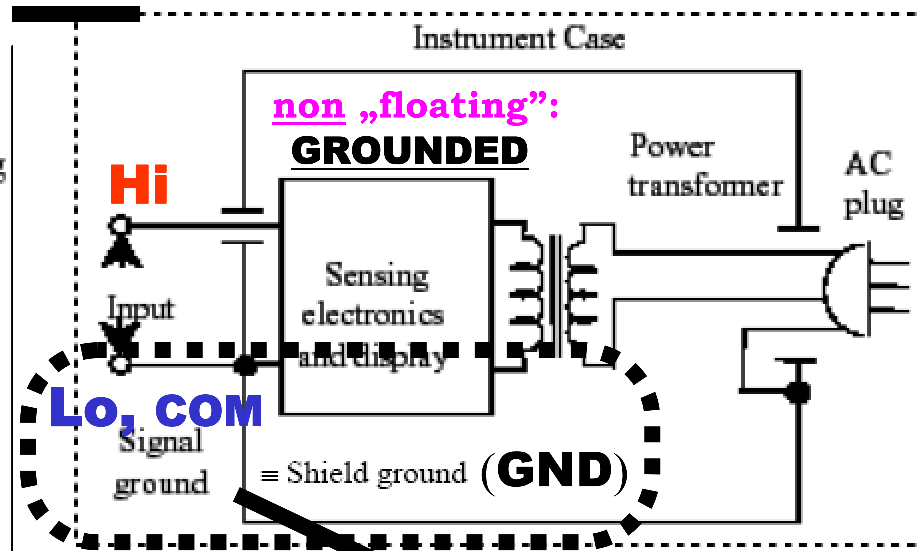
**Mérő<u>hálózat</u>** : „lebegő” műszer; <u>érintésvédelmi</u> föld (Shield ground)

ARBgen:

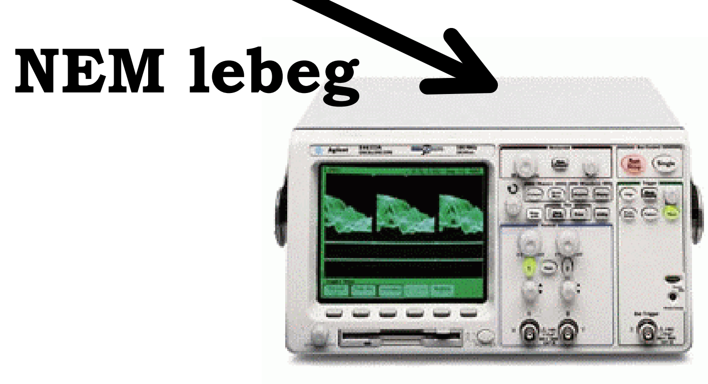
(PS; DMM)



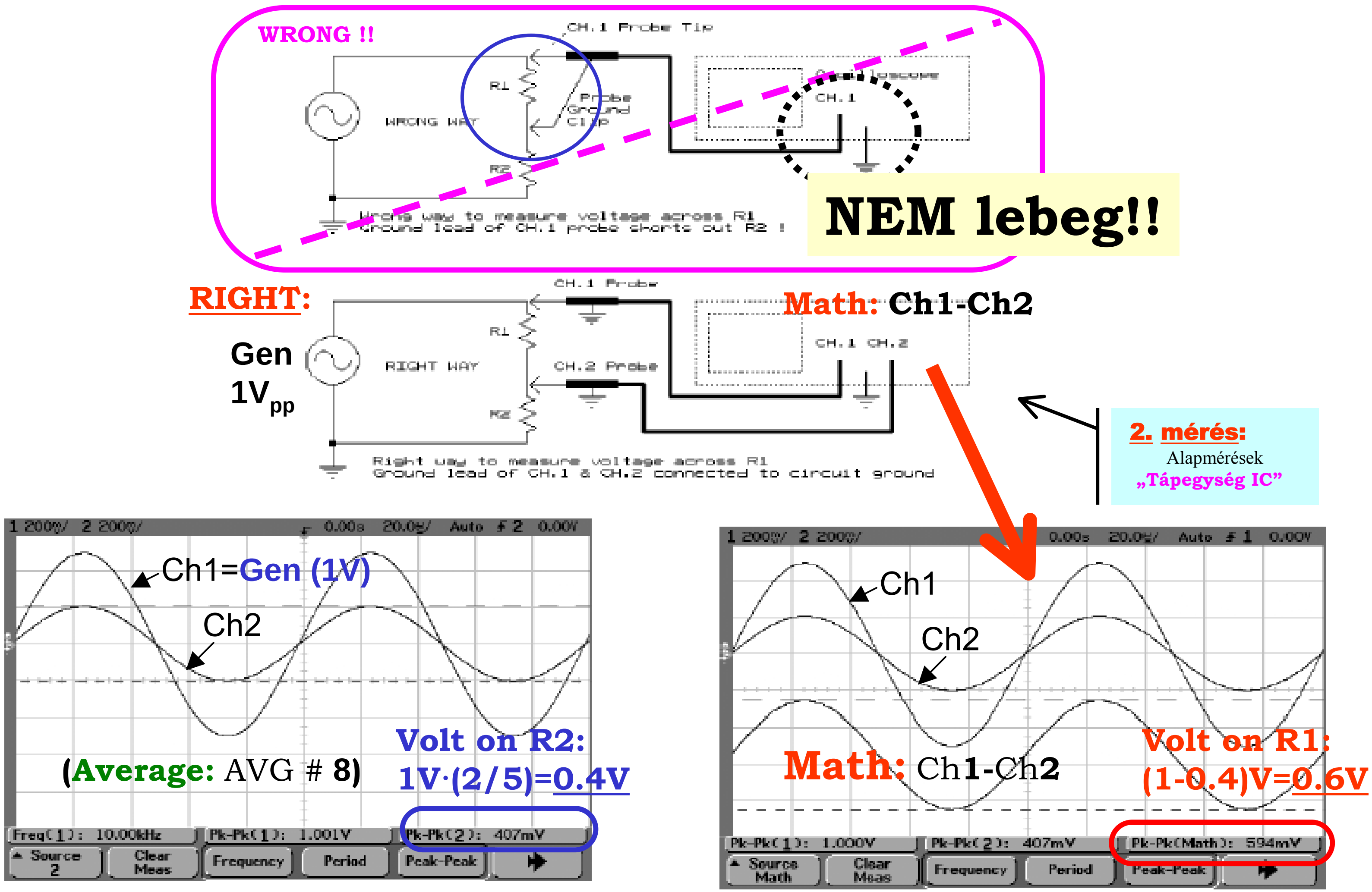

**Scope** (High Frequency):







# Scope : Measure voltage across R1 ( R1 = 3K, R2 = 2K ) → Math:1-2

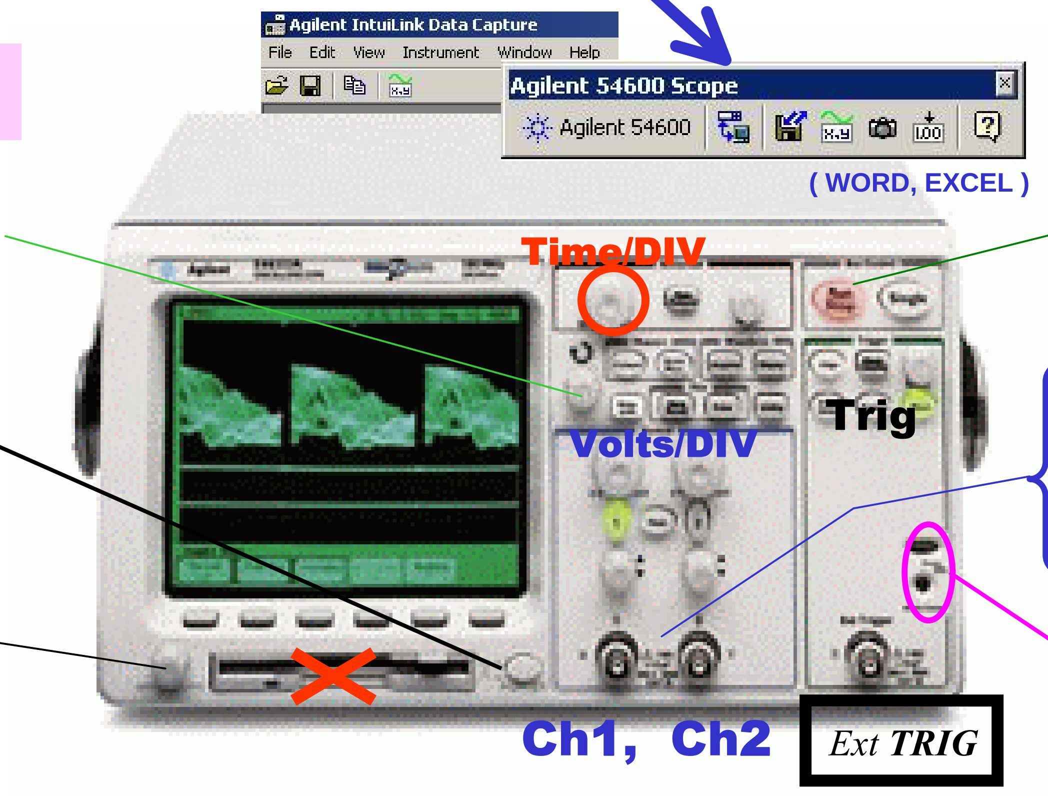


# Agilent **54622A** Portable **Oscilloscope (DSO)**

**2 Ch, 100 MHz;** max **200 Msa/s,** max **2 MB/ch (Mega*Zoom*)**

Hi-Def display, flexible **Trig;** auto**Meas, 2K FFT**

~~floppy disk~~; **GPIB, IntuiLink: Toolbar;** ~~Data Capture~~ *MOST **nem** használjuk*




**Everyday controls:**

Entry knob

**POWER**
**On**/Off

Intensity

**RUN / STOP**
**Single**

**BNC connectors**
*(Bayonet: quarter-turn locking mechanism)*
**coupling:** DC / AC

Probe comp (CAL)
**Output :**
SQU, **1.2KHz, 5V**

*Ext **TRIG***

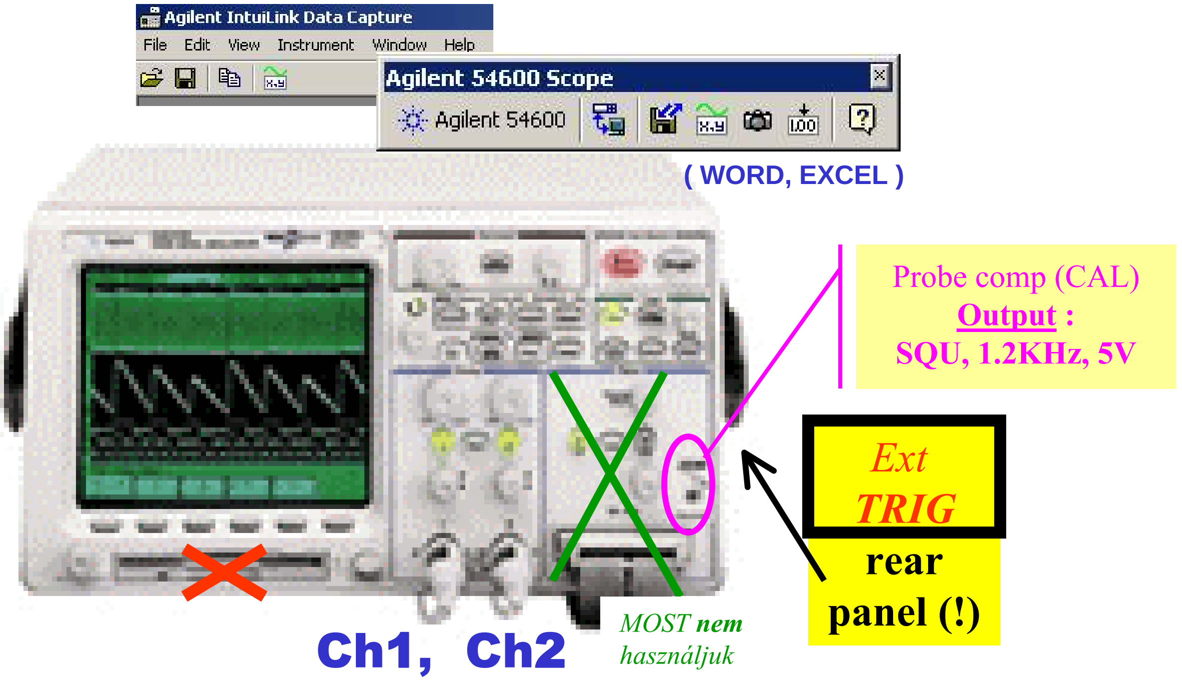
# 54622D MSO: Mixed Signal O'scope

**2 Ch, 100 MHz**; max **200 Msa/s**, max **2 MB/ch (Mega*Zoom*)**

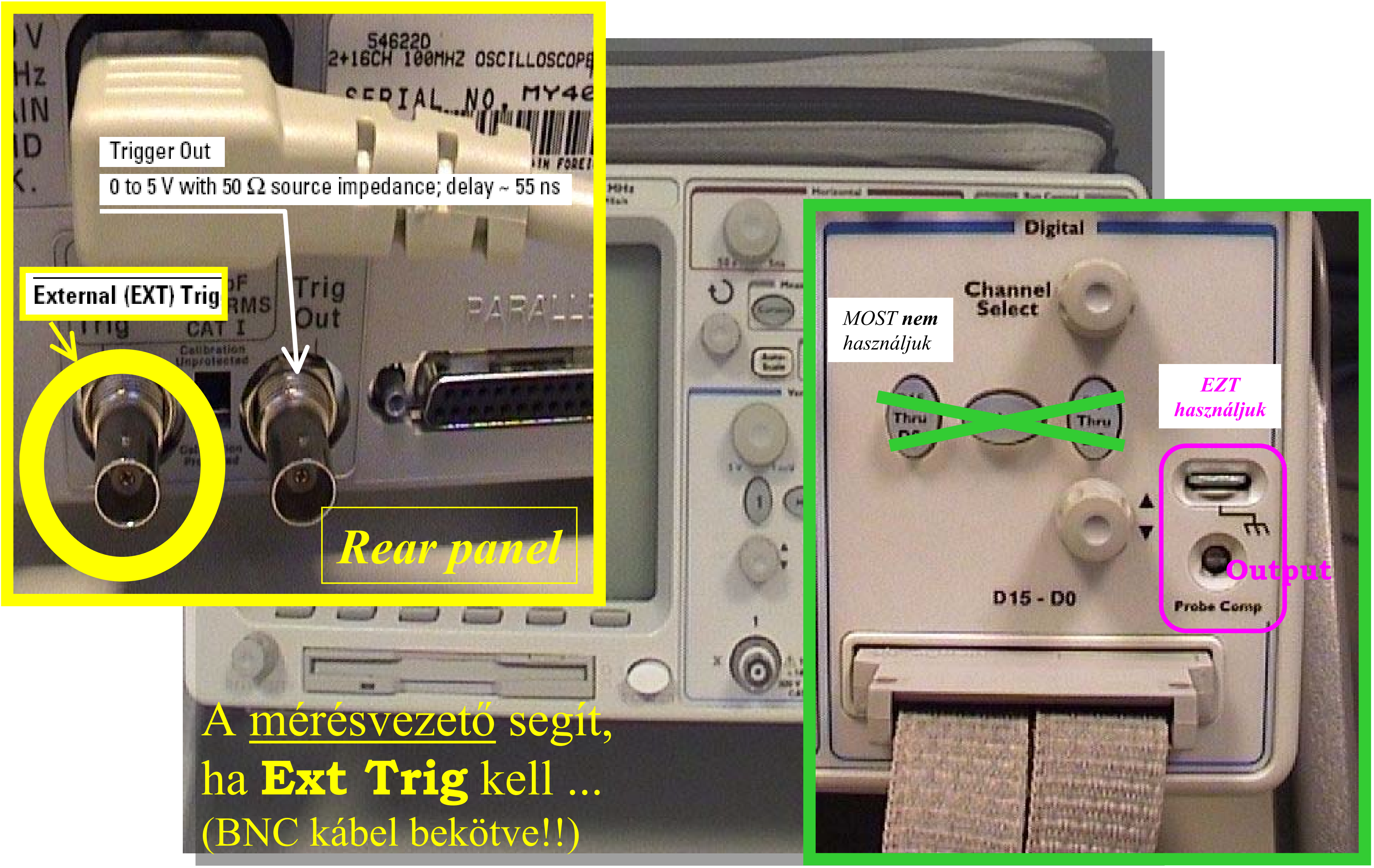
Hi-Def display, flexible **Trig;** auto**Meas, 2K FFT**

~~floppy disk~~; **GPIB, IntuiLink: Toolbar;** ~~Data Capture~~ *MOST **nem** használjuk*

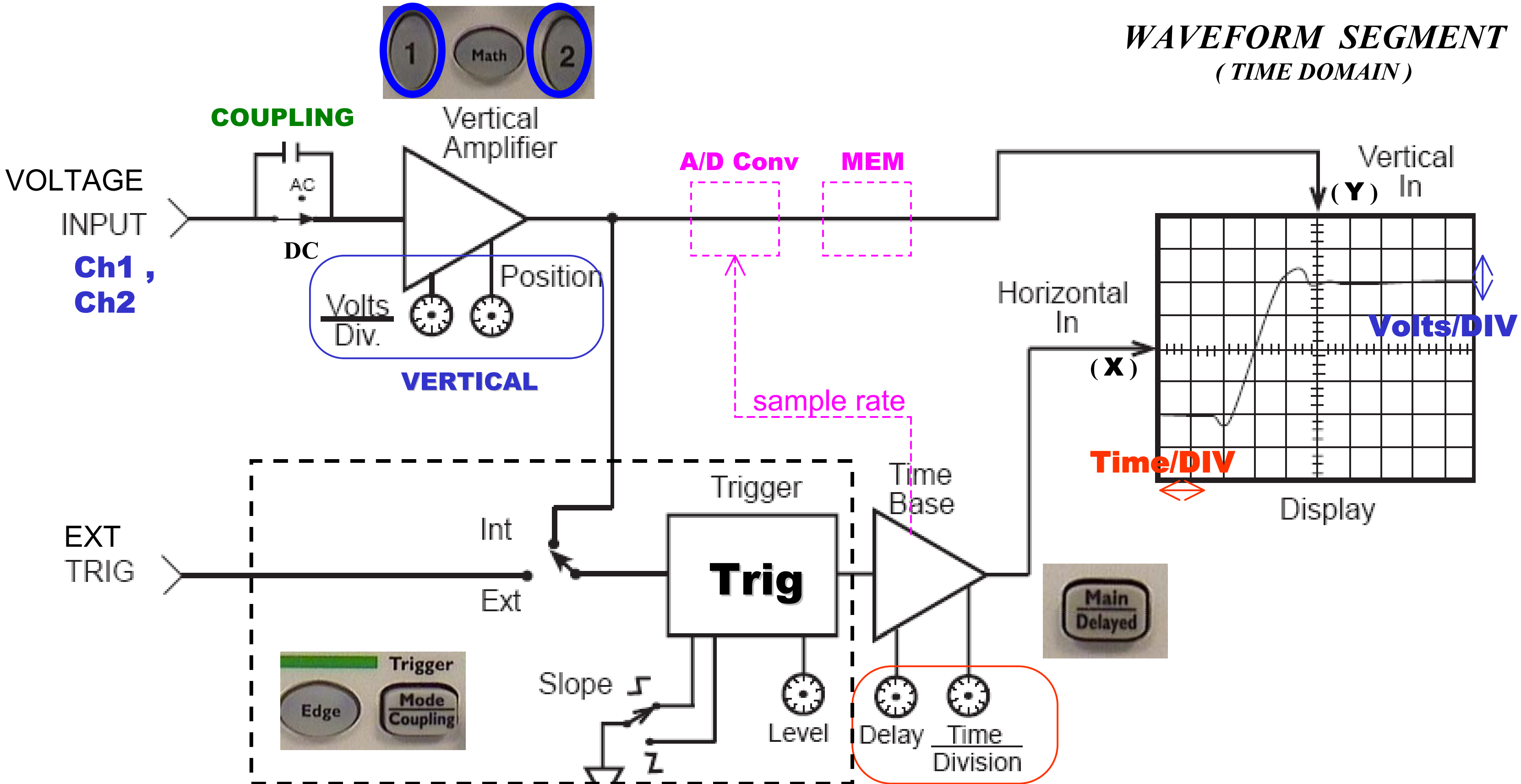
54622A DSO + ~~16 logic (digital timing) channels~~



# 54622D Mixed Signal O'scope (MSO)

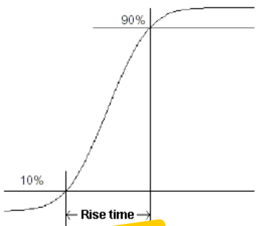


# Scope (graphic voltmeter) ... a "mental model"

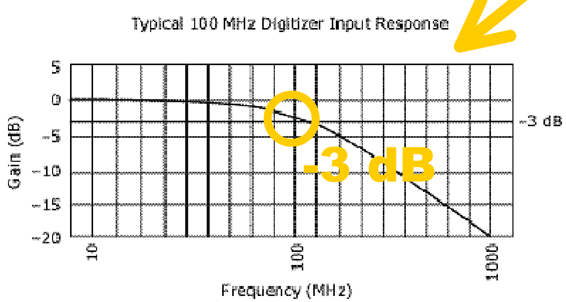


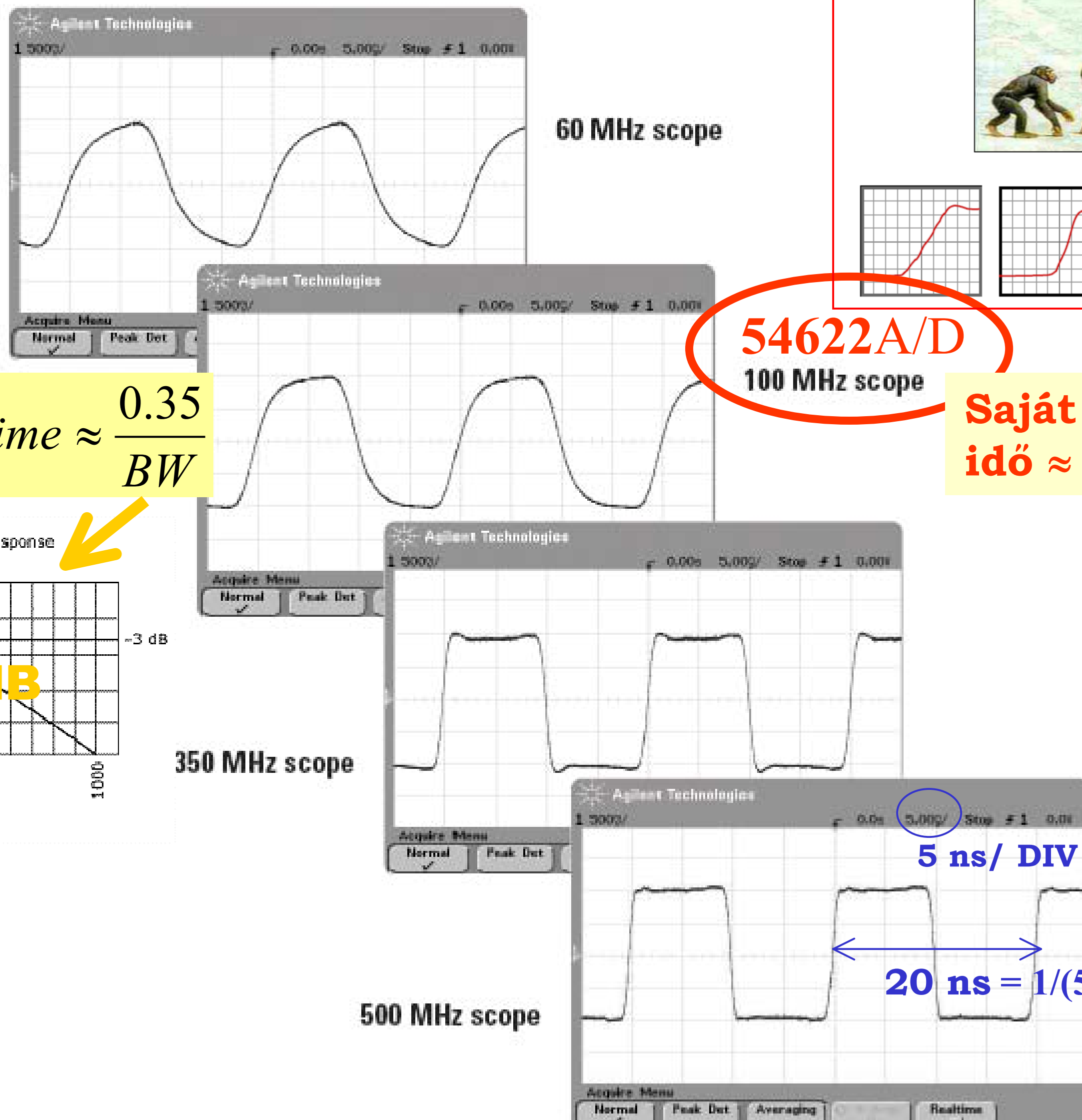

TRIGger: to stabilize repetitive waveform, and capture single-shot wfm

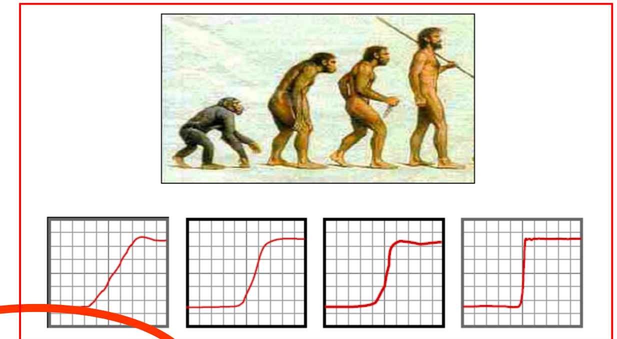
# **Scope** Bandwidth (BW) ... the most important characteristic




$$RiseTime \approx \frac{0.35}{BW}$$



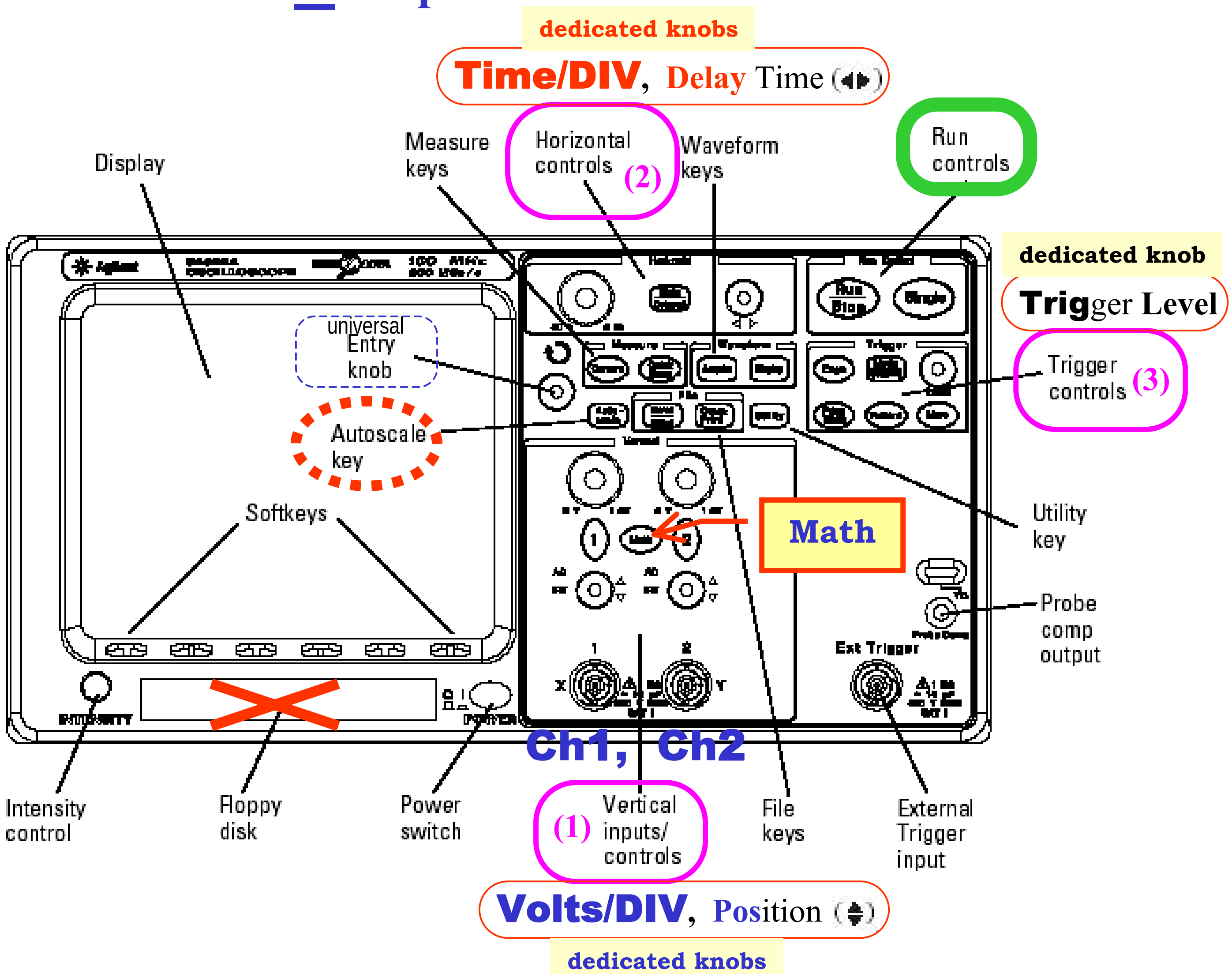



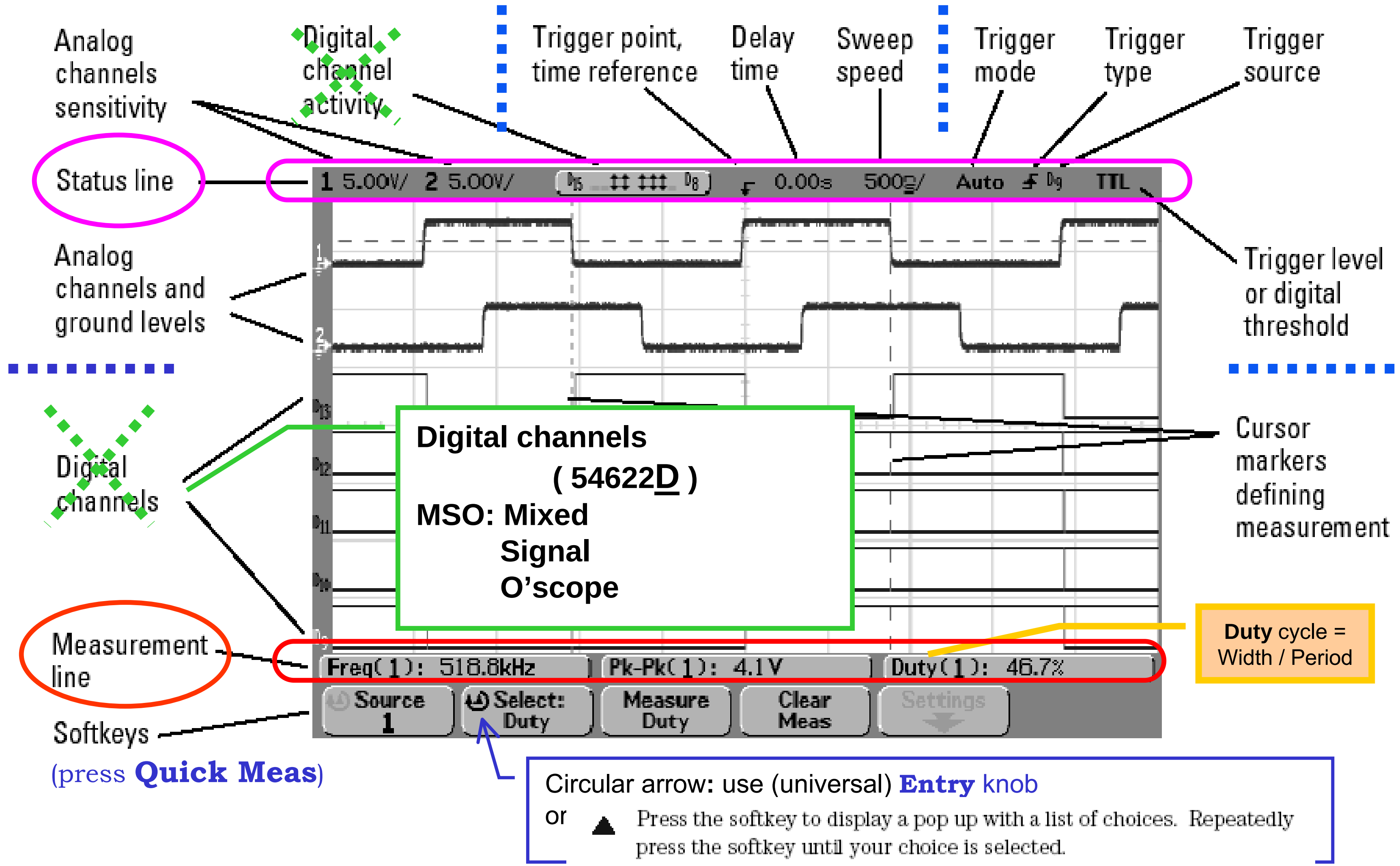
**Saját felfutási idő ≈ 3.5 ns**

# 54622A Scope - Front Panel

-----------------
(1) Vertical (1,2)
(2) Horizontal
(3) Trigger
[ AutoScale ]
-----------------
Run/Stop
[ MegaZoom ]
-----------------
Waveform
**Measure**
Math
-----------------
Utility
File
-----------------



# Scope - Display



# 54622D MSO: Mixed Signal O'scope

**2 Ch, 100 MHz;** max **200 Msa/s,** max **2 MB/ch (Mega*Zoom*)**

Hi-Def display, flexible **Trig;** auto**Meas, 2K FFT**

~~floppy disk~~; **GPIB, IntuiLink: Toolbars;** ~~Data Capture~~

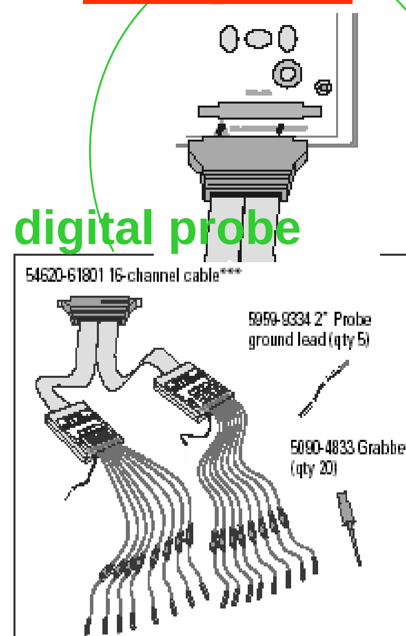
54622A DSO + ~~**16 logic (digital timing) channels**~~

MOST **nem** használjuk


( WORD, EXCEL )


**Maximum Input Voltage**

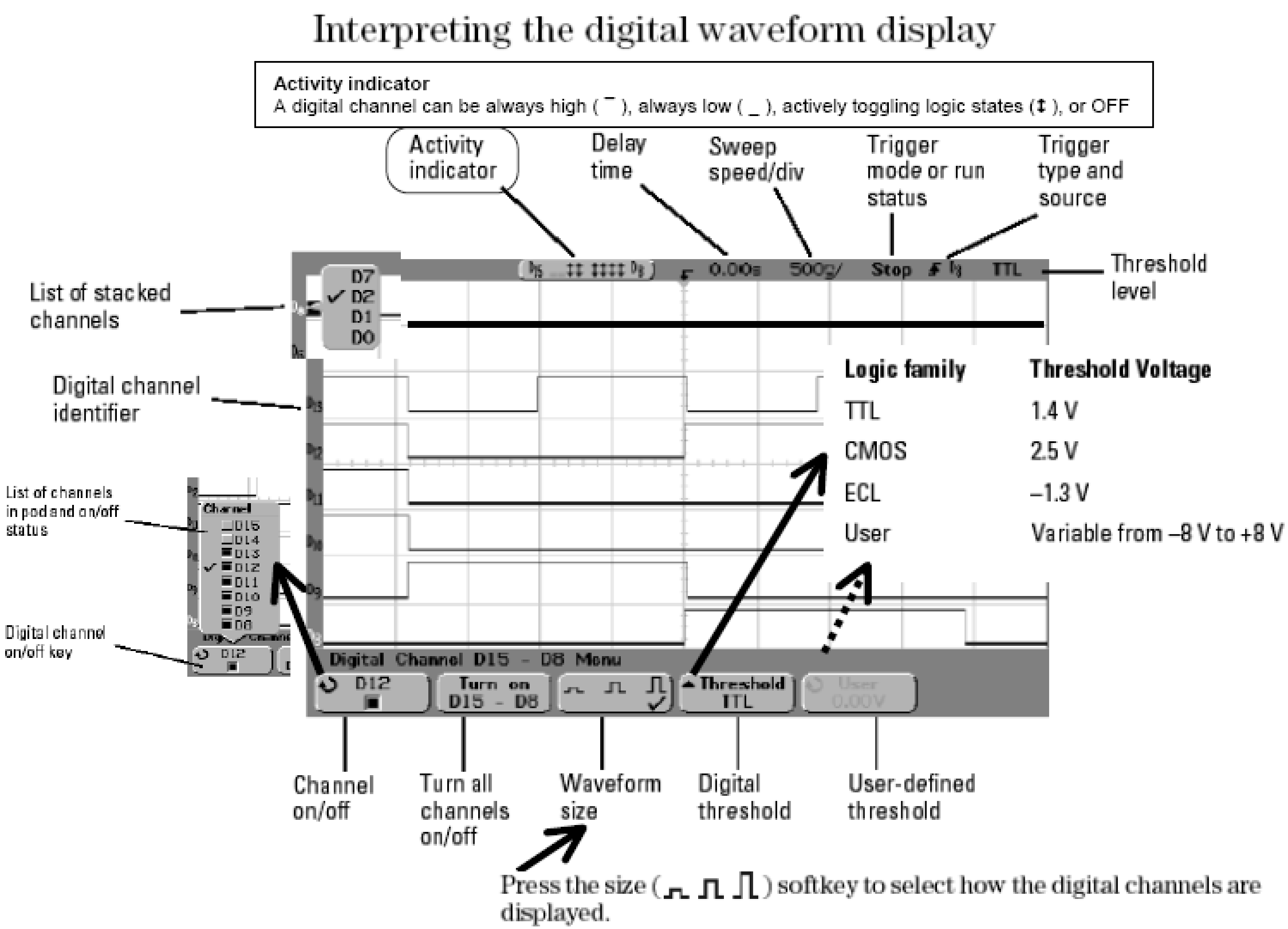
**± 40 V peak !!!**




*Ext* ***TRIG***

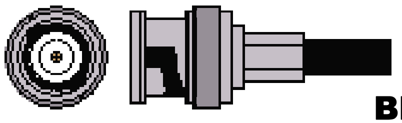
**rear panel (!)**

# Scope (MSO):



Interpreting the digital waveform display
Activity indicator
A digital channel can be always high ( ¯ ), always low ( _ ), actively toggling logic states (↕ ), or OFF
Activity indicator
Delay time
Sweep speed/div
Trigger mode or run status
Trigger type and source
Threshold level
List of stacked channels
D7
D2
D1
D0
Digital channel identifier
List of channels in pod and on/off status
Digital channel on/off key
Logic family
Threshold Voltage
TTL
1.4 V
CMOS
2.5 V
ECL
–1.3 V
User
Variable from –8 V to +8 V
0.00s
Stop
TTL
Digital Channel D15 - D8 Menu
D12
Turn on D15 - D8
Threshold TTL
Channel on/off
Turn all channels on/off
Waveform size
Digital threshold
User-defined threshold
Press the size ( ) softkey to select how the digital channels are displayed.

# Scope - **Ch1, Ch2** input ( **BNC** connectors )

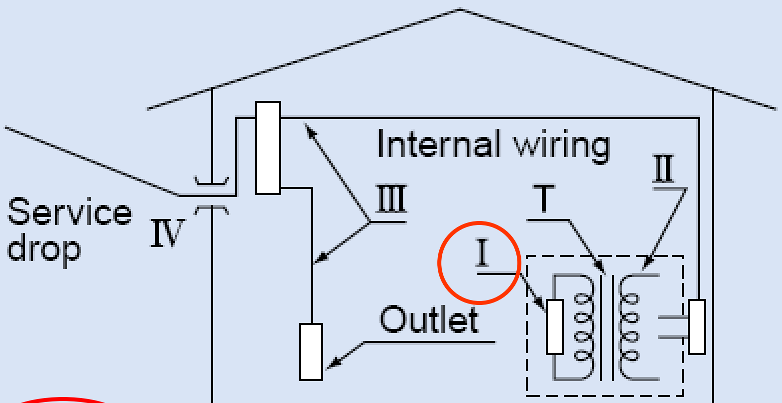


**BNC:** Bayonet Neill-Concelman (the inventors of the BNC connector)


**GROUNDED (non „floating”)**

## Overvoltage categories (CAT)

In order to ensure the safety of the user, IEC 60664 defines the ranges of use of measuring instruments by classifying power levels into overvoltage categories I through IV. This is because the excessive impulse or surge levels induced in a power line vary depending on the location of measurement (category). Categories with higher numerals designate locations that include larger surge voltages. Instruments that are designed for category III can thus withstand higher surge voltages than instruments designed for category II.



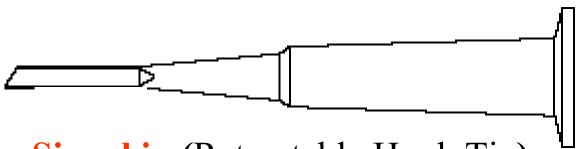

**Overvoltage category I (CAT I):**
Secondary circuits connected to an outlet via a power transformer.

**Overvoltage category II (CAT II):**
Primary circuits of a device connected to an outlet with a power cord.

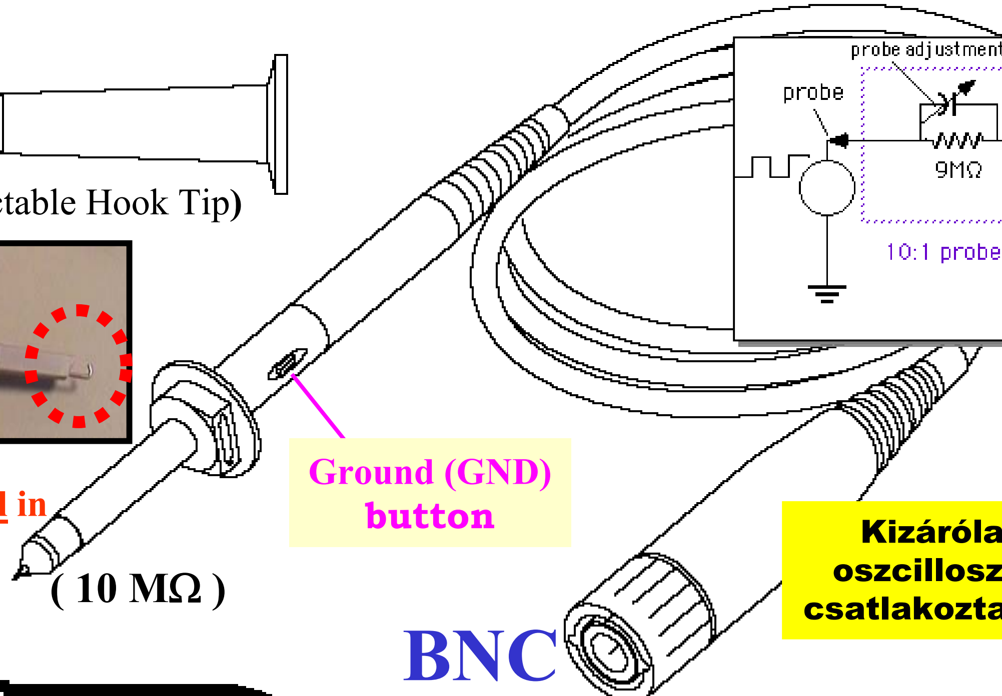
**Overvoltage category III (CAT III):**
Primary circuits of a device to which power is directly supplied from the power distribution panel, and circuits from the distribution panel to outlets.

**Overvoltage category IV (CAT IV):**
All service line entrance circuits through the power distribution panel

# Oscilloscope Probe (**10:1**)



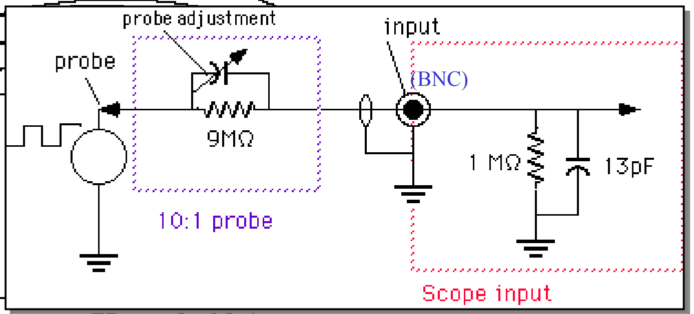
**Signal in** (Retractable Hook Tip)



**Signal in**

**( 10 MΩ )**

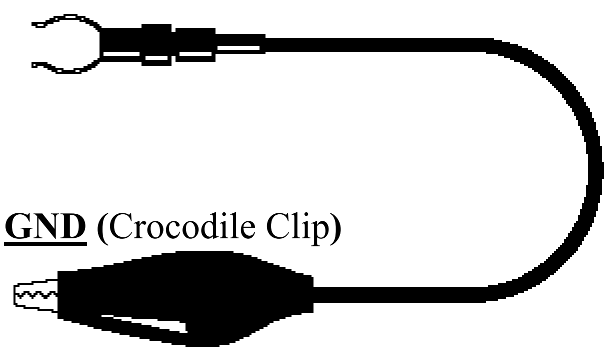
**Ground (GND) button**




**Kizárólag az oszcilloszkópra csatlakoztatható !!**

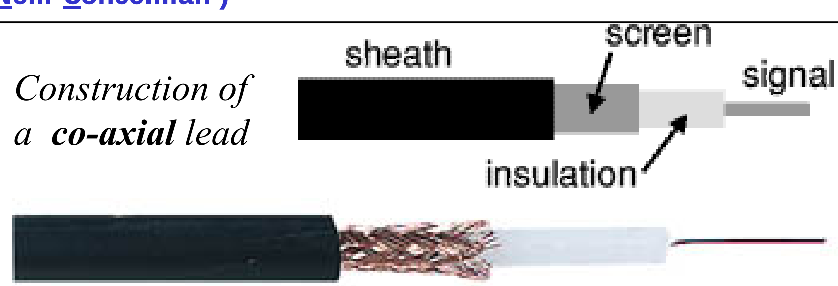
**BNC**

**( Bayonet Neill-Concelman )**



**GND** (Crocodile Clip)

*Construction of a **co-axial** lead*



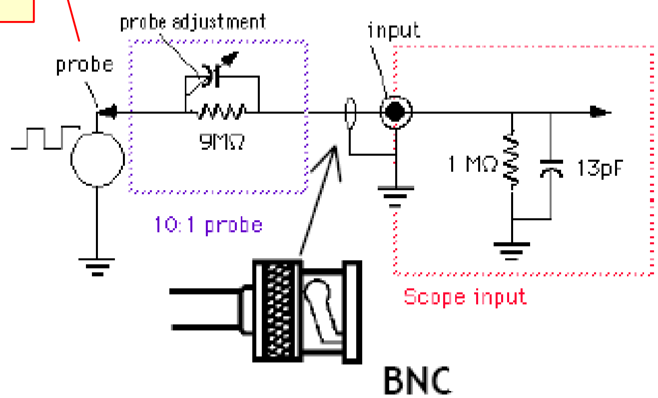
# Scope:

## Speciális mérőkábel (**kompenzált** osztó, **AUTO**probe)

BNC és <u>auto **10:1**</u> beállítás érzékelő → ÓVATOSAN kezelni !!

**Hi** : „injekciós tű”, **Lo ≡ GND (!)** : „krokodil-csipesz” , **Ref** button = GND

**... where the instrument meets UUT**

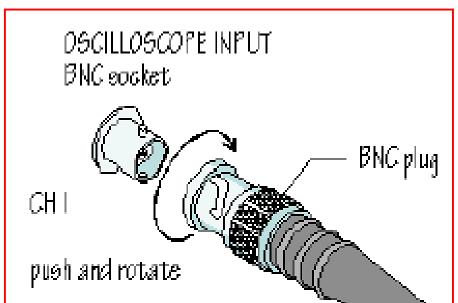


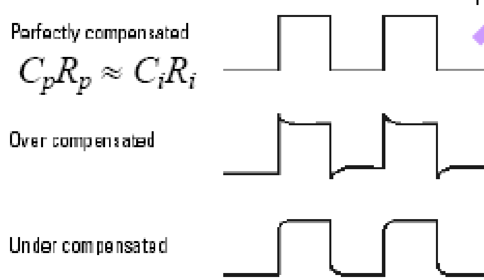

$$\frac{U_{out}}{U_{in}} = \frac{Z_i}{(R+Z_p)+Z_i}$$

$$= \frac{1}{\frac{R}{R_i}(1+j\omega C_i R_i) + \frac{R_p}{R_i}\cdot\frac{1+j\omega C_i R_i}{1+j\omega C_p R_p} + 1}$$

$$\approx \frac{\frac{1}{1+(R_p/R_i)}}{1+j\omega\frac{C_i R}{1+(R_p/R_i)}} \qquad R \ll R_i$$

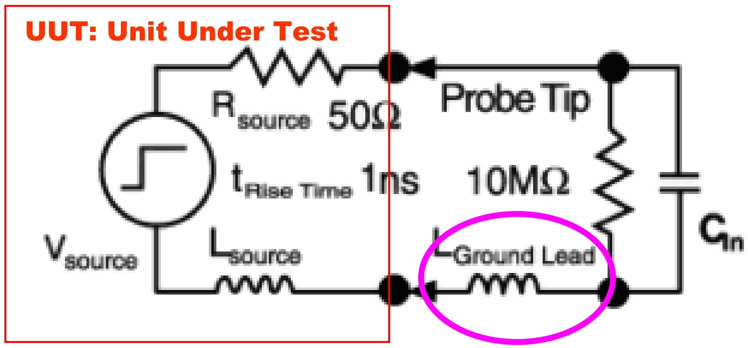
Érzékenység csökkenés, sávszélesség növekedés …



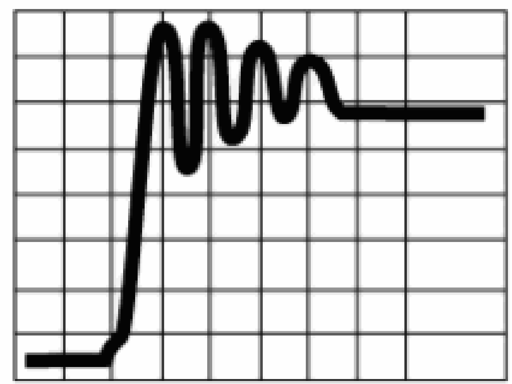




$R$ = 50 Ω (jel forrás-impedancia),
$R_p$ = 9 MΩ, $R_i$ = 1 MΩ

# GROUND LEAD INDUCTANCE EFFECTS




For a 10X Passive Probe with $C_{in}$ = 10 pF



- Ring Frequency using a 10 pF Input Capacitance 10X High Z Passive Probe and 6 inch ground lead.

Ring Amplitude ≈ **50% Error**

$$\text{Ring Frequency From GND Loop} = \frac{1}{2\pi\sqrt{LC}} = 50 - 70\ \text{MHz}$$

≈ 25 nH/inch =
10 nH/cm =
**1 nH/mm**

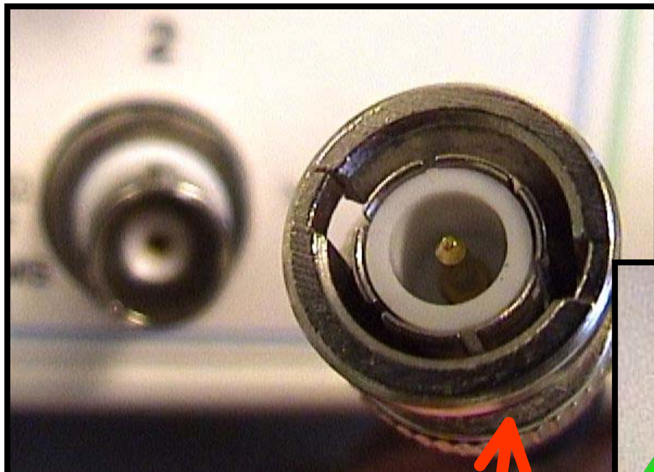
**10074C probe**

$C_{in} \approx$ **15 pF**

$$\frac{1}{2\cdot\pi\cdot\sqrt{150\cdot10^{-9}\cdot15\cdot10^{-12}}} = 1.1\times10^{8}$$

**100 MHz**

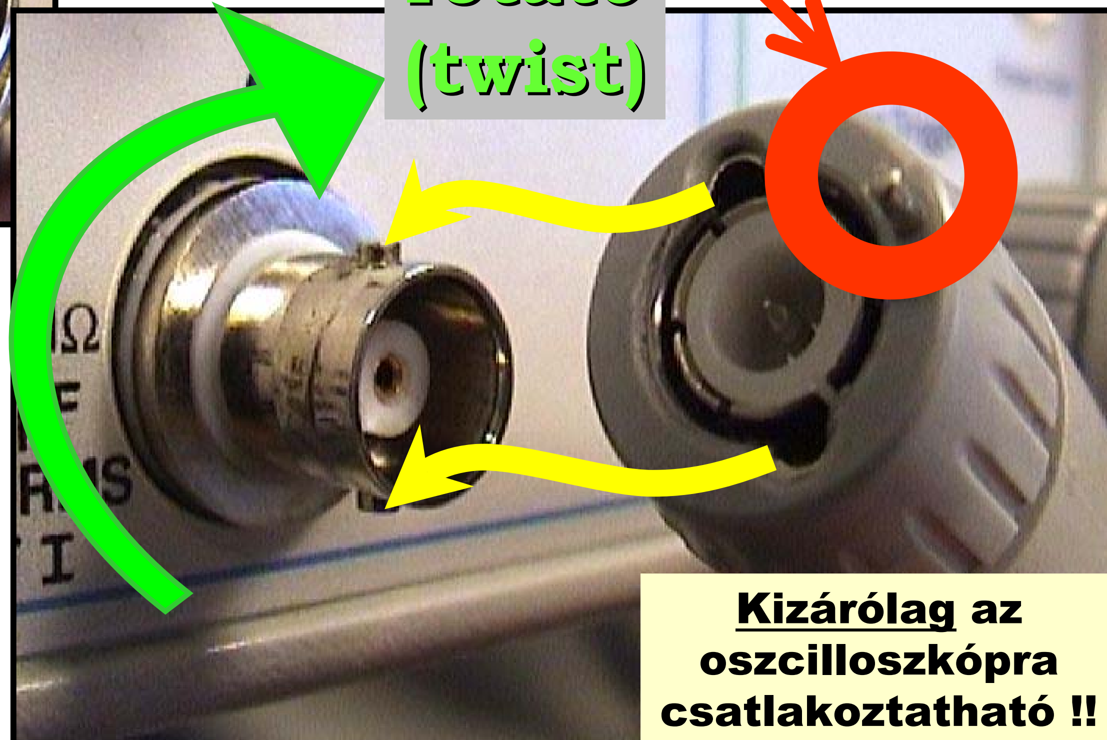
**Scope:** BNC



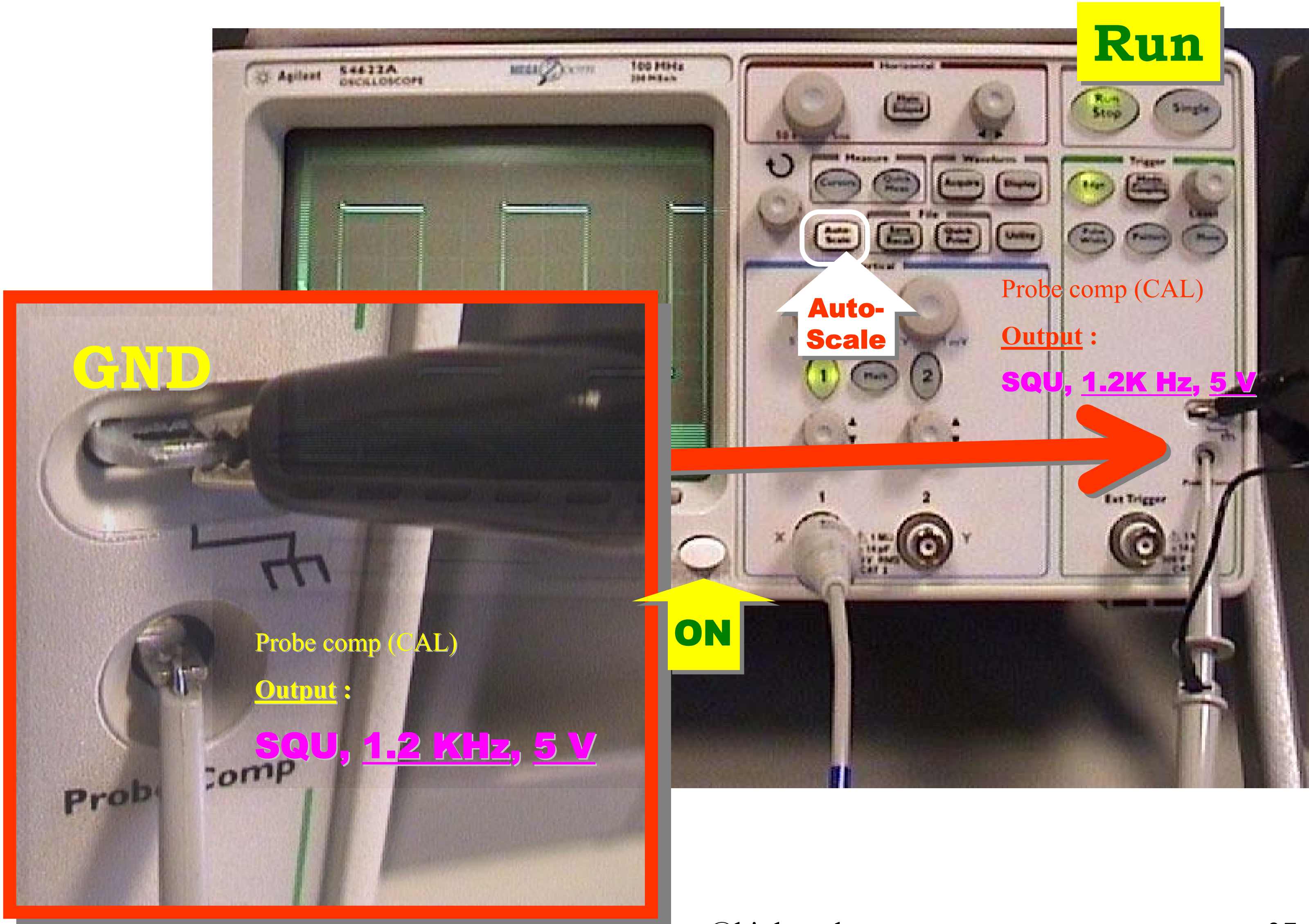
Generátorra is, oszcilloszkópra is csatlakoztatható

**Push and rotate (twist)**

AutoProbe (10 : 1)



**Scope:** Auto Probe → Probe Comp (Out) / **ON** , Auto Scale

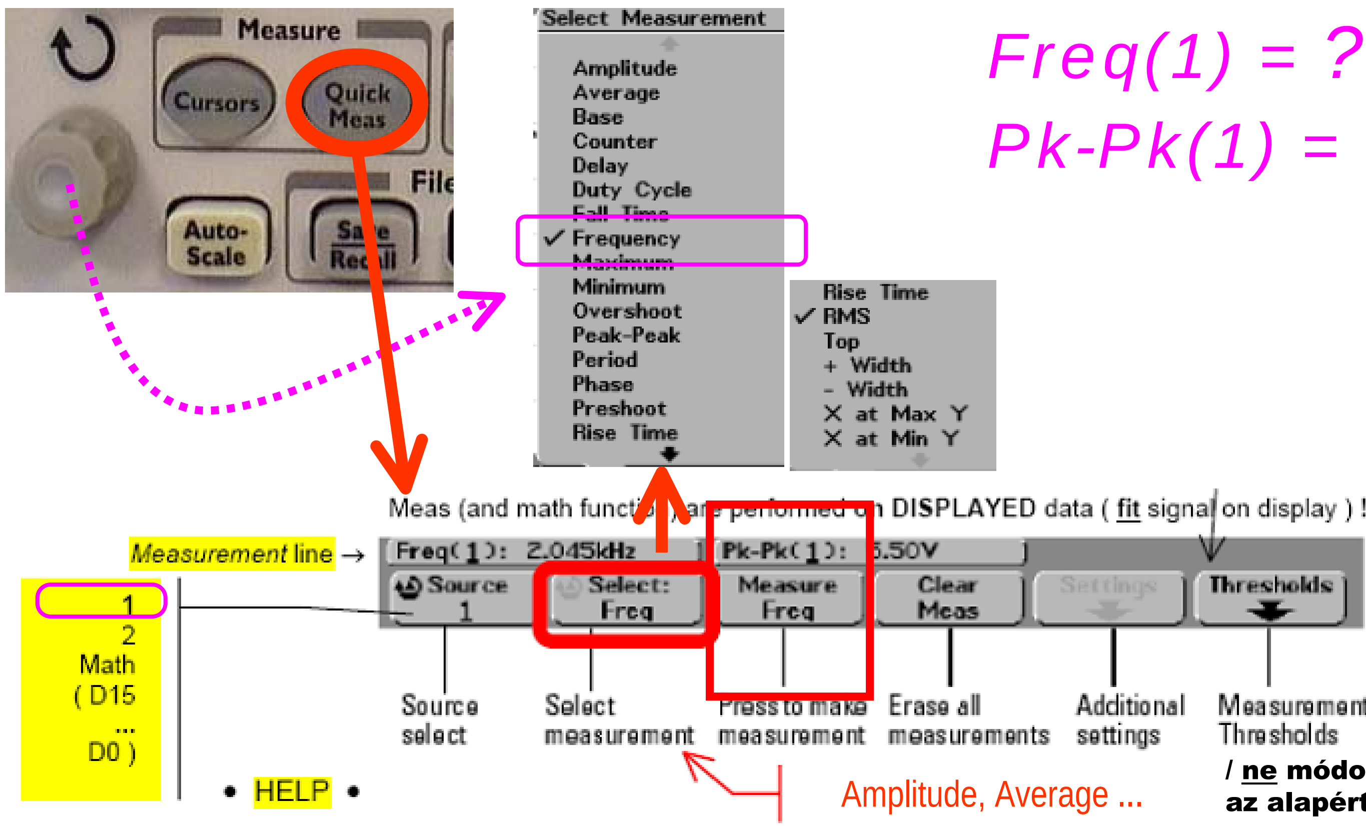


# Scope - Measure

## Quick Meas (“ Let the scope do it: `Select` / `Meas` ”)

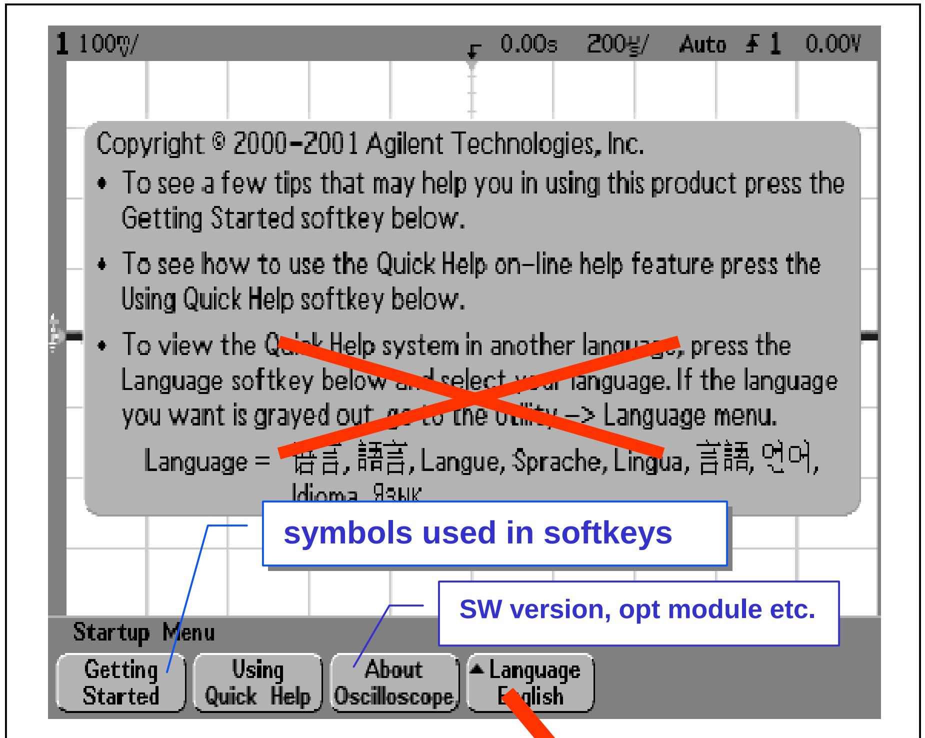
*Freq(1) = ?*

*Pk-Pk(1) = ?*



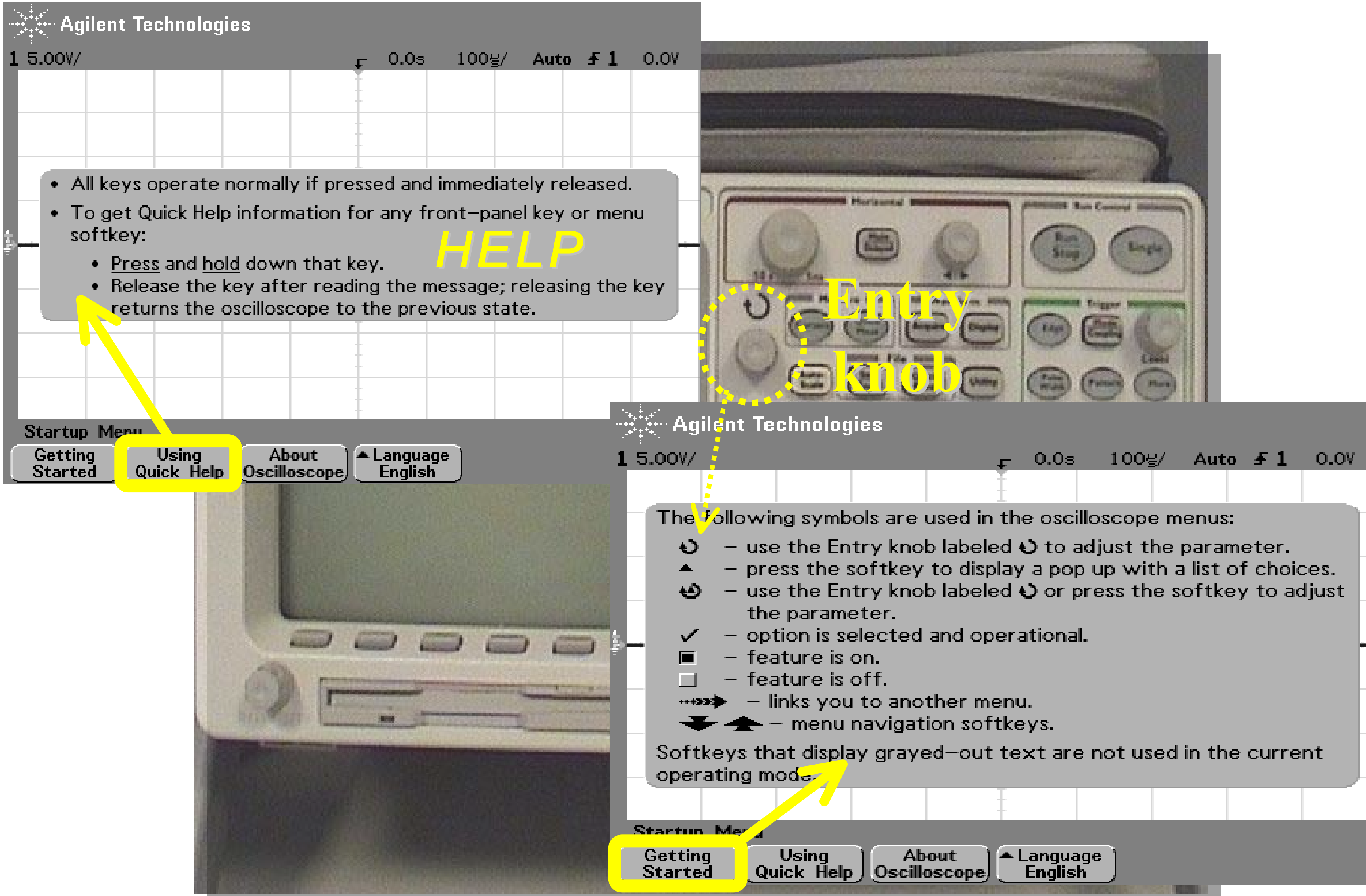

**/ ne módosítsuk az alapértelmezést /**

# **Scope:** Getting started ... (@ Power ON)



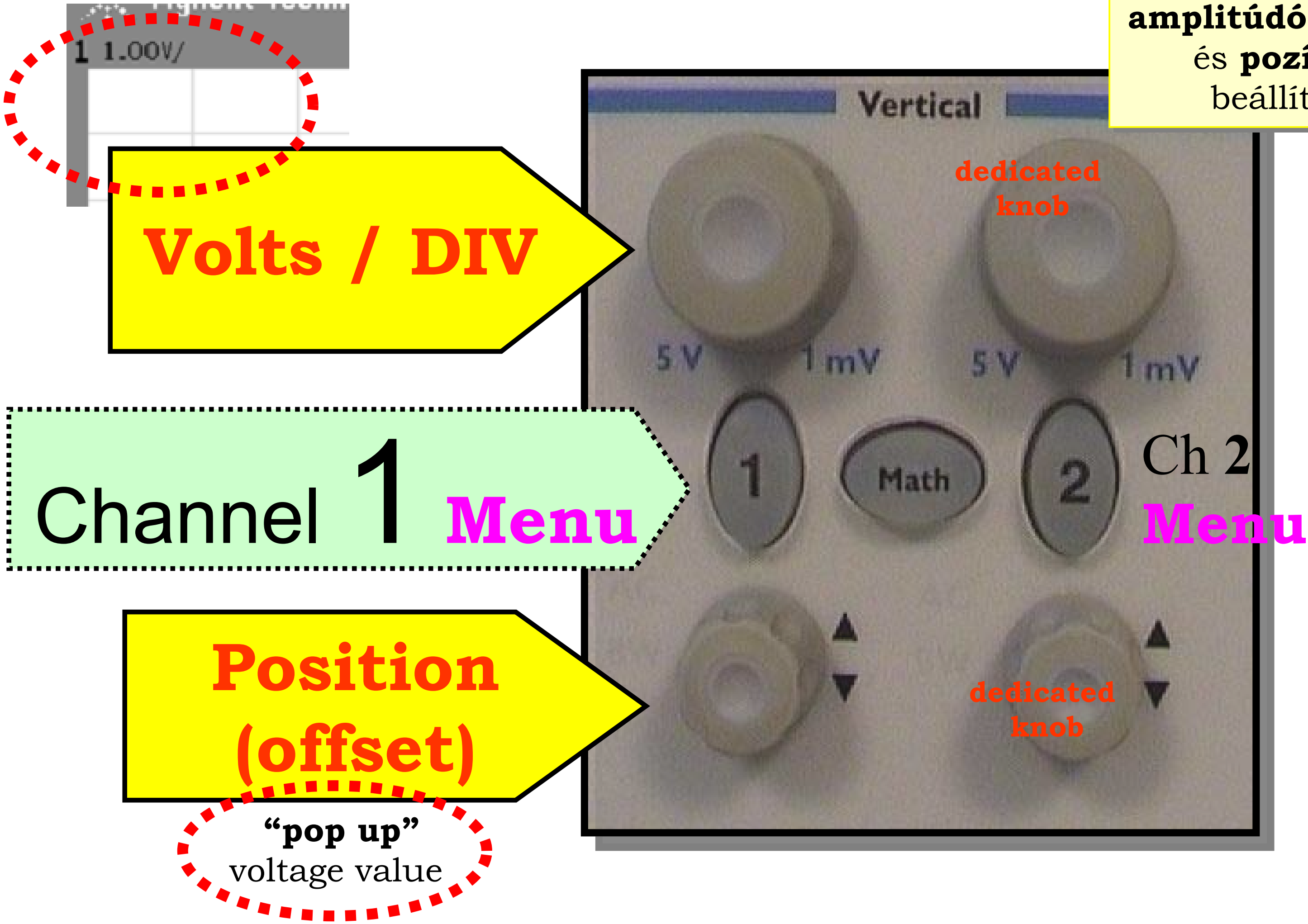

**Please DO NOT change (or delete) the language**

# 54622A/D scope (@ Power ON)

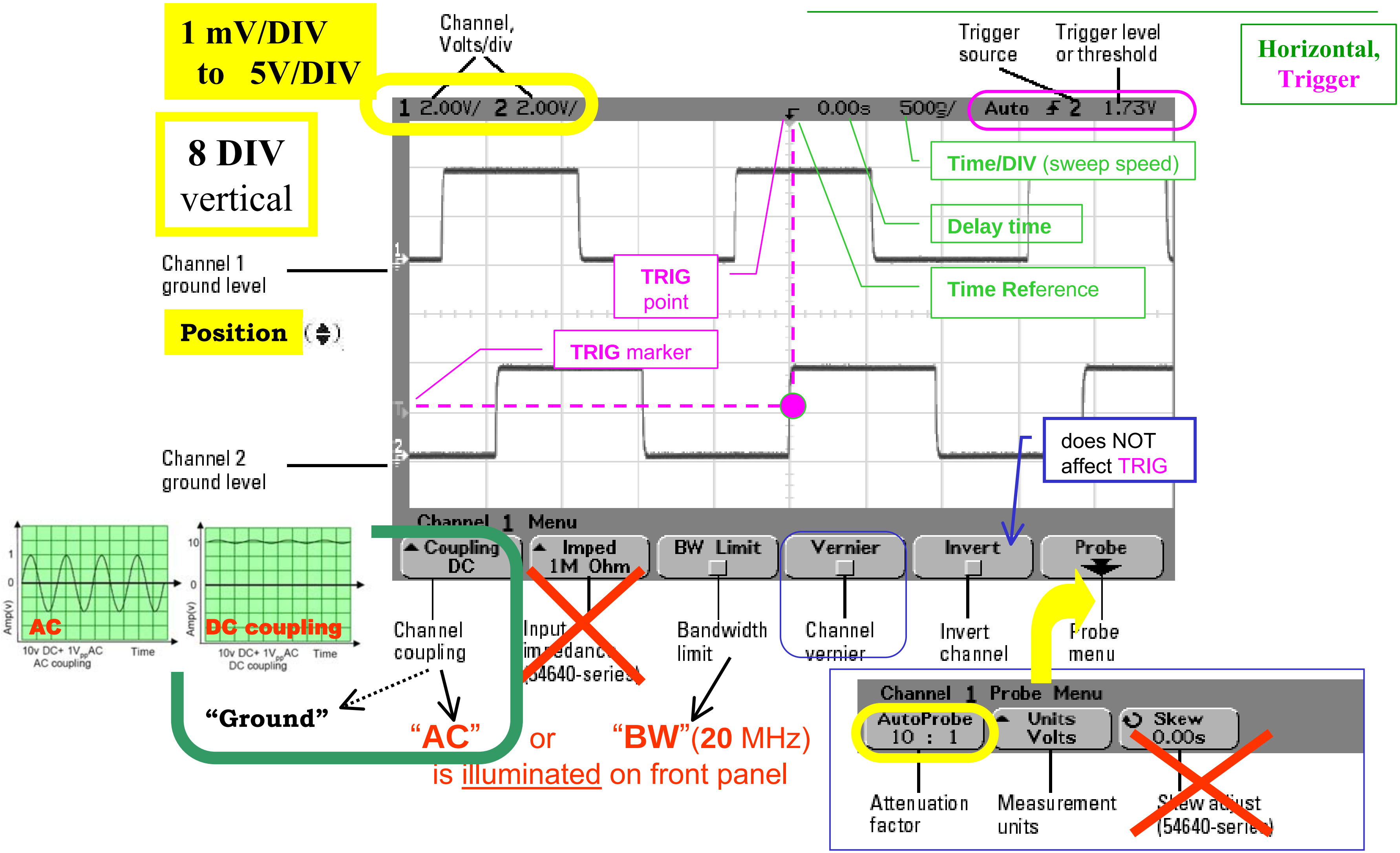


# Scope - Vertical

**Különálló (!)**
**amplitúdó (skála)**
és **pozíció**
beállítás

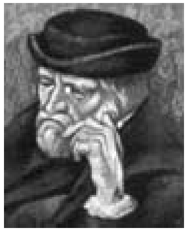


# Scope - Vertical : press 1 [or 2]

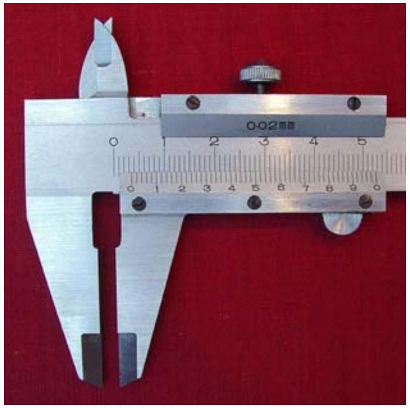


# **Scope -** Vernier scale

A **vernier** scale lets one read more precisely from a measurement scale. It was invented in **1631** by the *French* mathematician Pierre **Vernier** (1584-1638).

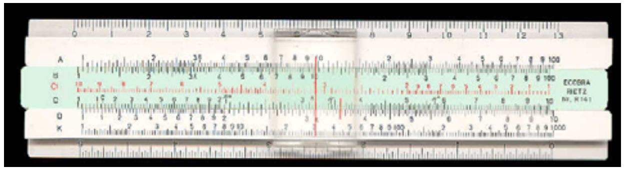


In some languages, this device is called **nonius**, which is the latin name of the *portugese* astronomer and mathematician Pedro **Nunes** (Lat. Petrus **Nonius**, 1502-1578).



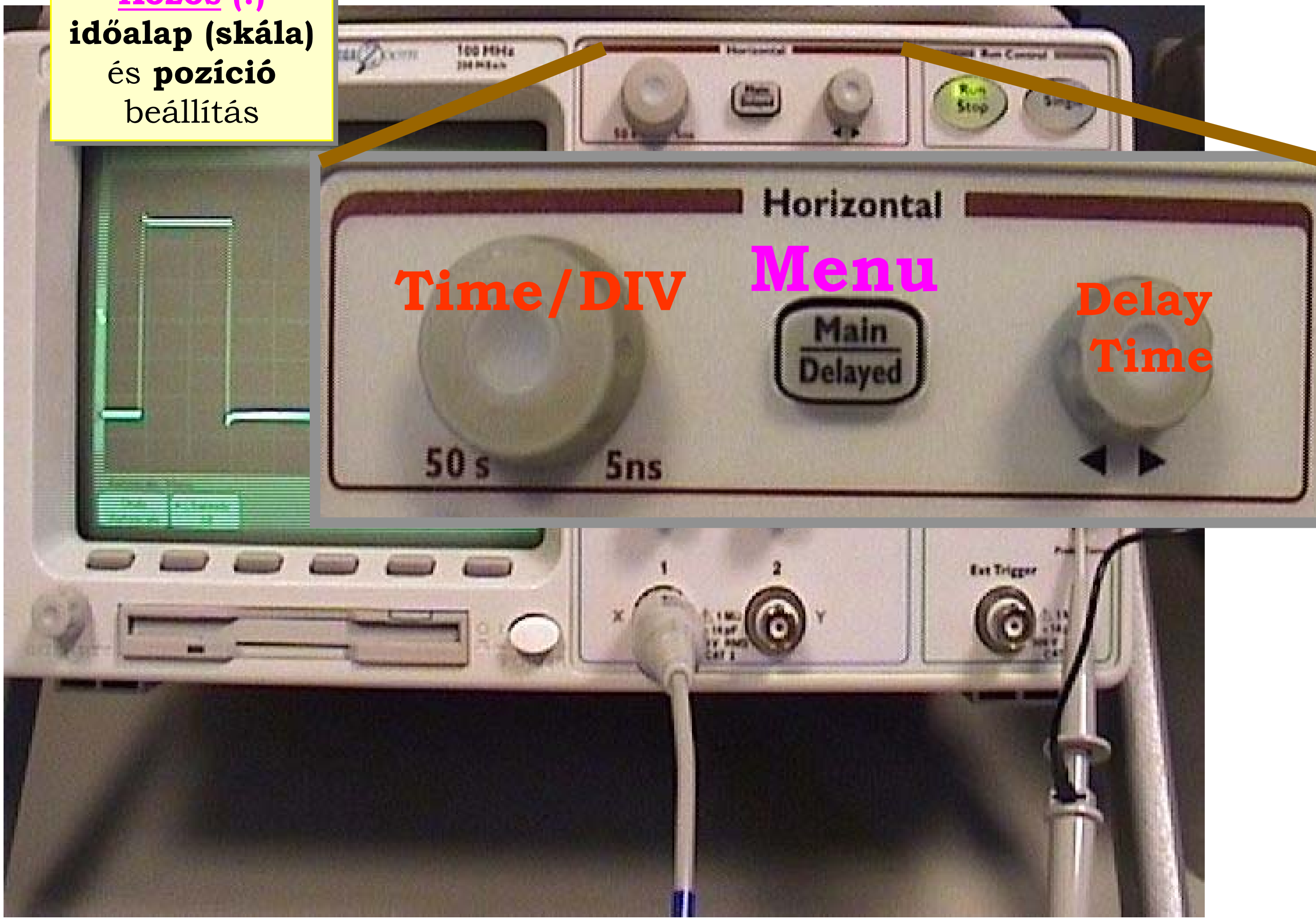
Verniers are common on sextant, machinists' measuring tools (all sorts, but especially **calipers** and micrometers) and on **slide rules**.

http://www.phy.ntnu.edu.tw/ntnujava/viewtopic.php?t=69

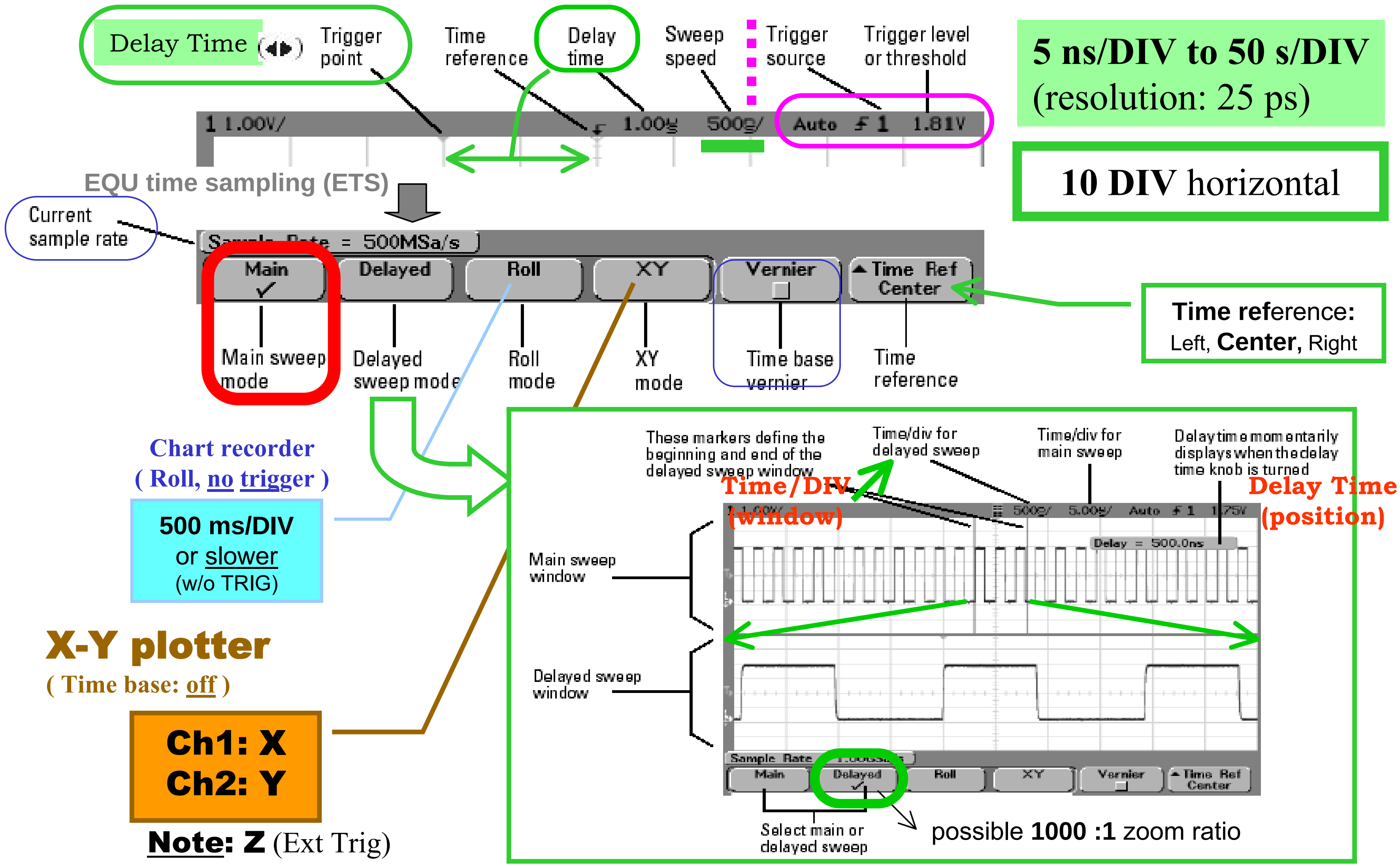


# Scope - Horizontal

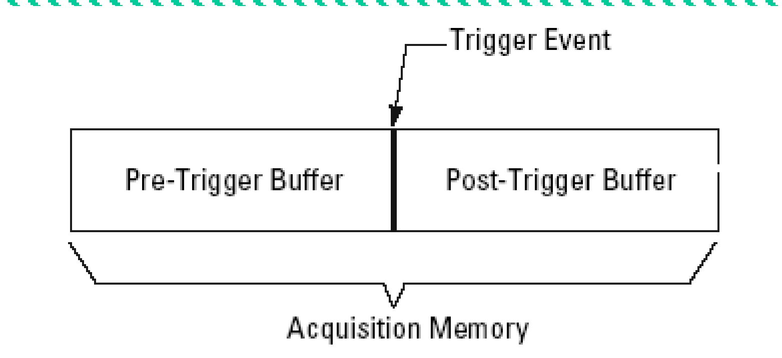
**Közös (!)**
**időalap (skála)**
és **pozíció**
beállítás

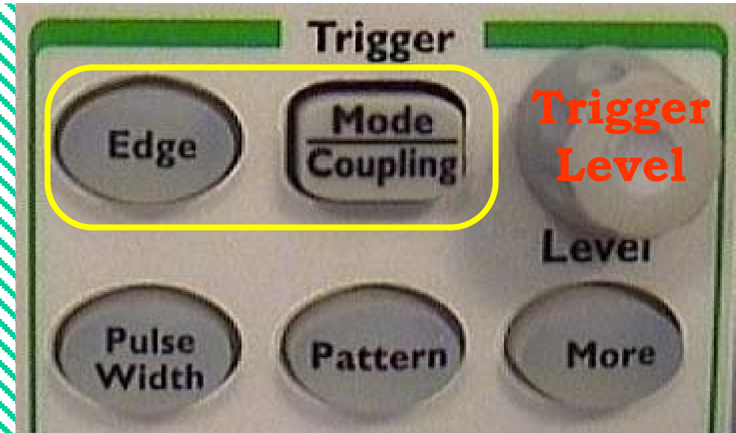


# Scope - Horizontal : press **Main/Delayed**



# Scope - Trigger : press **Mode/Coupling ; Edge**




**TRIG: to stabilize repetitive wfm, and capture single-shot wfm**

TRIGGER [**Mode/Coupling** ...*Holdoff*; **Edge** [20] ...*Int/Ext*] – **Sweep** „indítás"

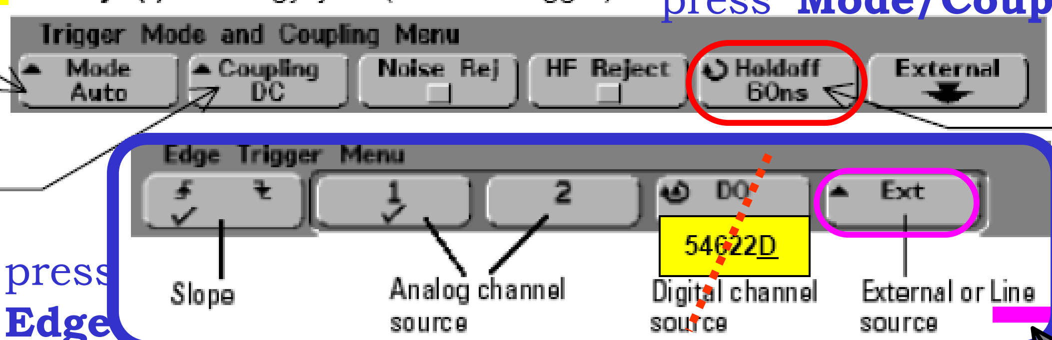
! **ANA szkóp** működése bemutatható ('Auto' módban 'Trigger Level' hatása)!

**DSO** trigger: **leállítja (!)** az adatgyűjtést (**Pre**/Post trigger) ... press **Mode/Coupling**

Auto Level
**Auto**
Normal

DC
AC
LF Reject
(TV)

press
**Edge**

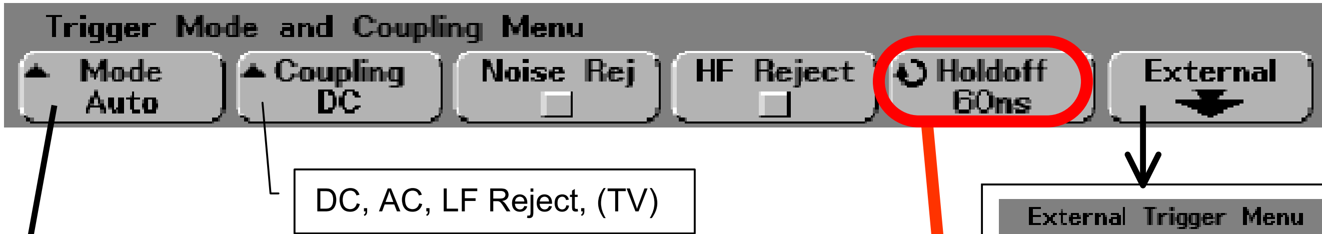



a sweep-et *követő* TRIG tiltás (álló kép beállításhoz)

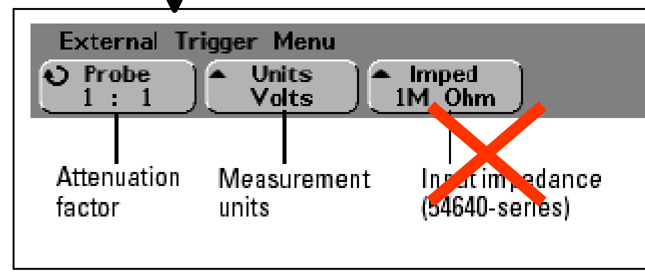
- „TRIGGER **Level** and icon (if ANA Ch)" – dedikált (közvetlen beállítás)

**2. mérés:**
Alapmérések
**„Tápegység IC"**

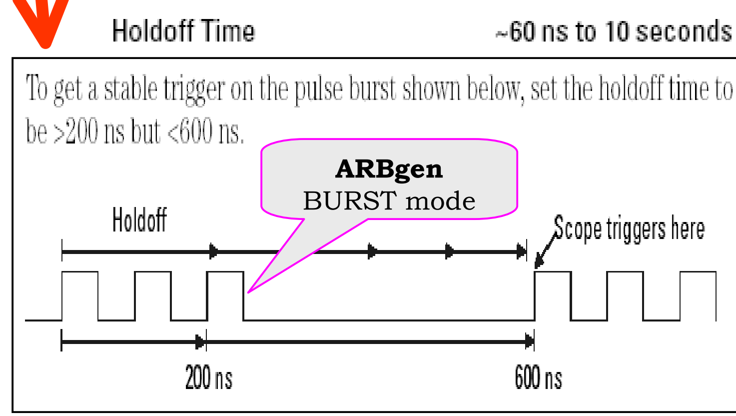
# Scope - Trigger mode




press **Mode/Coupling**



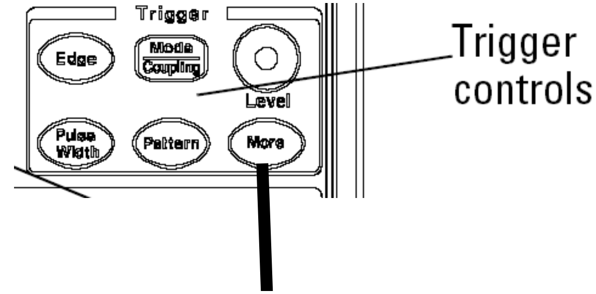

- **Normal** mode displays a waveform when the trigger conditions are met, otherwise the oscilloscope does not trigger and the display is not updated.
- **Auto** mode is the same as Normal mode, except it forces the oscilloscope to trigger if the trigger conditions are not met. **...as ANALOG Scope**
- **Auto Level** mode (54620-series only) works only when edge triggering on analog channels or external trigger. The oscilloscope first tries to Normal trigger. If no trigger is found, it searches for a signal at least 10% of full scale on the trigger source and sets the trigger level to the 50% amplitude point. If there is still no signal present, the oscilloscope auto triggers. This mode is useful when moving a probe from point to point on a circuit board.




Note: with *MegaZoom* technology, you can press **Stop**, then **pan and zoom** through the data to find where it repeats. **Measure** this time using the cursors, then **set Holdoff** to this number

# Scope - Trigger types

- **Edge**
- **Pattern**
- **Pulse width** (glitch)




| | |
|---|---|
| Pattern | Trigger on a pattern of high, low, and don't care levels and a rising or falling edge established across any of the sources. The analog channel's high or low level is defined by that channel's trigger level. |
| Pulse Width | Trigger when a positive- or negative-going pulse is less than, greater than, or within a specified range on any of the source channels.<br>Minimum pulse width setting: 5 ns<br>Maximum pulse width setting: 10 s |

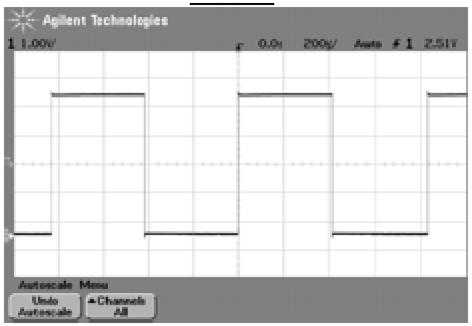
**More**

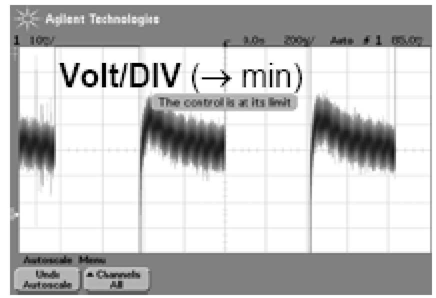
- **CAN** (**C**ontroller **A**rea **N**etwork)
- **Duration**: multi-channel pattern
- **I²C** (**I**nter-**IC** bus)
- **LIN** (**L**ocal **I**nterconnect **N**etwork)
- **Sequence**: Find event A, trigger on event B, with option to reset on event C or time delay.
- **SPI** (2 & 3 Wire **S**erial **P**eripheral **I**nterface)
- **TV**: Trigger on any analog channel for NTSC, PAL, PAL-M, or SECAM broadcast standards on either positive or negative composite video signals.
- **USB** (**U**niversal **S**eries **B**us)

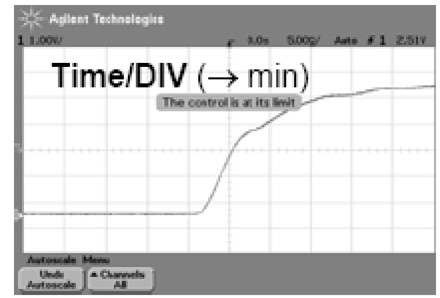
# Scope:

♣ Szemléltető **példa**: *saját forrás* mérése (**Scope Probe**, Ch1, 10:1 mérőkábel) – Auto-scale

Fedezzük fel a skála változtatás és a dedikált gombok hatását (→ *Status*: Állapot sáv) **…**




- VERT **Position** (⇕): a *rövid ideig* megjelenő érték-kijelzés a mozgó icon (GND ref) távolságát adja meg a képernyő közép-vonalához képest
- HOR **Delay time** (⇔): a trigger pontot (▼ symbol )mozgatja, és az érték-kijelzés azt adja meg, hogy a ∇ symbol (Time Ref, *Zoom* Ref) milyen távolságra van a trigger ponttól.

  Megjegyzés: a ▼ symbol (trigger pont) előtt **PRE-**, utána **POST-trigger** információ
- TRIG **Level:** növeljük icon (if ANA Ch) értékét a jel-csúcsérték fölé, ekkor ha

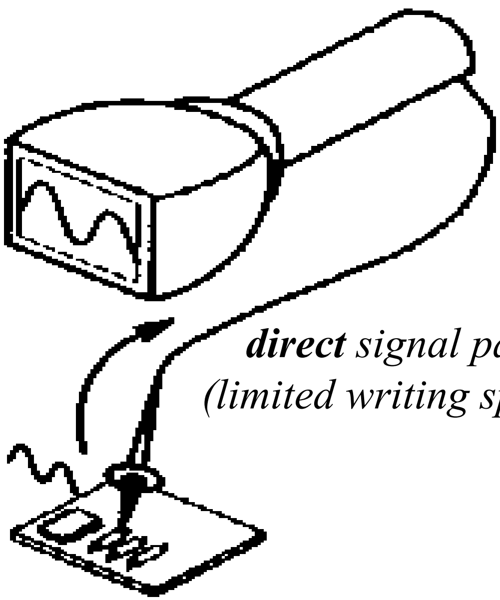
  TRIGger: Auto – megszűnik az álló ábra (→ **nincs szinkron**, mint **ANA scope!!**),

  (*átváltva*) Normal – **„befagy”** a kijelzés (→ mint **DSO,** *villog* a Trig’d )

Scope

## ANALÓG :

***közvetlen “rajzolás” (képernyõre írás)***



***direct** signal path*
*(limited writing speed)*

Analog Oscilloscopes Trace Signals

**54622A/D**

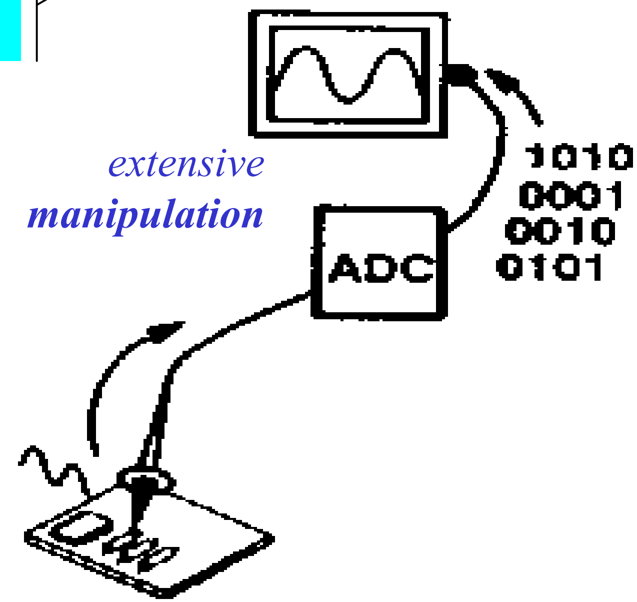
## DIGITÁLIS :

Acquire

***numerikus “tárolás” (memóriába írás) és virtuális nyomvonal “rekonstrukció”***

Display

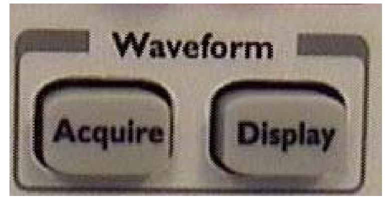
*extensive*
***manipulation***




Digital Oscilloscopes Sample Signals and Constructs Displays

# Scope: Waveform – **Rekord** felvétel és megjelenítés

## ACQUIRE:
**digitalizálás** (numerikus minták)
→ mintavétel és kvantálás

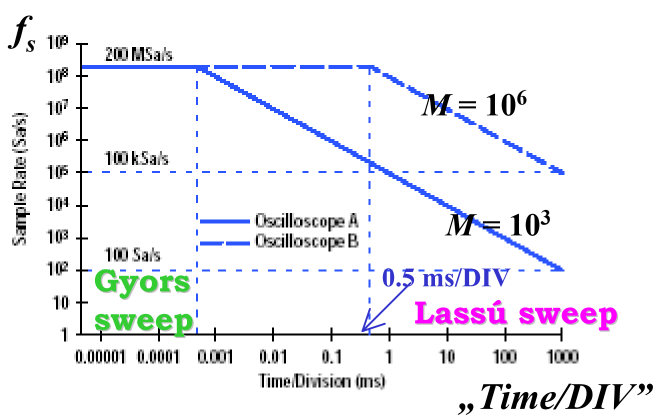



## DISPLAY :
**rekonstrukció** („virtuális" nyomvonal)
→ pixel-ek

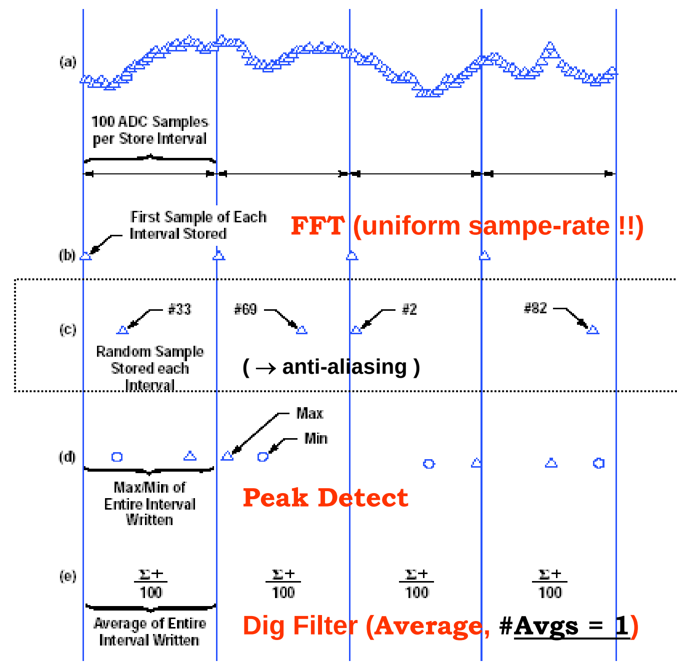
A memória kapacitás ( *M* ) **korlátozza** a minta-gyakoriságot ( *fs, sample rate* ):

$$fs = M/(10\cdot\text{"}Time/DIV\text{"}) \le 200 MSa/s$$

a DSO **sávszélessége** tehát változik (!!) az **időalap (Time/DIV)** módosításával
( → **Peak Det**ect: glitch detect)

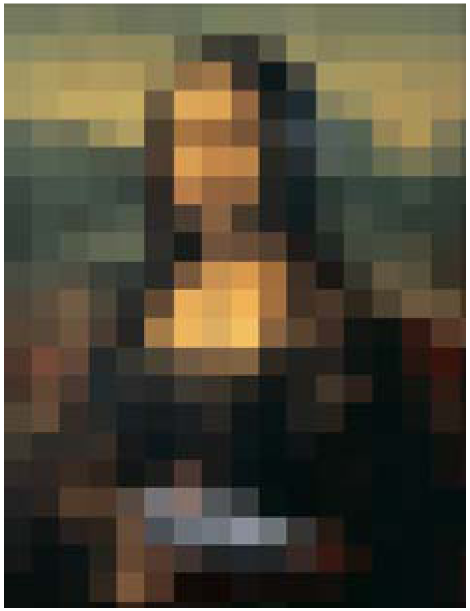



max **1-2(4)•10⁶ (Mega) point** memória
*kontra*
**1•10³** (Kilo) pixel display (**compression !**)



# **Scope** - Why is long Memory important

1a



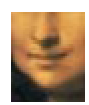
2a

3

1b

10 kpts

2b



100 kpts

1 Mpts
Full resolution of entire image

**… finally you know why Mona Lisa is smiling**
(listening to Leo's new music player)

# Scope - Waveform : press **Acquire**



**Lassú sweep**

**1 ms/DIV** or slower
(10 ms/5 ns = 2M)

**Gyors sweep**

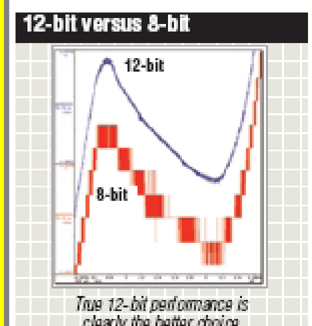
**2 us/Div** or faster *
(20 us/5 ns = 4K),
with reduced BW
(200MSPS/4= 50MHz)

(@ **one** TRIG event,
SINC interpolation)

*or infrequent trigger,
complex waveform

| #AVG | resolution |
|---|---|
| 1 | 8 bit |
| 4 | 9 |
| 16 | 10 |
| 64 | 11 |
| **256** | **12** |

( @ stable, multiple TRIG,
up to 16K **#AVG** )



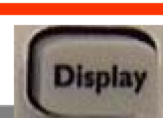

**#AVG = 1** **HiRes**

| | |
|---|---|
| **2 us/DIV** | **8 bit** |
| 5 us/ | 9 |
| 20 us/ | 10 |
| 100 us/ | 11 |
| **500 us/** | **12 bit** |

**OS: oversampling &**
**DF: decimation filter**
( @ one TRIG )

---

# Waveform : press **Display**

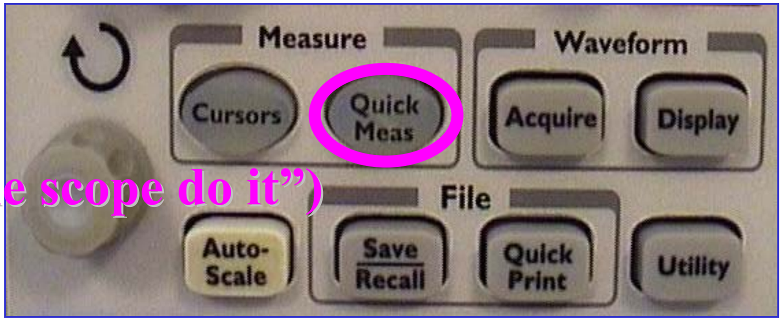




**OFF**

**ON** ( “connect the dot”:
LIN interpolation )

## **Scope -** Measuring methods




Auto: **Quick Meas** **("Let the scope do it")**

Manual: **Cursors**

"Eyeballing": graticule markings – Display / **Grid** [ 20% ]

*counting* the (minor) divisions, and
*multiplying* by the readout sensitivity
… like ***Analog Scope***

*Maximizing* measurement Accuracy, the first rule :

set the highest resolution ($\rightarrow$ scale; **Vernier; Delayed**)

# Scope - Measure : press **Quick Meas; Cursors**

MEASURE [**Quick Meas**, **Cursors**] – Paraméter **mérések**

- ! (Display) **Grid** : „hagyományos (**ANA szkóp**) mérés” is lehetséges !
- Egyidejűleg három **auto** param. mérés:

NE módosítsuk az alap-értelmezést (csak ha célszerű : pl. 9. mérés)

Meas (and math function) are performed on **DISPLAYED** data ( fit signal on display ) !!

*Measurement* line →

1
2
Math
( D15
...
D0 )


press **Quick Meas**

Source select | Select measurement | Press to make measurement | Erase all measurements | Additional settings | Measurement Thresholds

Amplitude, Average ...

- HELP •
- **Manuális** mérővonalak (**kurzorok**):

Normal
(Binary
Hex)


press **Cursors**

1, 2, Math

**X: relative to TRIGger point**

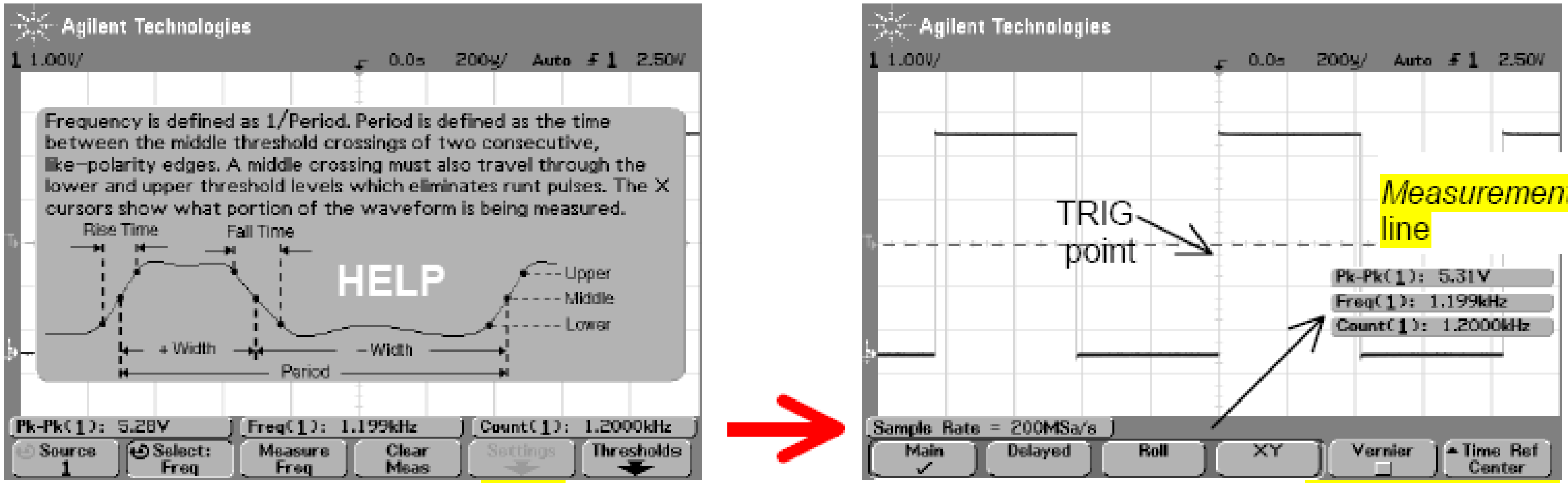
**Y: relative to GND point**

Measurements made with **Quick Meas** may give incorrect results, particularly on noisy signals.

Look at the cursor lines to see if ***you*** agree that the cursor lines are showing what you want to measure. If your displayed signal is noisy for any reason, try using **Averaging** to clean it up.

# Scope:

♣ Szemléltető **példa:** (folytatás, *egységes* alap-helyzethez: **Auto-scale**)



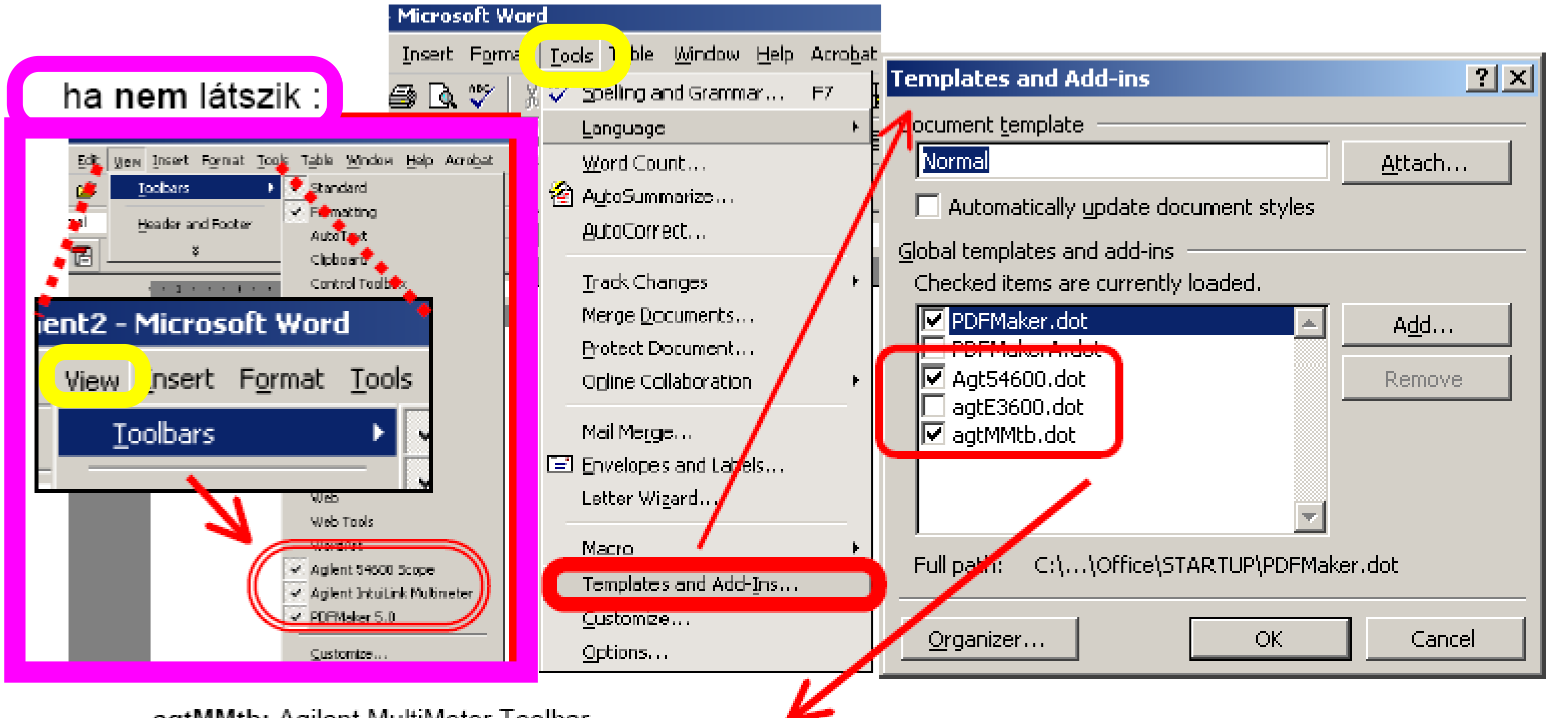

**Quick Meas:** Vpp, Freq [Select: HELP], Counter **Main/Delayed** (→display: **'Sample Rate'**)

Módosítsuk a skálákat, és figyeljük meg a hatásokat. (Pl. ha *nincs* egy teljes periódus a képernyőn, akkor Freq: *No edges*, de Counter: továbbra is működik!)

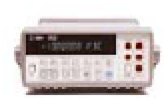
# Scope - dokumentálás:

## *„IntuiLink”* Word Toolbar

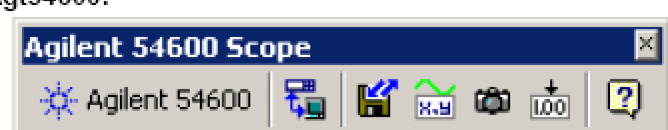
**Tools** | Add-Ins... (ha nem látszik → **View** | Toolbars ...)




agtMMtb: Agilent MultiMeter Toolbar

Agt54600:




# Scope - dokumentálás:

**e-Jegyzőkönyv**: Word **Save as ... (G: drive)**!!
A jegyzőkönyv **ékezetes** betűkkel készül!


nagyobb (2K) mintaszám Excel Toolbar-ral,

a **teljes** memória „Data Capture" SW-rel érhető el (és az FFT is !)

NEM használjuk

Word **Toolbar** (*IntuiLink* tasakból), **vagy**

**Tools** | Add-Ins... **Agt54600.dot** (ha nem látszik → View | Toolbars : √ )

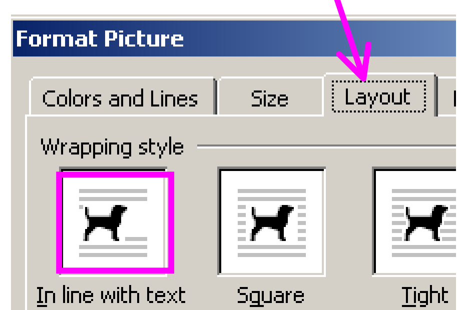
Connect to Scope: GPIB address – **7**

Get waveform data (N° of points: 100 | 250 | 500), and *make* a graph

Get Screen Image (Scope display) → Format **Picture** / Layout, Size ...

Get single measurement

**WORD**
**Right click**
on picture




**"bal Kutya" ...**

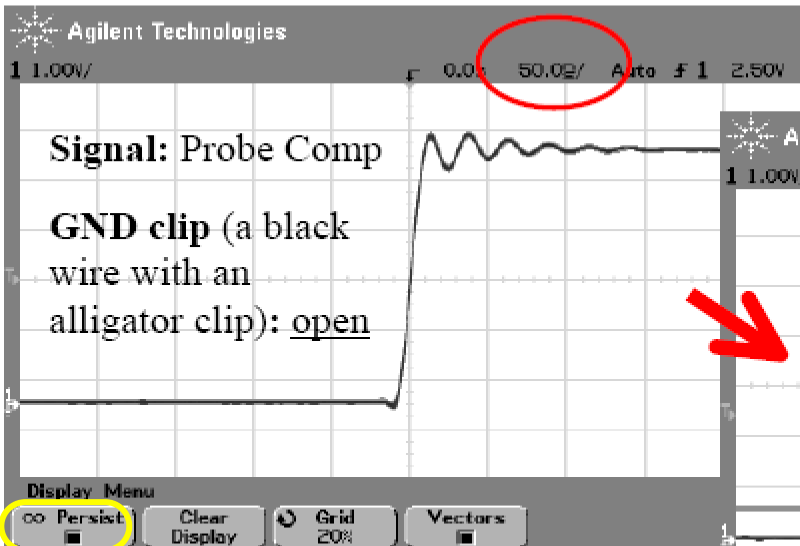
# (1) Scope – ∞ Persistence

♣ **Comparing waveforms** (overlaying)
Save a waveform trace (21) to the screen with "∞ **Persistence**"

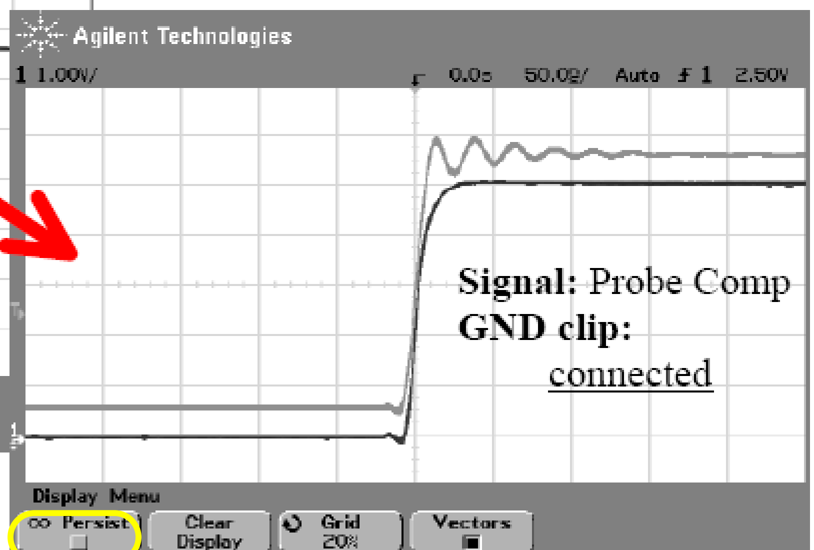
press **Display**

**∞ Persist**—infinite persistence acquires data, displaying the most recent trace in full-bright and previously acquired waveforms in half-bright.

**Clear Display**—clears the display.




∞ **Persist:** On/Off (to **freeze** the trace press the key TWICE)



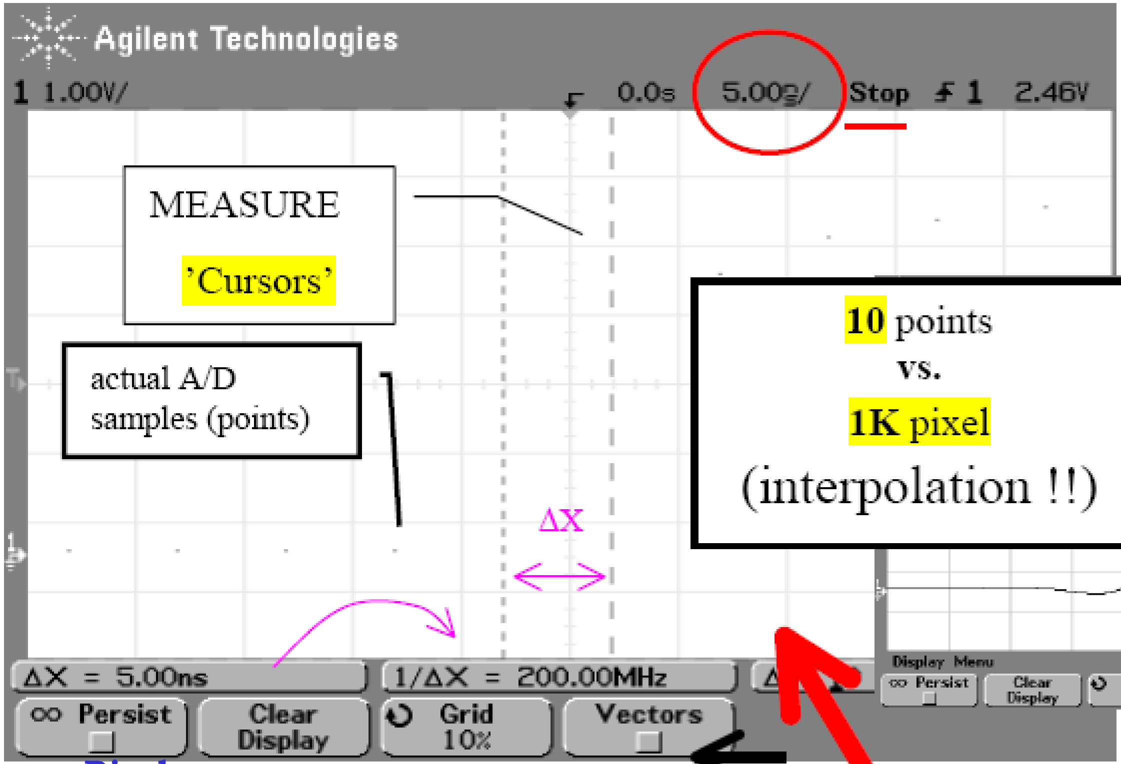

position knob (⬍) moves the **live** signal vertically (↓)

(21) vs. ... **screen**shot (as image File) **to the memory** [ press **Save/Recall** ]

# (2a) Scope – **Interpolation …**

♣ **"Display Miles"** of scope screens per trigger

Signal: Scope **Probe Comp**, Time/Div: **5ns**/, Run: **Single**, Display: Vectors: Off/**On**





press **Display**

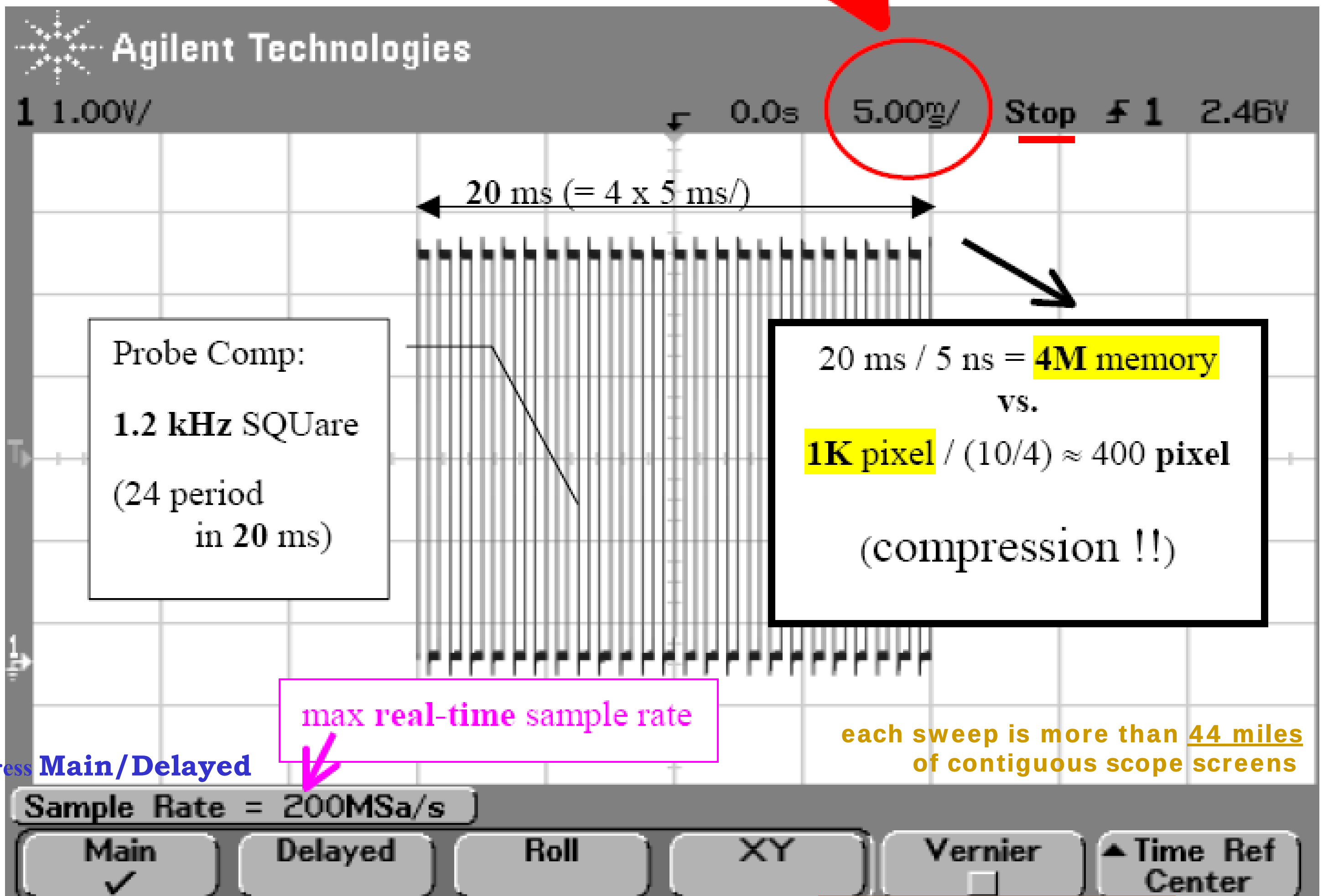
kis részlet a display-en
*kontra*
nagy rekord a memóriában

**(Mega)Zoom**: Time/DIV: **5ms**/

# (2b) Scope – ... **Compression**

## (Mega)Zoom: Time/DIV: 5ms/

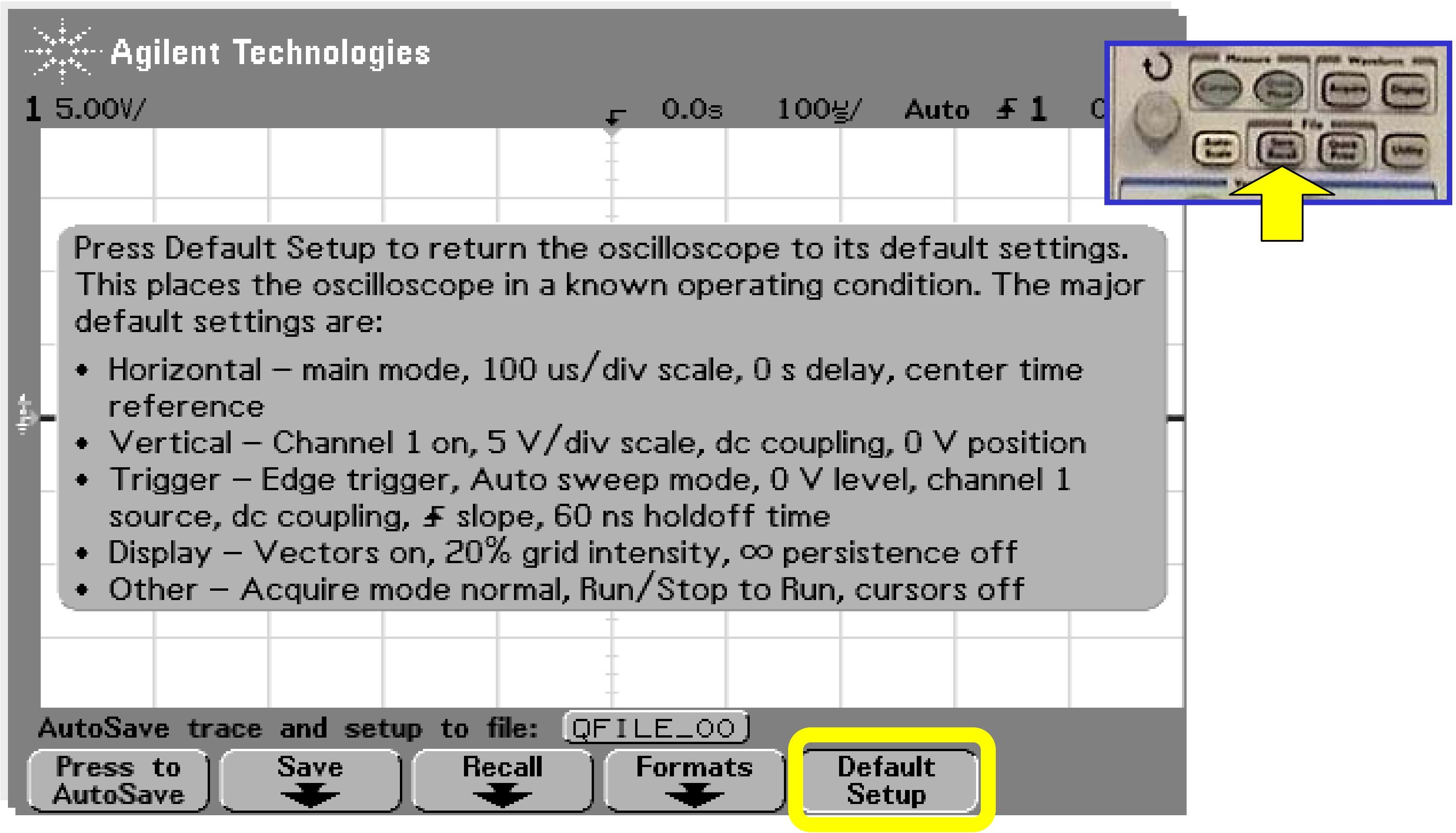
kis részlet a display-en
*kontra*
nagy rekord a memóriában




press **Main/Delayed**

$$4\frac{Mpts}{ACQuisition}\cdot\frac{7''\,display}{10\,pts}\cdot\frac{1\,foot}{12''}\cdot\frac{1\,mile}{5280\,feet}=44.2\frac{''display\quad miles''}{ACQuisition}$$

# Scope - File : press **Save/Recall** – Default Setup



# Scope - File : press **Save/Recall**

Current waveform **trace** and oscilloscope **setup**
to internal memory ( **3** non-volatile ) or ~~floppy disk~~


(…a link to **Utility** / ~~Print~~ Config)

~~Floppy disk (**QFILE_nn**)~~
~~**.TRC** trace file~~
~~**.SPC** setup file~~

**Trace, Setup or**
**Trace and Setup** (to meas recalled trace with cursors)


**Recalling overwrites current settings**
Because recalling a setup will overwrite the oscilloscope's current settings, you may want to save the existing setup first.


Internal memory (**INTERN_n**, n is **0,1,2**)
[ Floppy disk (**QFILE_nn**) ]

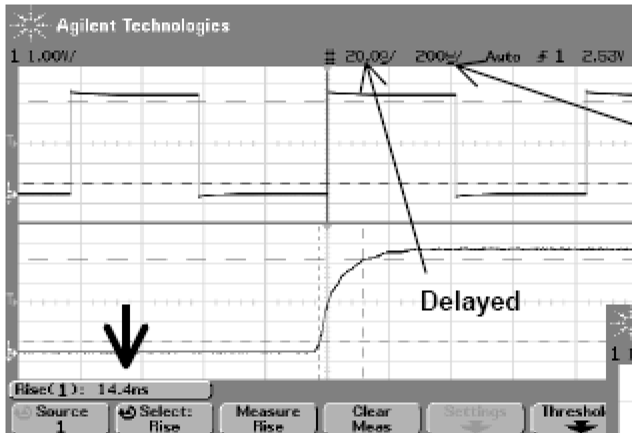
# (3) Scope:

- Szemléltető **példa**: *egységes* alap-helyzethez **'Save/Recall / Default Setup'** (!!)
  ... és gyakoroljuk a kézi beállítású („normális”) megjelenítést!

  HOR Main/Delayed: **Delayed** → késleltetett sweep megismerése

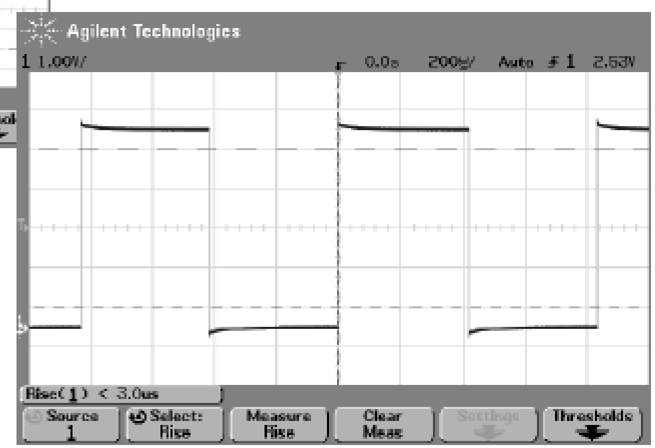
  QuickMeas: **Rise Time** (mérés a *kinagyított* részben !) , és *dokumentálás*:

Képernyő – **ábra**



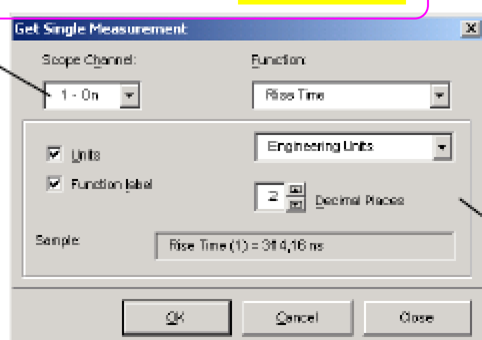

Delayed

ez a beállítás: **Main**
( 200us/DIV )
NEM felel meg
a felfutási idő
méréséhez ...




Felfutási idő – **mérési adat**

Ch1
vagy
Ch2
(Math *nem*)

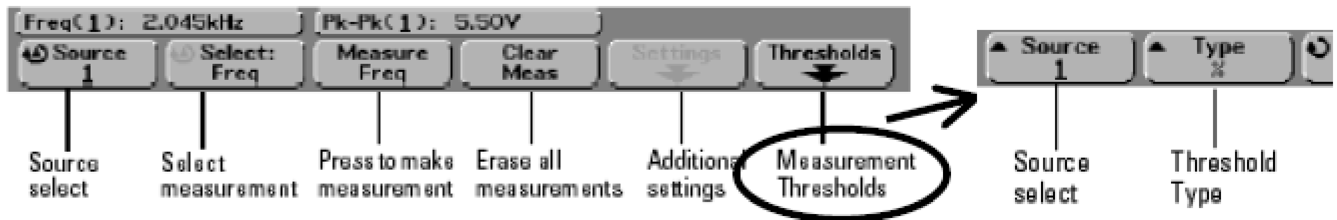



Rise Time (1) = 3,00 us ( ?! )

(Az igen eltérő adatok oka: távvezérléssel **Main** sweep-módban mér !! **Ellenőrzizzük!**)

# Scope - **Quick Meas (1- Time)**

Press the **Quick Meas** key to display the automatic measurement menu.



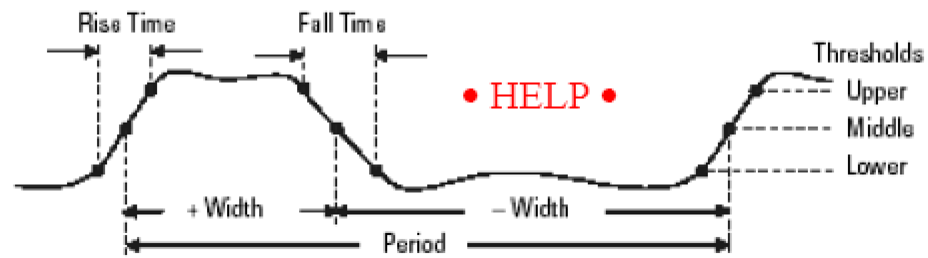

## Time Measurements

- Counter
- Duty Cycle
- Frequency
- Period
- Rise Time*
- Fall Time*
- + Width
- – Width
- **X at Max***
- **X at Min***

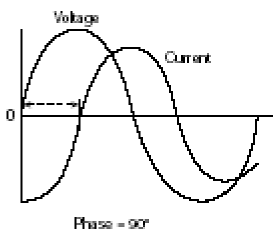
$$\text{Duty cycle} = \frac{+\text{Width}}{\text{Period}} \times 100$$

**Changing default thresholds may change measurement results**

The default lower, middle, and upper threshold values are 10%, 50%, and 90% of the value between Top and Base. Changing these threshold definitions from the the default values may change the returned measurement results for Average, Delay, Duty Cycle, Fall Time, Frequency, Overshoot, Period, Phase, Preshoot, Rise Time, RMS, +Width, and -Width.




• HELP •




## Phase and Delay

- Phase*
- Delay*

$$\text{Phase} = \frac{\text{Delay}}{\text{Source 1 Period}} \times 360$$

Automatic measurements **Phase**, and **Delay** are not valid for digital channels on the mixed-signal oscilloscope or for the math FFT function. The two sources defined in the phase and delay measurement must be turned.

* Measurement on **analog** channels only.

## Scope - **Quick Meas (1)**

Time = delta-time

the elapsed time between 2 events as defined by the crossing of a specific level [ *Rel* or *Abs* setting]

**Direct** ( Period, **…** ) vs. **Indirect** ( *calculated*: Freq = 1/Period, **…** )

### *Maximizing* Time measurement Accuracy:

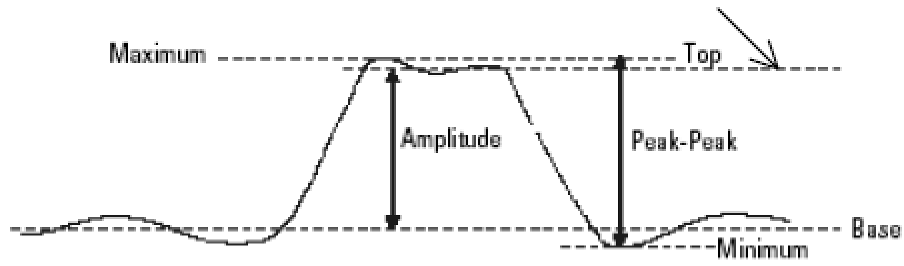
- **Delayed** sweep
- Noise reduction
  - **AVG** (repetitive wfm)
  - **AVG #1** (Hi_Res)
  - **BW limit** ( Period, Width, 2Ch: Delay )
  - TRIG noise (jitter) **Rej**ecting: TRIG **Mode/Coupling**
  - Expanding Amplitude (= increasing slope)
- *Live with noise*: Display/**Persistence** and **Cursors** to the center of a noise band

# Scope - **Quick Meas (2 - Voltage)**

$$\text{Average} = \frac{\sum x_i}{n}$$

$$\text{RMS (dc)} = \sqrt{\frac{\sum_{i=1}^{n} x_i^2}{n}}$$

**Voltage Measurements**
- **Average***
- Amplitude*
- Base*
- Maximum*
- Minimum*
- Peak-to-Peak*
- **RMS***
- Top*



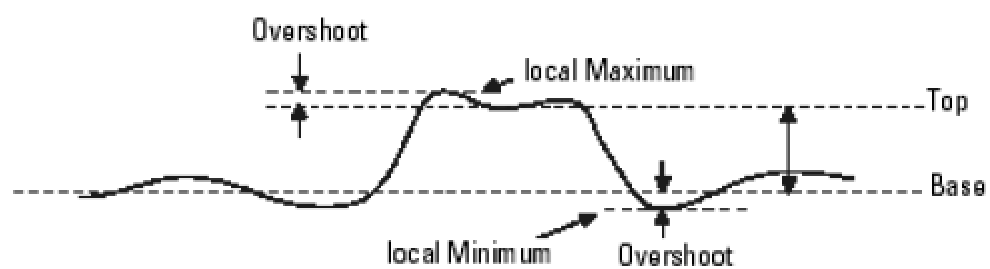

**Average, RMS (dc) :** over one or more **full periods**.
If less than one period is displayed, RMS (dc) or average is calculated on the full *width* of the display. The **X cursors** show what interval of the waveform is being measured.

**Preshoot and Overshoot**
- Preshoot*
- Overshoot*

$$\text{Rising edge overshoot} = \frac{\text{local Maximum} - \text{Top}}{\text{Amplitude}} \times 100$$

$$\text{Falling edge overshoot} = \frac{\text{Base} - \text{local Minimum}}{\text{Amplitude}} \times 100$$

Preshoot is distortion that *precedes* a major edge transition expressed as a percentage of Amplitude. The **X cursors** show which edge is being measured (edge *closest to* the trigger reference point).




* Measurement on **analog** channels only.

# Voltage = potential-difference

**Absolute:** ref_to GND (Max, ...) vs. **Relative** (Ampl = Top - Base, ...)

**DC** or **AC** coupled (!!)

## *Maximizing* Voltage measurement Accuracy:

- Noise reduction
  - **AVG** (repetitive wfm)
  - **AVG #1** ( Hi_Res )
- Peak-to-Peak (any noise, spikes, over-shoot …): **Peak Det**ect
- Diff. meas: **Math 1-2**
- **Position** (⇕) as a "nulling voltmeter"

  Placing the measured level at the *center* HOR graticule line

  (Don't be afraid to overdrive!)

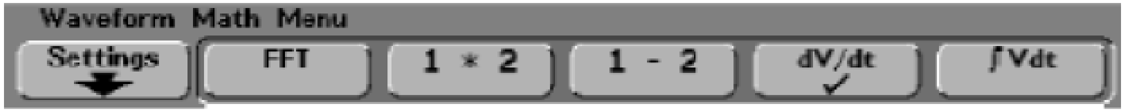
  *Offset voltage*: diff. between GND and graticule center

## (4) Scope:

♣ *Mielőtt* kicseréljük a mérőkábelt (→ ARBgen méréshez 50Ω , BNC), **„kézrátétellel"** fedezzük fel „mi is van a levegőben" (kapacitív csatolás, az ember mint antenna) .. mérjünk is ( Freq ) ... vagy *átváltva* TRIG Normal, rövid érintésekkel ( *villogó* Trig'd ) vegyünk „mintá(ka)t"

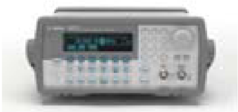
Megjegyzés: a **2** csatornás mérést, a **Roll** és az **XY** módot, az **Averaging** rekord-felvételt (és a **Realtime** rekord-felvételt és megjelenítést), illetve a **Math** lehetőségeket, célszerűen, az ARBgen megismerése után vizsgáljuk.

❼ MATH (**FFT**, Sub:**1-2**, **...**) – Jel**feldolgozás**



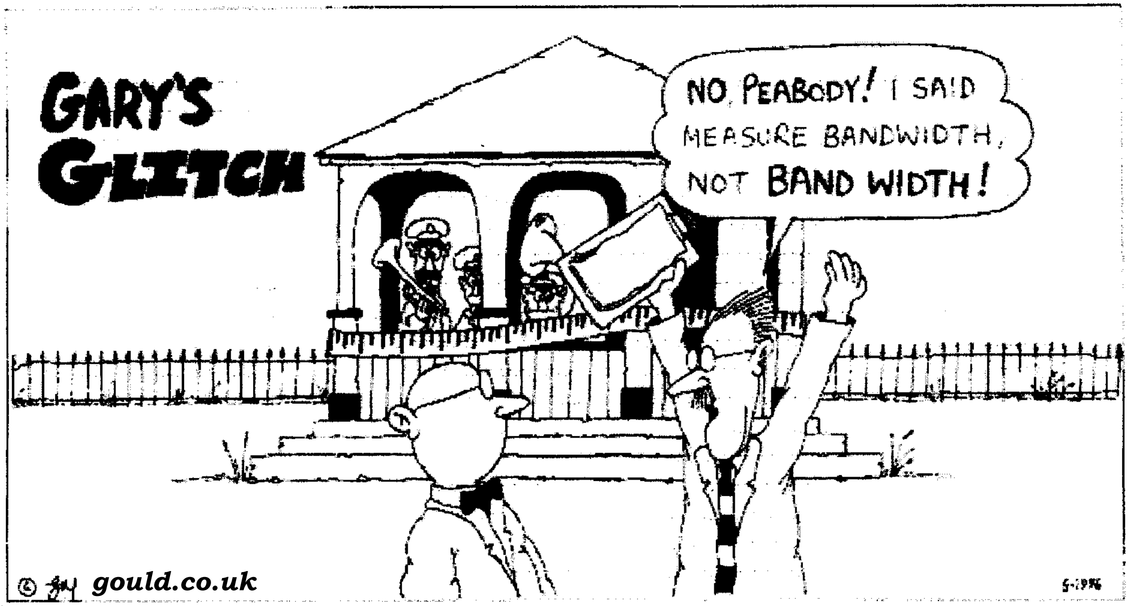

frekvencia-tartomány: 2K **FFT** ... aliasing (Nyquist wall), windows

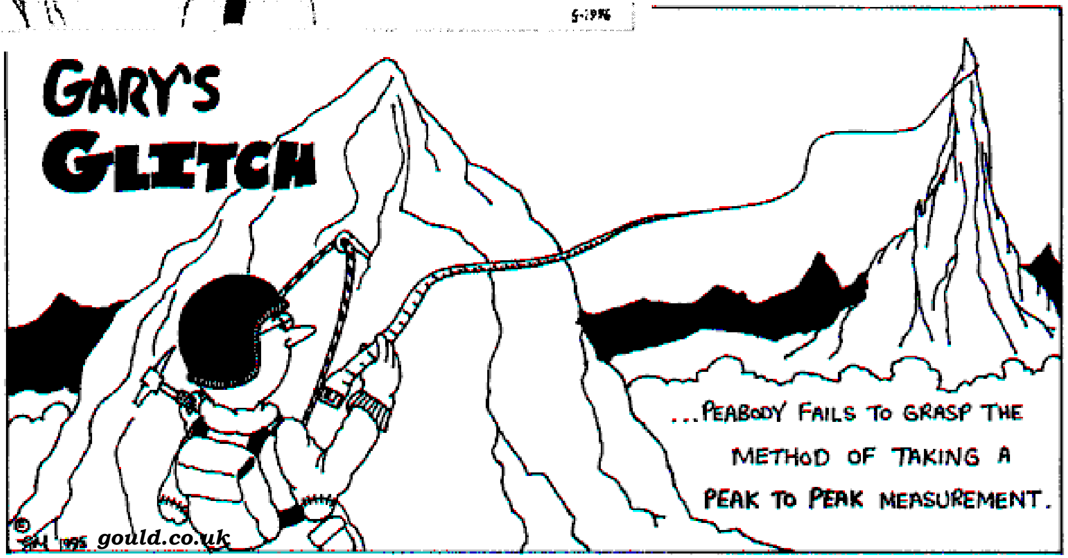
• **differenciális méréshez** ( **Lo ≡ GND !** miatt ) **Sub: 1-2** •



Részletesebben **ARBgen** – ral vizsgáljuk!

# ( SZÜNET )


GARY'S GLITCH
NO, PEABODY! I SAID MEASURE BANDWIDTH, NOT BAND WIDTH!
© gould.co.uk

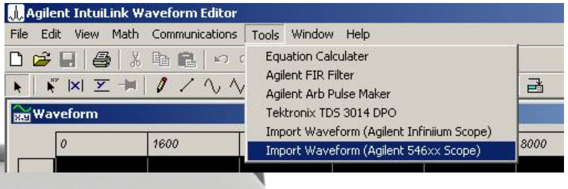

GARY'S GLITCH
...PEABODY FAILS TO GRASP THE METHOD OF TAKING A PEAK TO PEAK MEASUREMENT.
© 1995 gould.co.uk

# Agilent **33220A** Function/**ARB**itrary waveform **generator**

**20 MHz** **sine** and **square**, ARBs; / modulations /

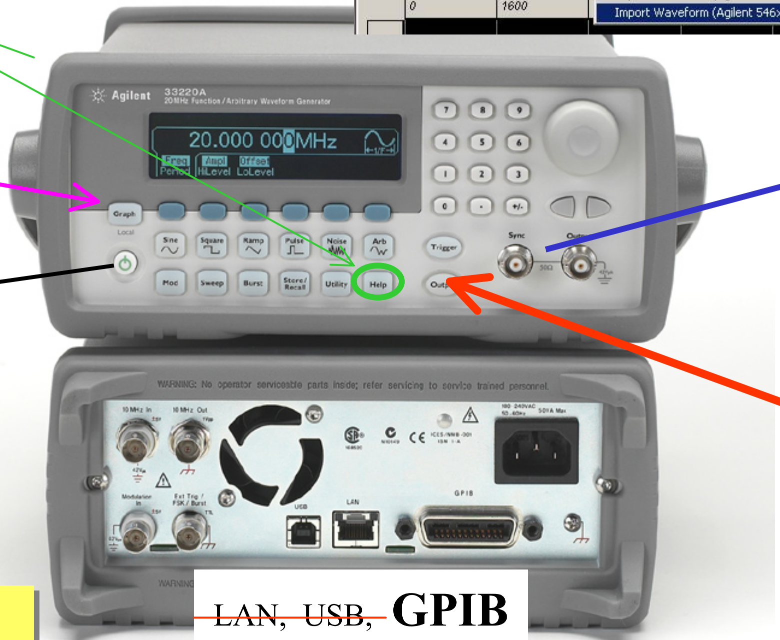
14-bit, 50 MSa/s, 64K-point **DDS**; variable-edge pulse

**GPIB** (USB, LAN), **IntuiLink:** ~~Waveform Editor~~ | *MOST **nem** használjuk*




built-in **HELP**

Go to **Local**




**BNC Connectors**

( *SYNC – always ON*
**OUTPUT – On/Off** )

**POWER On**/Off

Pwr on
**default state:**
Sine, 1 KHz
0.1Vpp @ $R_L$=50Ω
**Out: Off**

**OUTPUT On/Off** switch

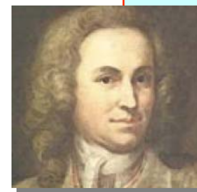
***FOP:***
*Fifty Ohm* **[50-Ω]** *Party*

~~LAN, USB,~~ **GPIB**

# ARBgen - DDS: Direct Digital Synthesis

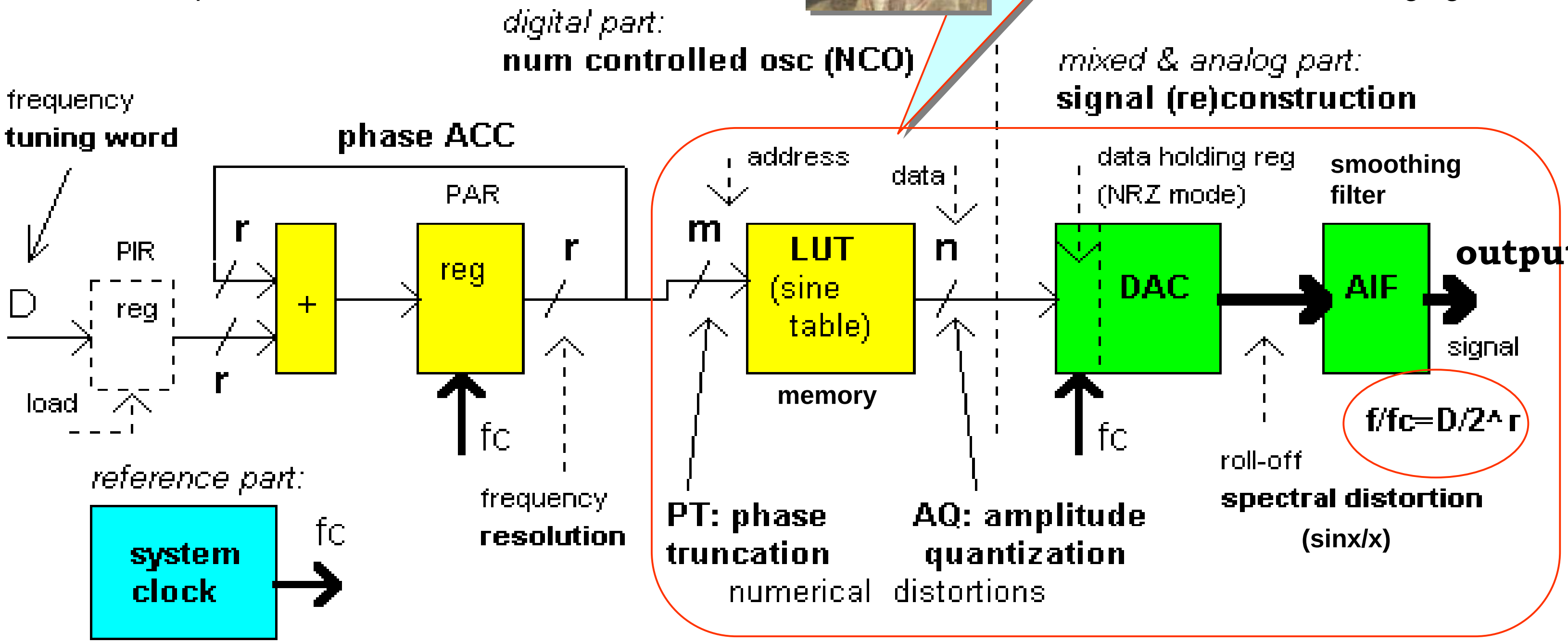
( @ constant $f_c$ clock-rate )

**… mint a CD lejátszó !!**



**PIR :** phase increment register
Phase **ACC :** accumulator
**LUT :** look-up table

**NRZ :** non return to zero
**DAC :** digital to analog converter
**AIF :** anti imaging filter

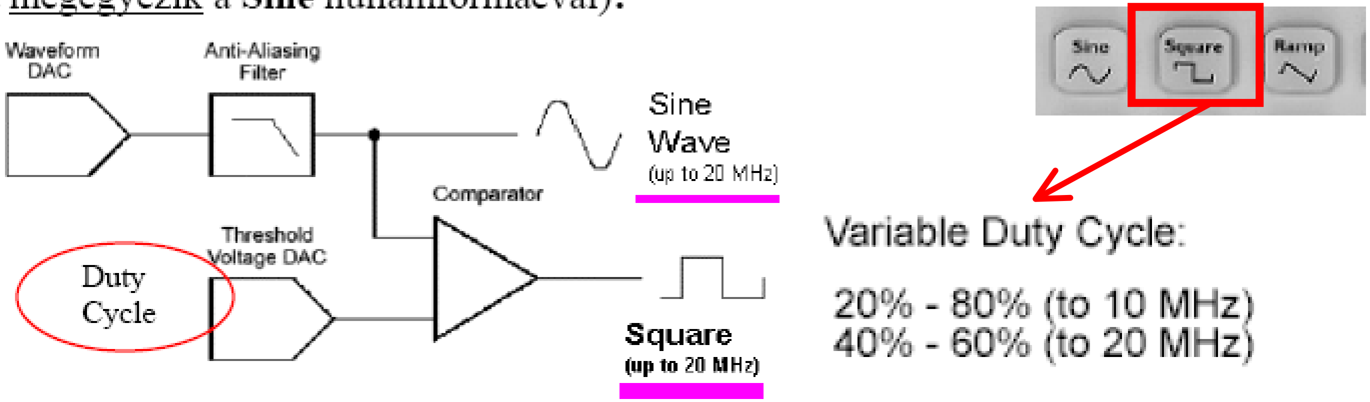



**33220A** : r = **64** bit, m = **16** bit (64K memory), n = **14**bit, fc = **50** MHz
**14** bit (16K memory)

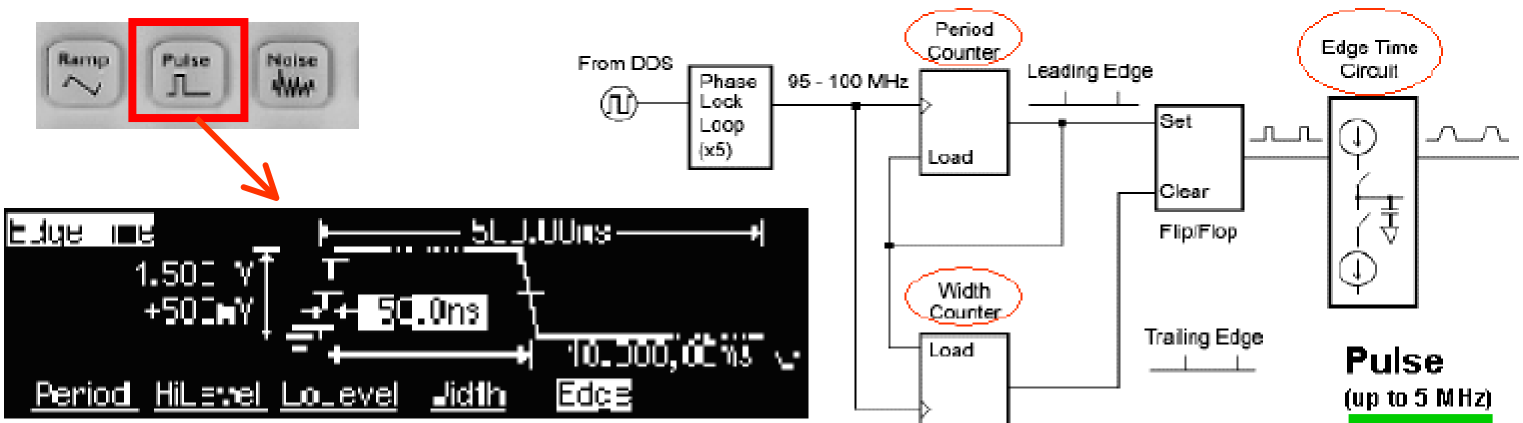
FREQ resolution (int): 2.7 pHz ( $2^r = \mathbf{2^{64}} = 2^{4+10+10+10+10+10+10} = \mathbf{2^4 . 10^{3+3+3+3+3+3}}$ )

# **ARBgen:** Square, Pulse Wfm

*Speciális* módszer a **Square** hullámforma generálására (ezért lehetséges az, hogy ennek max. frekvenciája megegyezik a **Sine** hullámformáéval):




*Speciális* hardver állítja elő a **Pulse** hullámformát:



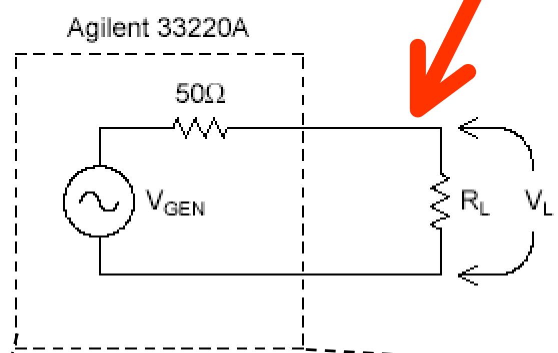
# **ARBgen:** Output amplitude

Setting of the **termination ($R_L$)** is simply provided *as a convenience* to ensure that the **displayed $V_L$** voltage *matches* the **expected load** :

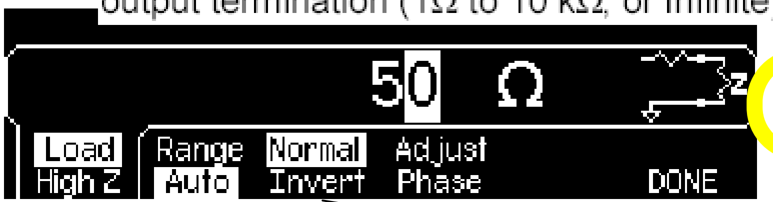
*1 ohm – 10 Kohm* or *High* impedance,

the default $R_L$ is **50 ohm**.

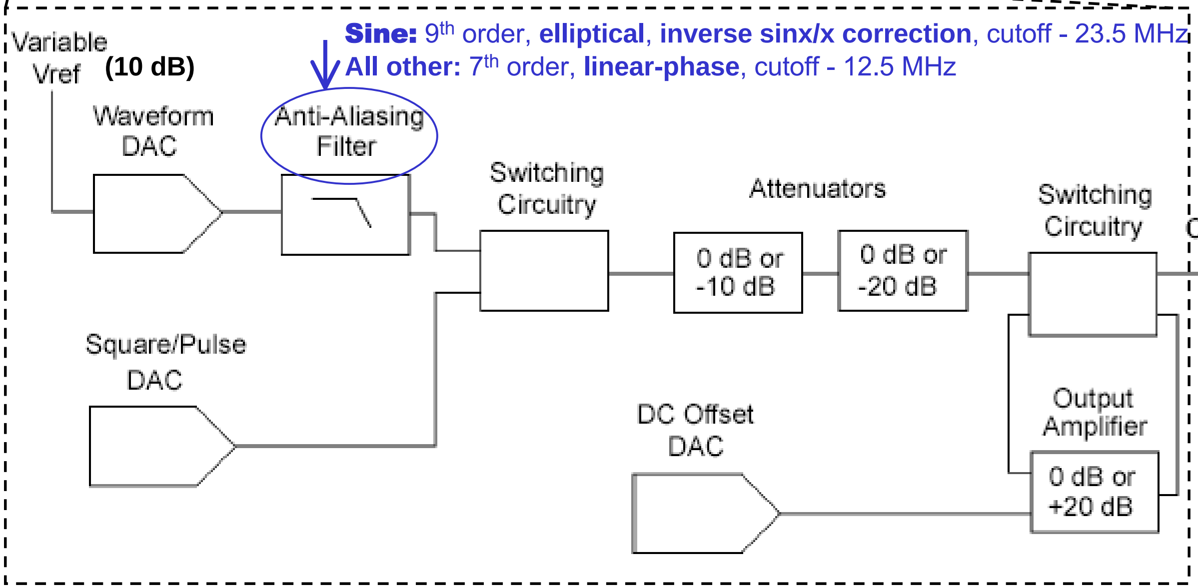
If you specify **50 ohm** termination but are actually terminating into an **open** circuit, the output will be **twice ( x2 !!)** the value specified !!

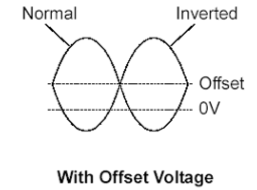



output termination (1Ω to 10 kΩ, or Infinite)




**Utility/** Output setup



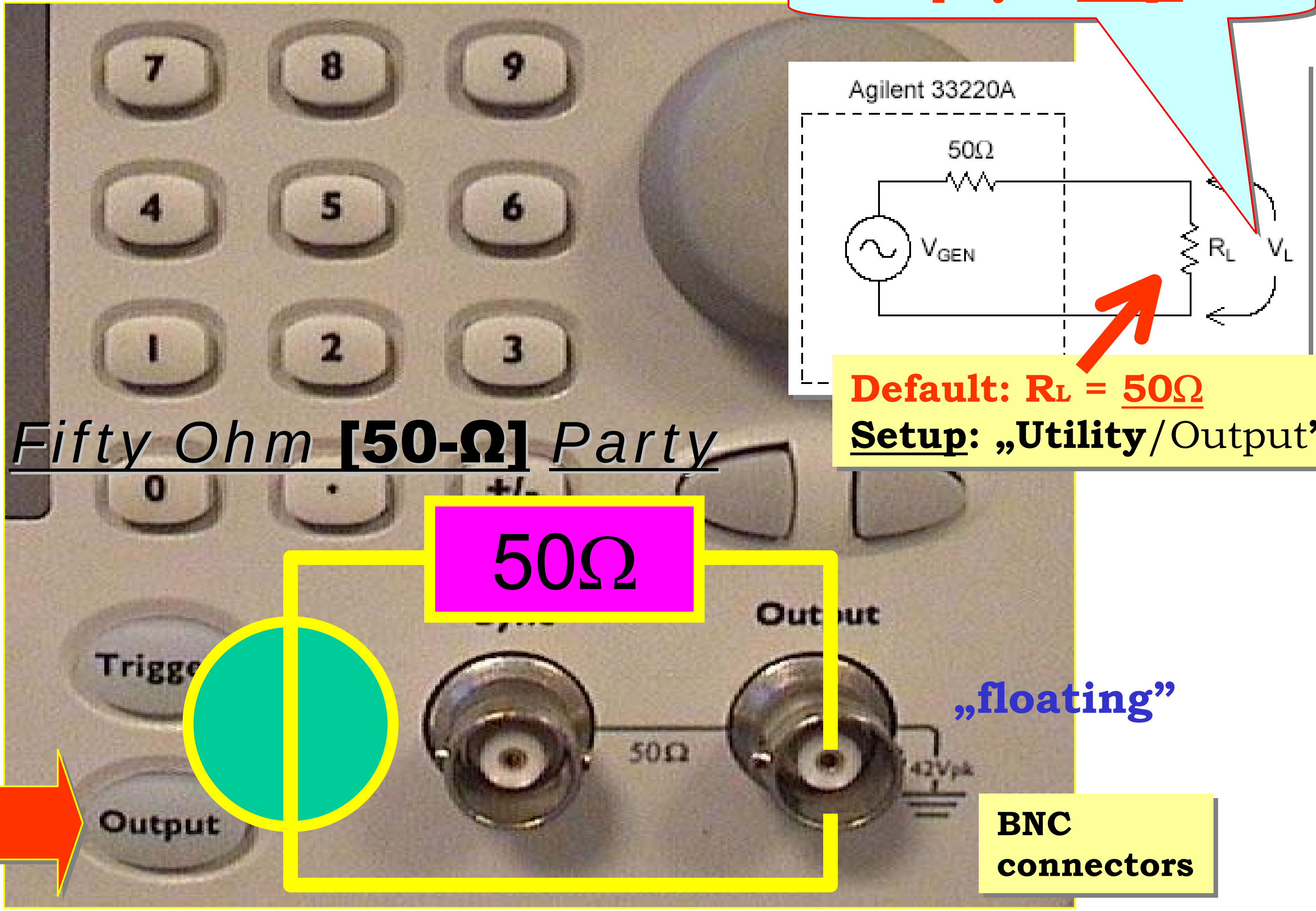




**... finoman csatlakozni !!**

OUTPUT On/Off

# **ARBgen** Output - 50Ω source impedance

**Displayed Ampl !!**




**Default: $R_L$ = 50Ω**
**Setup: „Utility/Output"**

*FOP: Fifty Ohm* **[50-Ω]** *Party*

**„floating"**

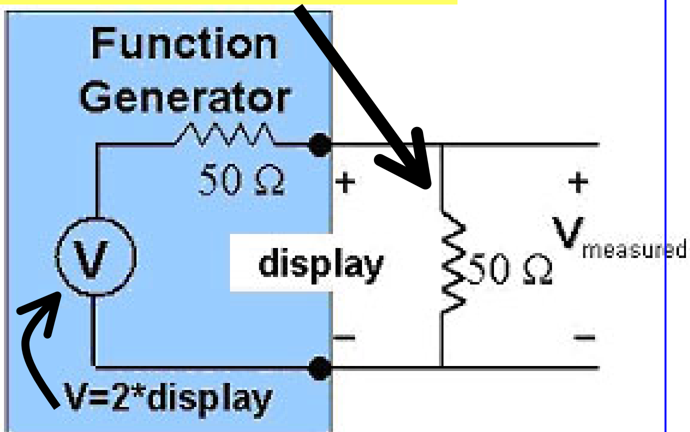
**BNC connectors**

# Why your function generator outputs twice (!!) the programmed voltage?

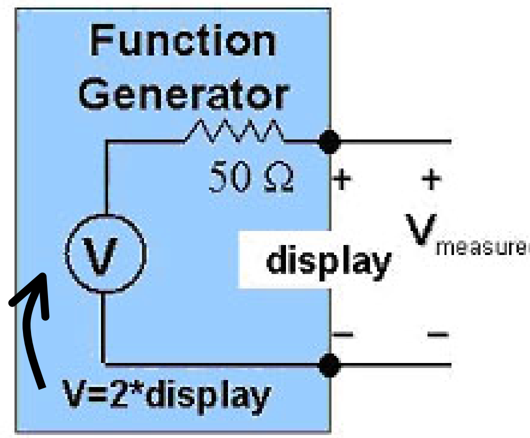
The **default setting** for Agilent function generators is to display the desired voltage as though terminated into a 50 Ohm load.

*FOP:*
*Fifty Ohm* **[50-Ω]** *Party*

When a high impedance device, such as an **oscilloscope** is used to measure the output of the function generator, the waveform appears to be **twice** the voltage set on the display of the function generator.




$$V_{measured} = ½V = ½ \, (2^* \text{ display})$$
$$V_{measured} = \text{display}$$




$$V_{measured} = V = 2^*\text{display}$$
$$V_{measured} \neq \text{display}$$

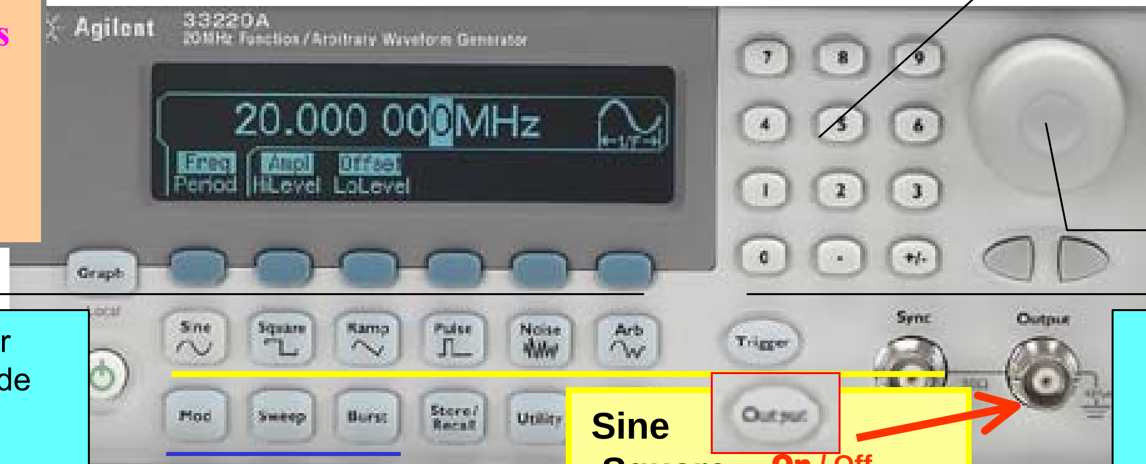
The Agilent 33220A function generator includes a feature that allows the output termination to be **set** to any impedance from **1 to 10 k Ohm**, or **infinite**.

# ARBgen - Front Panel

--------------
**1. Function**
**2. Parameters**
--------------
3. Output
**On** / Off
--------------

**Setting**

**Tuning**




**Graph** or **Menu** mode

**Softkeys**
to configure the Parameters

*…always adjust Parameters from left to right*

**Mod**
Type: AM
FM
PM
FSK
PWM
Source: INT
EXT

**Sweep**
LIN or LOG

**Burst**
N cycle or
EXT-gated

**Sine**
**Square**
**Ramp**
**Pulse**
**Noise**
**Arb** (currently selected)

**DC** ( 'Utility' key | DC on )

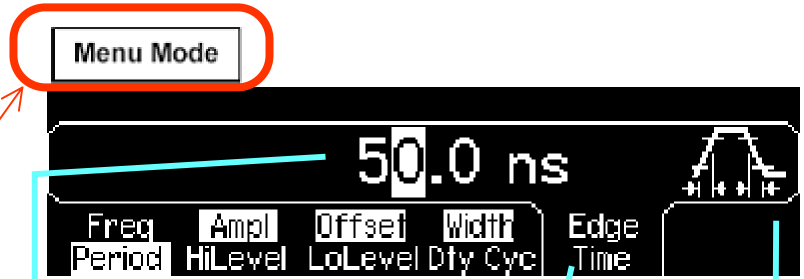
**On** / Off

**Knob and cursor keys**
to modify the displayed number
**Keypad**
to enter numbers, and
**Softkeys**
to select units

| | Sine | Square | Ramp | Pulse | Noise | DC | Arb |
|---|---|---|---|---|---|---|---|
| AM, FM, PM, FSK Carrier | • | • | • | | | | • |
| PWM Carrier | | | | • | | | |
| Sweep Mode | • | • | • | | | | • |
| Burst Mode | • | • | • | • | •[1] | | • |

[1] *Allowed in the External Gated burst mode only.*

# **ARBgen** Display: **numeric** vs. **graphical** views



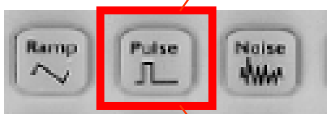

**Parameters**

**numeric readout**

softkey labels

display icon

**Function**




---

**Methods:**

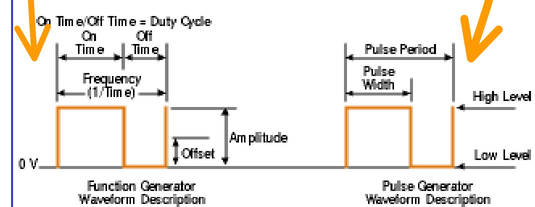
Frequency / Duty Cycle

**vs.**

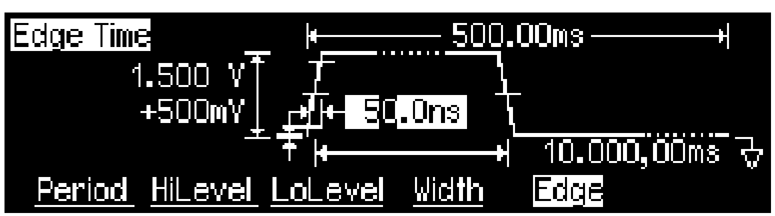
Period / pulse Width

---

**( Let the ARBgen perform the calculation ... )**




Press the [Graph] key to enable the Graph Mode. The name of the currently selected parameter, shown in the upper-left corner of the display, and the parameter's numeric value field are both highlighted.

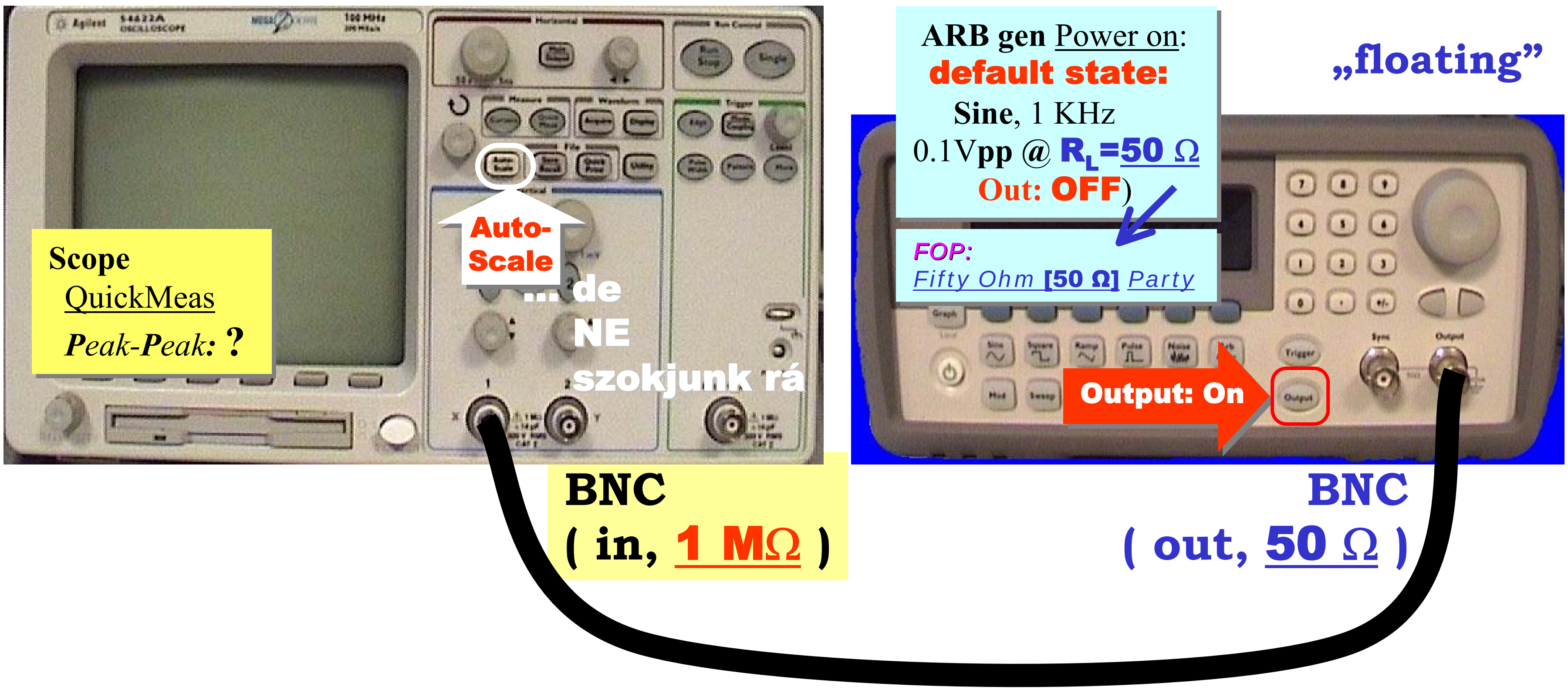



To exit the Graph Mode, press [Graph] again.

**Parameters**

# Scope / ARBgen :

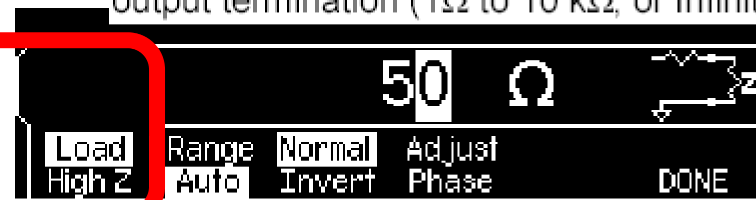
GROUNDED
(non „floating”) !!



## ARBgen:


Utility/
**Output setup**

output termination (1Ω to 10 kΩ, or Infinite)




♣ a terhelés hatása: **a legfontosabb**, amire **figyelni** kell !

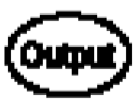
- **ARBgen**: Ampl: 1 Vpp, Output: **ON**

**Scope**: Auto-scale, QuickMeas: Peak-Peak: ≈ **2** Vpp (?!!)

(Az ok**:** *alap-beállításnál* a generátor **50Ω** terhelést tételez fel, valójában 1 MΩ a terhelés: az oszcilloszkóp bemenete.)

**ARBgen**: Utility**: Output Setup**: Load ↓ **High Z** . Ampl = **2** Vpp !

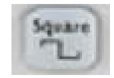
(Ahhoz, hogy fix 50Ω forrás-impedanciával 1 Vpp legyen 50Ω terhelésen, a generátor forrás-feszültsége: 2 Vpp . Átdefiniálva a terhelést a valóságos helyzetre („ közel ∞ impedancia: High Z"), az ARBgen display most már a (*változatalan*) forrás-feszültséget mutatja.)




key a kimenet bekapcsolása előtt (a **fix** 50Ω forrás-ellenállás miatt) – **gondoljuk át** a feltételezett **terhelő ellenállás** (Output setup) és ahova kötjük a kimenetet: a tényleges **terhelés** hatását **!!**

## ARBgen – Utility/Output Setup: **High Z**

- **SINE**
  - Freq: **8** KHz
  - Ampl: 3 V**pp**
  - Offset: 0 V



- **SQUARE**
  - Freq: **1.5** KHz
  - **HiLevel:** 3.2 V
  - **LoLevel:** 0 V

**TTL, CMOS 3.3V**

- ***RMS = ?***

- ***RiseTime = ?***

# ARBgen:

❶ **Jelalak** (vagy modulációhoz *vivő*) választás

shape: Sine, Square ... Pulse ... ARB (*one_at_a_time*)

Speciális: DC („Utility”/ ’DC on’)

❷ **Paraméter(ek)** beállítása

Menu or Graph mode: Freq, Ampl, Offset ... Duty Cycle, Edge Time ...

Note: set the AC *magnitude* before setting the *offset* ! (or **HiLevel** / **LoLevel**)

# ARBgen / Scope:

♣ Szemléltető **példa:** közvetlenül ARBgen **Output** (**ON**) → Scope Ch1 (BNC kábel)

- **Sine** Freq, Ampl [24] / Offset .. HiLevel / LoLevel

  (*Figyeljük meg* az oszcilloszkópon a paraméterek változtatásnak hatását!)

- **Square** ... Duty Cycle
- **Ramp** ... Symmetry
- **Pulse** ... Width, Edge Time (→ Scope: gyors sweep, ARBgen: **Graph** mode)
- **Noise** [25] (→ Scope: lassúbb sweep, ARBgen**: Menu** mode – visszaváltás)
- **ARB** Select Wform: Built-In [26] : ... Sinc(≡sin(x)/x), Cardiac

| Function | Minimum Frequency | Maximum Frequency |
|---|---|---|
| Sine | 1 µHz | 20 MHz |
| Square | 1 µHz | 20 MHz |
| Ramp | 1 µHz | 200 kHz |
| Pulse | 500 µHz | 5 MHz |
| Noise, DC | Not Applicable | Not Applicable |
| Arbs | 1 µHz | 6 MHz |

Set Freq:
1 (0.33) Hz ≡
60 (180) beat/min

**Scope** HOR:
**Roll** mode
(no TRIG !!)

# ARBgen:

**Sync (out)** – a generált jel periódusával megegyező **négyszög** jel

Sine, Ramp, Pulse: *50% - os*, Square: a jellel *azonos* a kitöltési tényező ...

Modulációnál a *referencia* a moduláló jel (mod source: INT), vagy a (belső)vivő (EXT)

# ARBgen / Scope:

♣ Szemléltető **példa**: **két** csatornás oszcilloszkóp-mérés, **Output:** Ch1, **Sync:** Ch2,

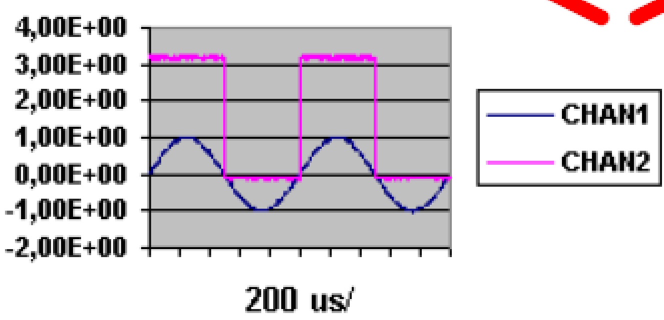
**ARBgen:** Store/Recall: **Set to Defaults**: YES ; (→ **Sine**) Set: Ampl: **1** Vpp, Output: **ON** (!)

**Scope:** Auto-scale

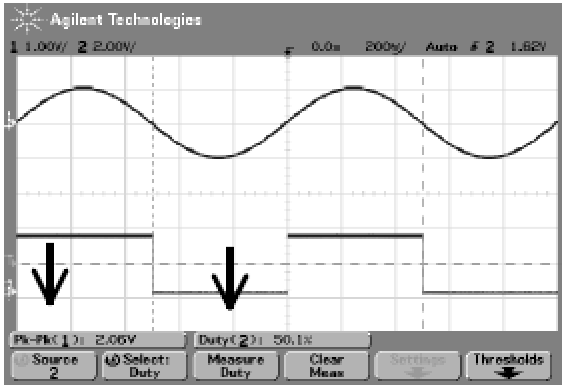
(a) Auto-scale után vegyük le Ch2 kábelt, és *magyarázzuk meg* a jelenséget
(Scope ...[Auto-scale miatt] **Trig Source**: Ch2, és megszünt a szinkron!)

(b) Visszatéve a kábelt, *dokumentálás* (**Scope**):

Get waveform data (N° of points: 500), and *make* a graph :




Get Screen Image :

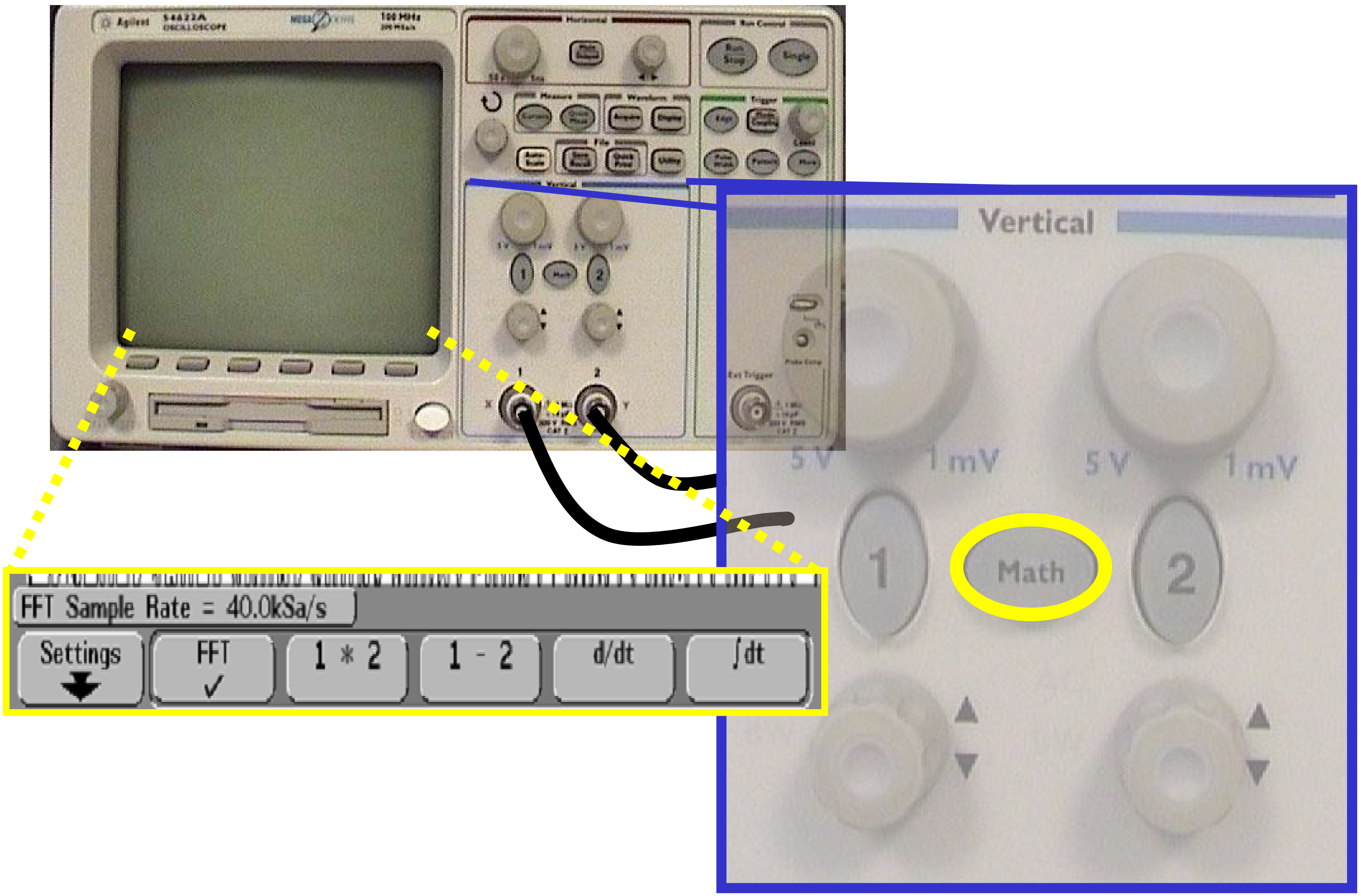



Get single measurement :

Ch1 :Volts Peak-to-Peak (1) = 2,063 V (... mert 1MΩ a terhelés 50Ω helyett)

Ch2: Duty Cycle (2) = 49,9 % (... más időpont, ezért eltér Screen Image adatától)

# Scope: **Math**

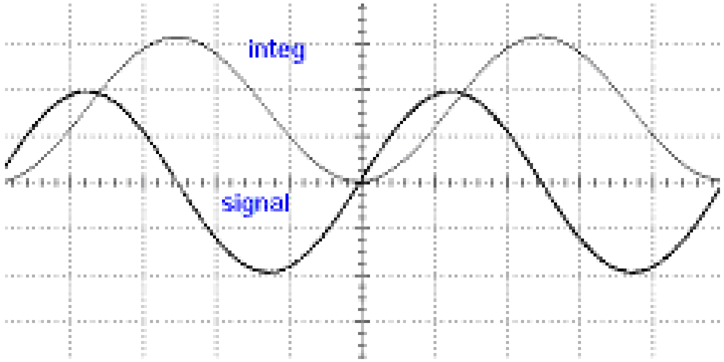


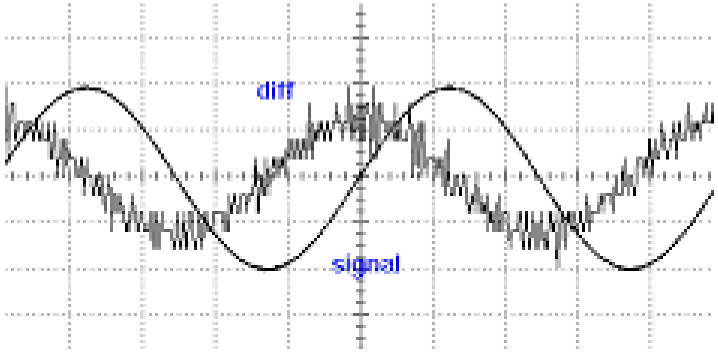
FFT Sample Rate = 40.0kSa/s
Settings
FFT
1 * 2
1 - 2
d/dt
∫dt
Vertical
5 V
1 mV
5 V
1 mV
1
Math
2

# Scope:

- Folytatás: Scope **Math** *bemutatása* (kétfajta jel is van, csak rövid *áttekintés*)
  Ch1: **Sine** [27] → integrálás, differenciálás (a *zajosság* [28] oka?), **FFT**
  Ch2: **Square** → **FFT** (source: Ch**2 !**) … ugye, ilyen kell legyen a spektrum
  Math **1-2**: … mit várunk ? (**Fontos:** Math *forrása* [ **1** , **2** ] **ki** is **kapcsolható!**)

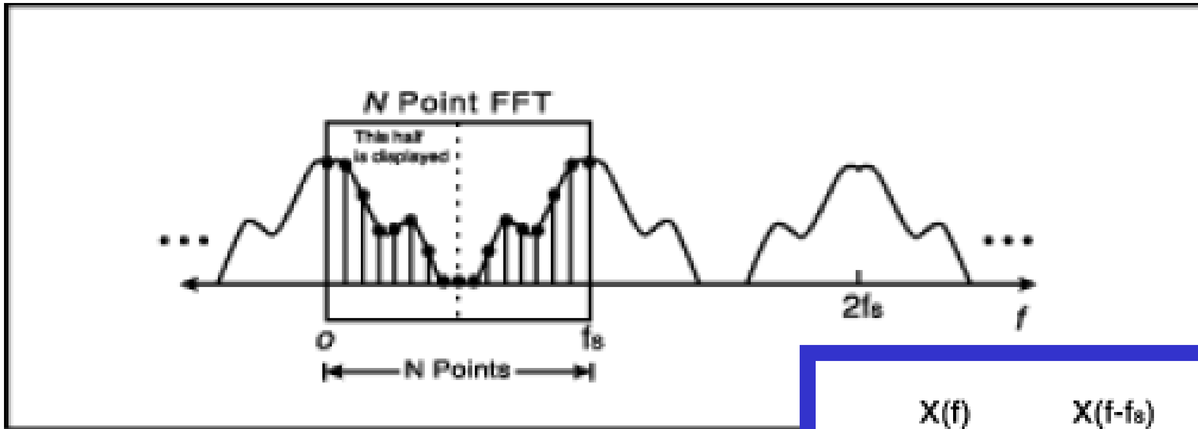
- Folytatás: Scope Main/Delayed : **XY** ( X ≡Ch1 / Y ≡Ch2 ) *bemutatása* … miért *ilyen* az ábra ? (**Figyelem: XY** üzemód esetén **Ext Trig** bemenet maradjon üresen **!!**)

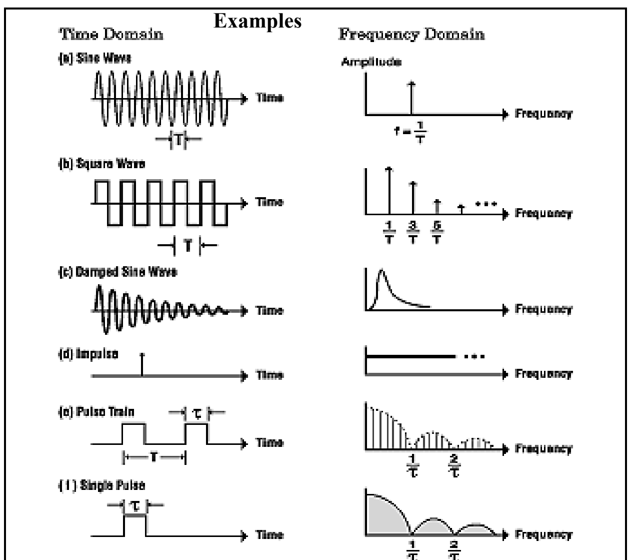


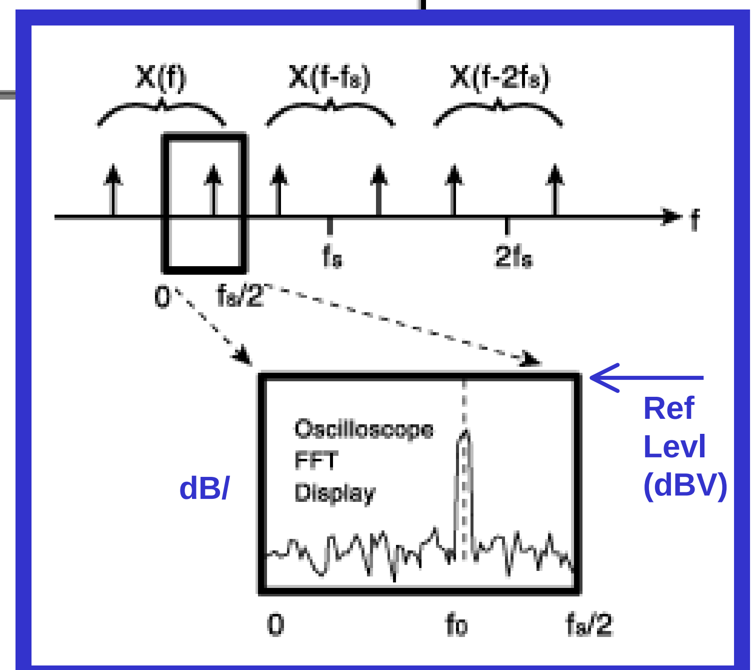



# Scope -FFT:

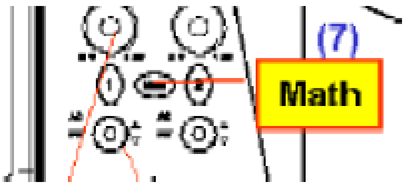
**Periodic sampling** (fs: sample rate) → **spectral replications** (images)



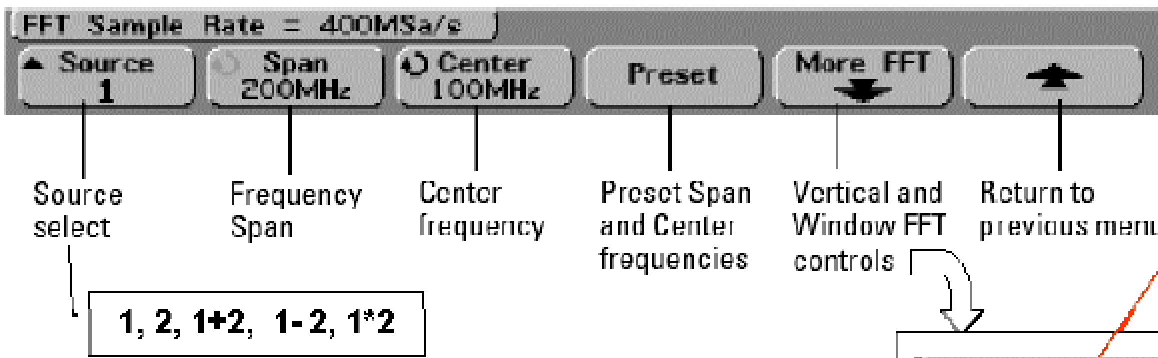



# Scope -FFT:

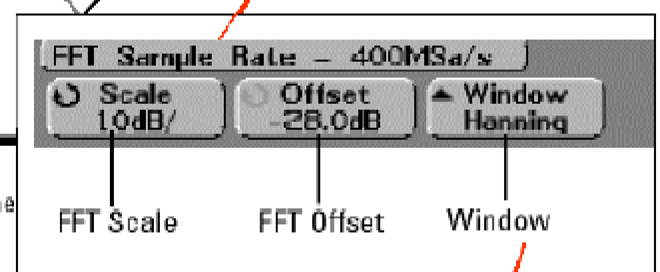



**2K FFT** (dBV vs. frequency)

Press the **Math** key, press the **FFT** softkey, then press the **Settings** softkey to display the FFT menu.




set by Time/DIV




**Hanning (freq)**
**Flat Top (ampl)**
Rectangular

**Scale and offset considerations**

If you do not manually change the FFT scale or offset settings, when you turn the horizontal sweep speed knob, the span and center frequency settings will automatically change to allow optimum viewing of the full spectrum. If you do manually set scale or offset, turning the sweep speed knob will not change the span or center frequency settings, allowing you see better detail around a specific frequency. Pressing the FFT **Preset** softkey will automatically rescale the waveform and span and center will again automatically track the horizontal sweep speed setting.

# 54622A Oscilloscope (Scope) – 2K FFT spectrum analysis

N (= **2K**) point FFT:

(1) Data capture (time record)

$T = N \cdot \Delta t = 10 \cdot$ **"Time/DIV"**

**T:** capture time

$\Delta t = 1/fs$, and **fs:** FFT sample rate

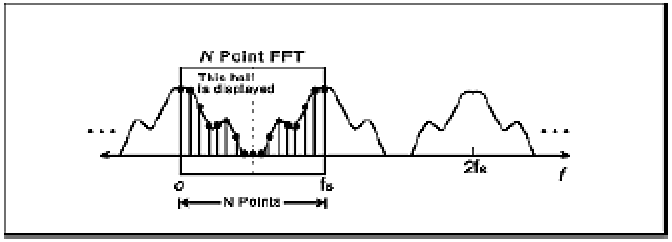
↓

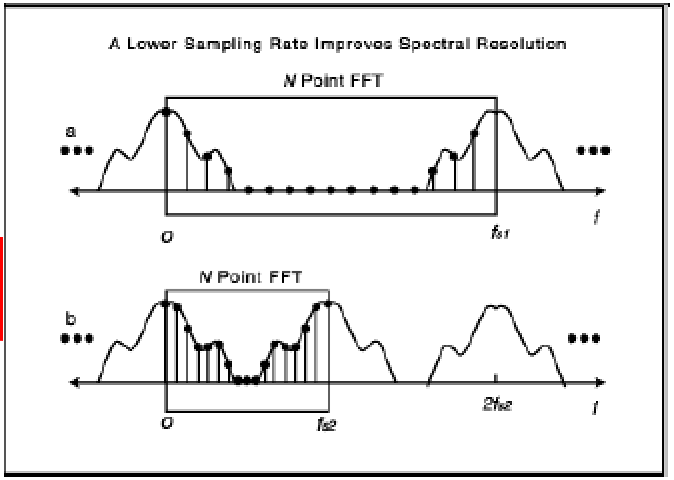
**fs** = (N/10)/**"Time/DIV"**

(2) Math: FFT (= DFT = Fourier series)

**Span = fs/2**
**Resolution** ($\Delta f$) = 1/T = **fs**/N = 0.1/**"Time/DIV"**

- Key performance specifications of the FFT operation depend on the sweep time (**"Time/DIV"**)



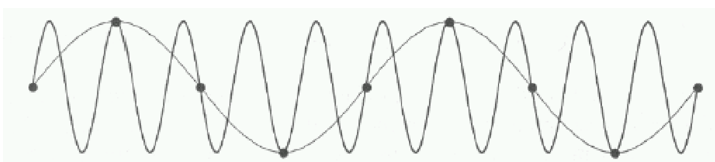

**FFT Units** The readout for the horizontal axis changes from time to **frequency** (Hz) and the vertical readout changes from volts to **dB**. FFT units (amplitude) will be displayed in **dBV** when channel units is set to Volts

Note: Once the function is displayed, the analog channel(s) may be turned off for better viewing

**Aliasing** Aliasing happens when there are frequency components in the signal higher than **half** the effective sample rate. Components of the input signal above the Nyquist frequency will be mirrored (aliased) on the display and reflected off the right edge

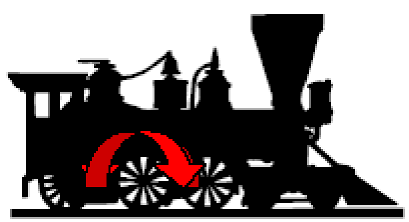
# Aliasing Artefacts

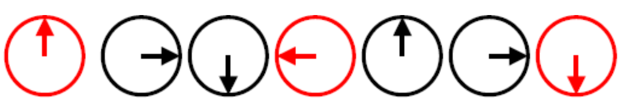
- **Moiré Patterns**
- **Aliasing**

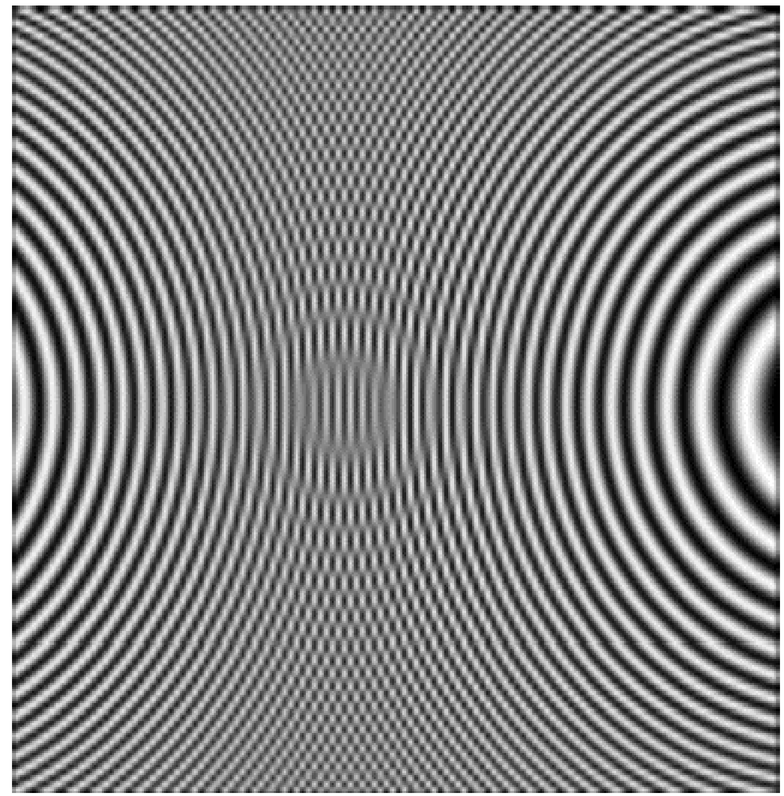


http://www.dsptutor.freeuk.com/aliasing/AD102.html

Car wheels

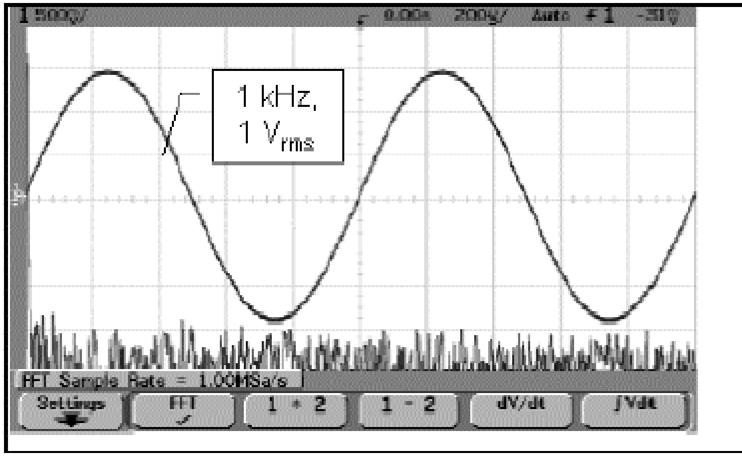






# Scope:

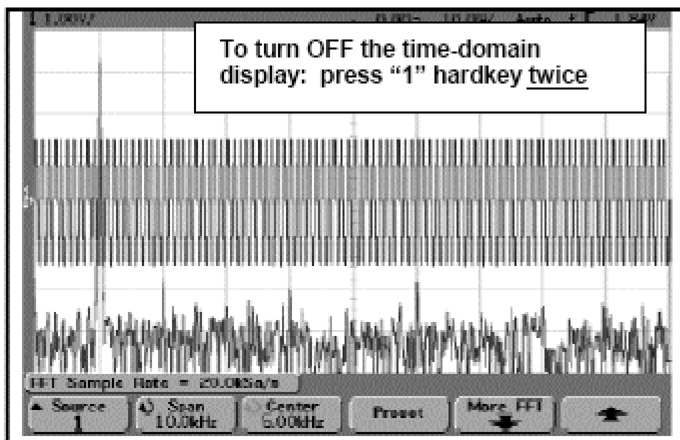
## Time domain vs. frequency domain ($\Delta t \cdot \Delta f = 1/N$; N = 2K)




time/div = 200 μs
FFT sample rate = 1.00 MSa/s
Span = 500 kHz
Center = 250 kHz

**$\Delta t$ = 1 / sample_rate**

**change the time/DIV (i.e. sample_rate)**

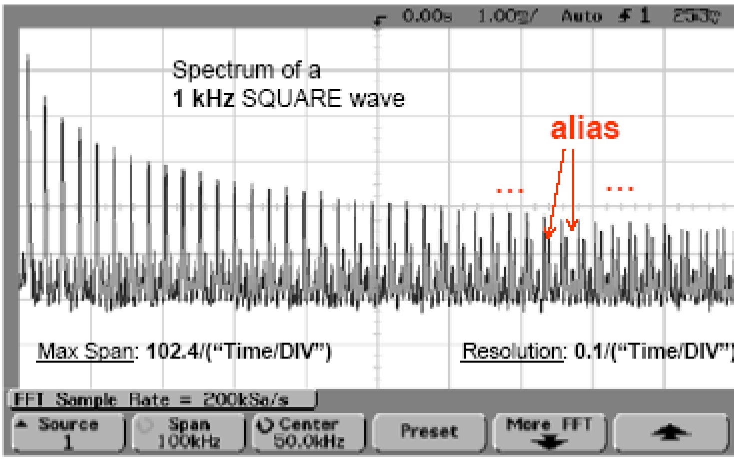


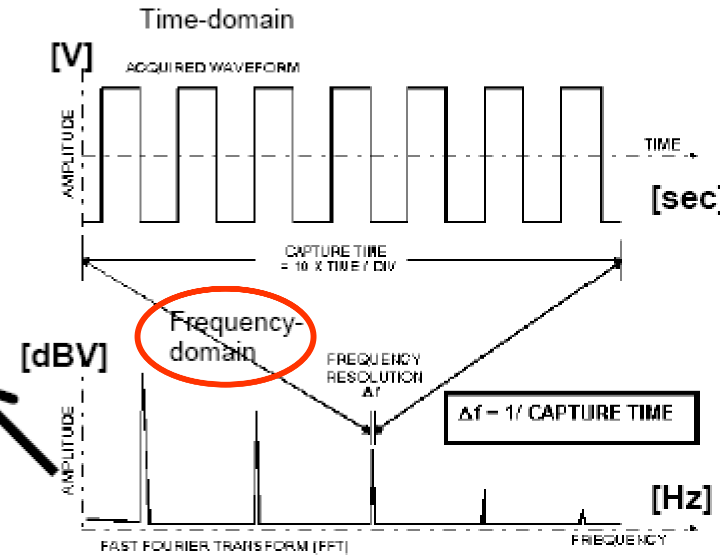

time/div = 10 ms
FFT sample rate = 20 kSa/s
Span = 10.0 kHz
Center = 5.00 kHz

There are two (2) graphs shown here: voltage vs. time (over a 100 ms interval) and voltage vs. *frequency* (in a "window" 10 kHz wide).

**$\Delta f$ = sample_rate / N**

# Scope - FFT display




**Window** The type of "window" that is used to generate the FFT is important:

**Hanning –** for making **accurate <u>frequency</u> measurements** or for resolving two freq that are close together

**Flat Top –** for making **accurate <u>amplitude</u> measurements** of frequency peaks

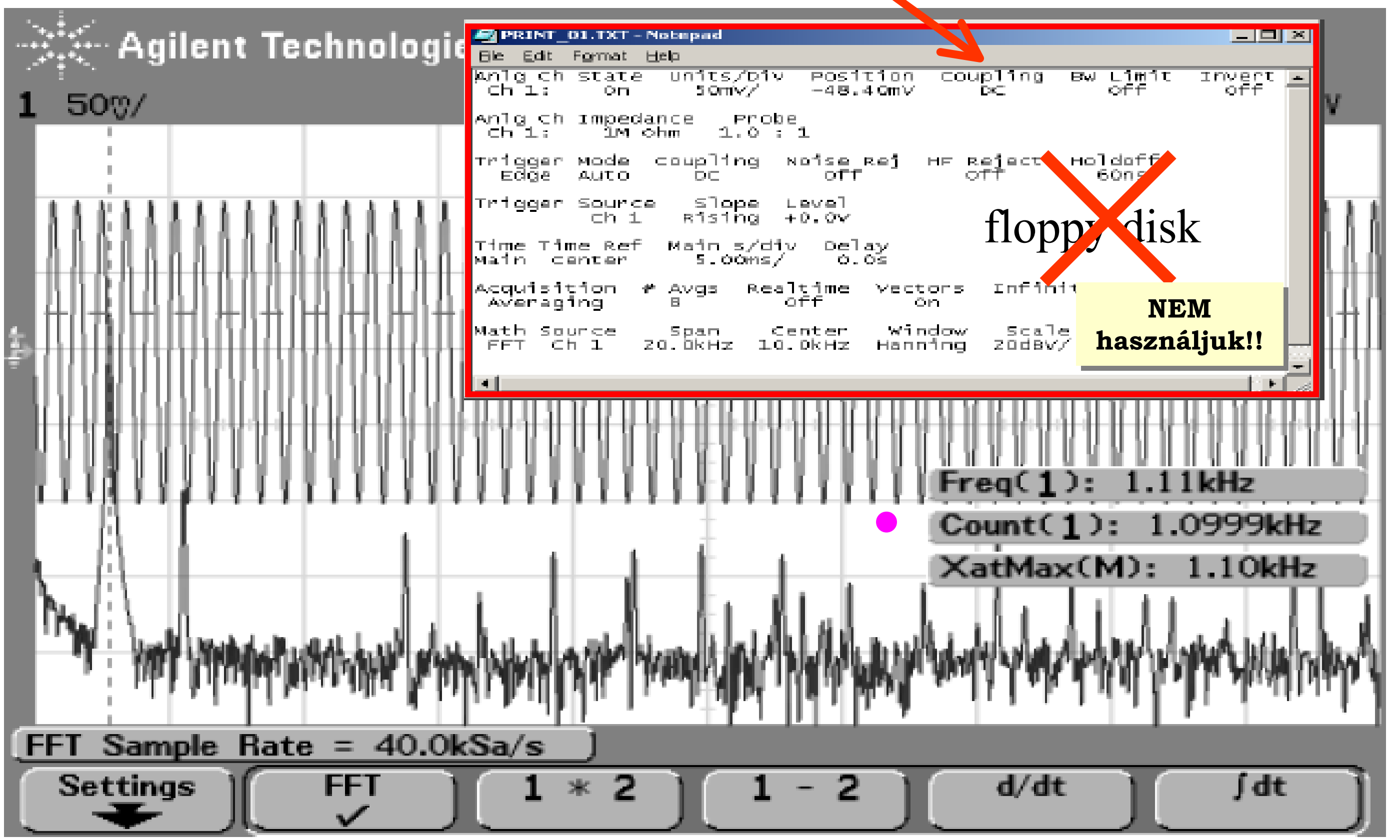
**Rectangular –** good freq resolution and ampl accuracy, **but** use only where there will be no **leakage** effects; use on self-windowing waveforms (as pseudo-random noise, impulses, sine bursts, and decaying sinusoids)

**Spectral Leakage** The FFT operation assumes that the time record repeats. Unless there are an integral number of cycles of the sampled waveform in the record, a discontinuity is created at the end of the record. This is referred to as leakage. In order to minimize spectral leakage, **windows** that approach zero smoothly at the beginning and end of the signal are employed as filters to the FFT.

# Scope - FFT display

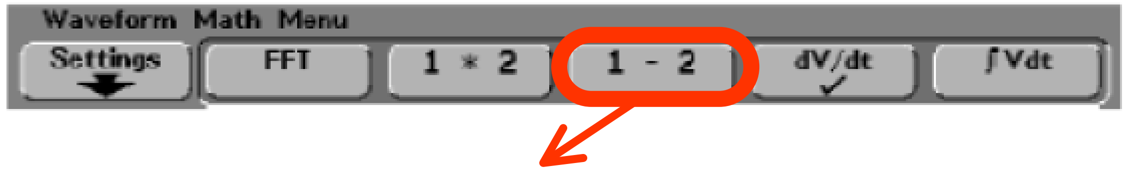
**Example:** Frequency Measurement (… and print oscilloscope scale Factors)

- Freq
- Counter (**built in** 5 digit reciprocal counter)
- Math (FFT)




(press **Math**)

# Scope - Subtract : press **Math / softkey 1-2**




## Subtract

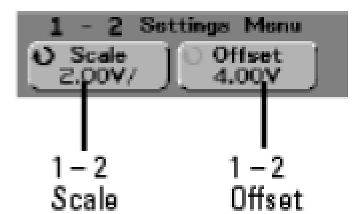
When you select **1 – 2**, Ch2 voltage values are subtracted from Ch1 voltage values *point by point*, and the result is displayed.

**You can use 1 – 2 to make a differential measurement or to compare two waveforms.**

| |
|---|
| To perform the **addition** of Ch1 and Ch2, select **Invert** in the Ch2 menu and perform the **1 – 2** math function. |

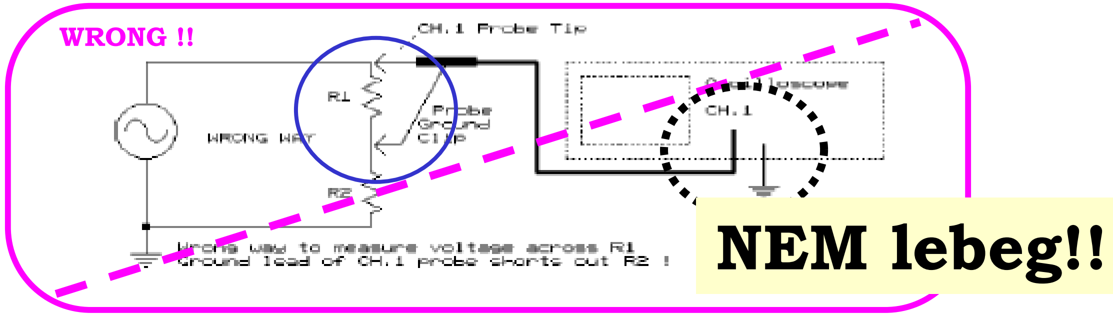
**Scale** allows you to set your own vertical scale factors for subtract, expressed as V/div (Volts/division) or A/div (Amps/division). Units are set in the channel **Probe** menu.

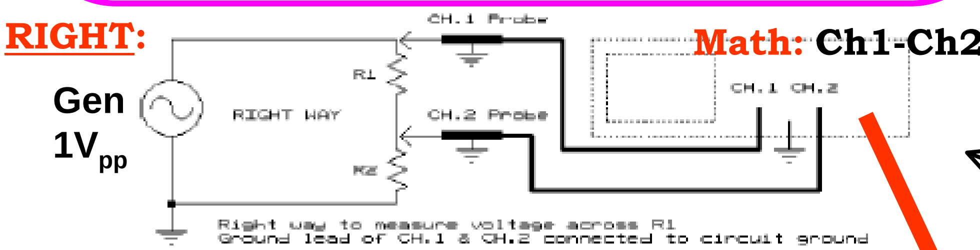
**Offset** allows you to set your own offset for the **1 – 2** math function. The offset value is in Volts or Amps and is represented by the *center* graticule of the display.



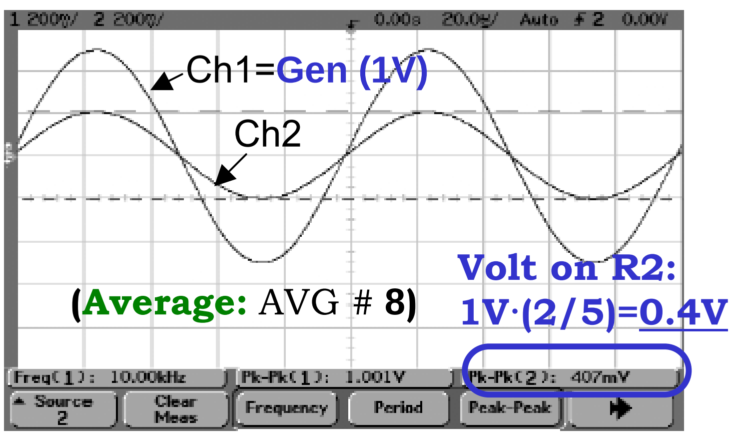

**Subtract** / Settings

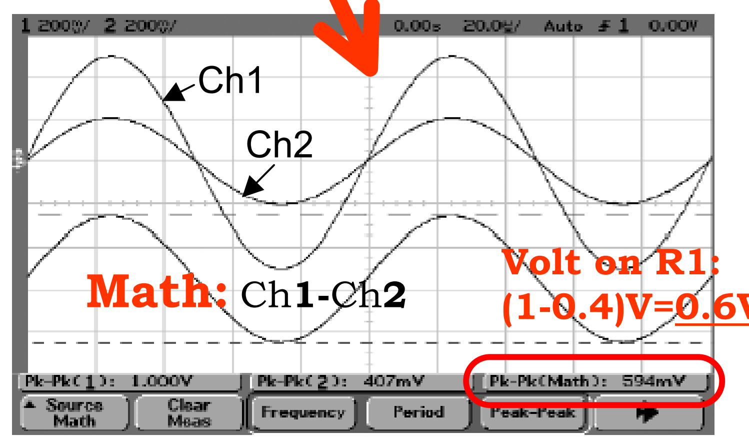
## **Scope :** Measure voltage **across R1** ( R1 = 3K, R2 = 2K ) → **Math: 1-2**



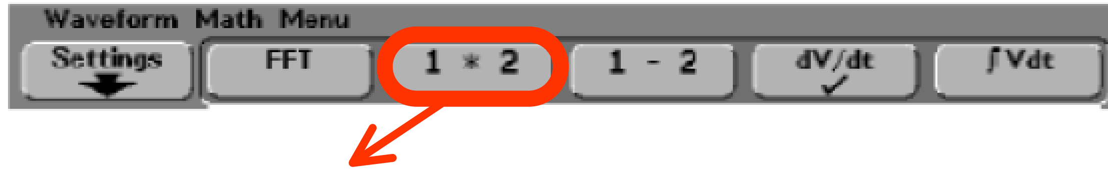




**2. mérés:**
Alapmérések
**„Tápegység IC"**



# Scope - <u>Multiply</u> : press **Math / ** softkey **1*2**



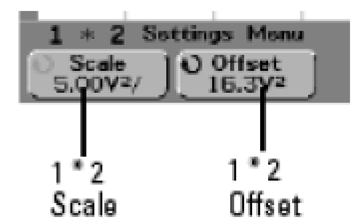

## Multiply

When you select **1 * 2**, Ch1 and Ch2 voltage values are multiplied *point by point*, and the result is displayed.

**1 * 2 is useful for seeing <u>power</u> relationships when one of the channels is proportional to the current.**

**Scale** allows you to set your own vertical scale factors for multiply expressed as $V^2$/div (Volts-squared/division), $A^2$/div (Amps-squared/division), or W/div (Watts/division or Volt-Amps/division). Units are set in the channel **Probe** menu.

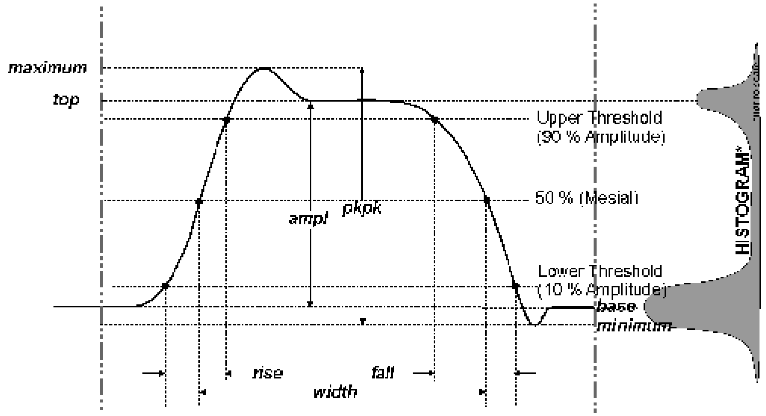
**Offset** allows you to set your own offset for the multiply math function. The offset value is in $V^2$ (Volts-squared), $A^2$ (Amps-squared), or W (Watts) and is represented by the *center* graticule of the display.

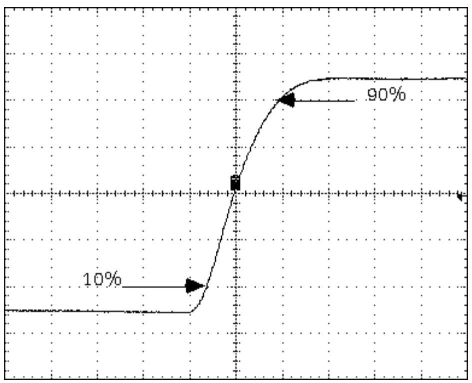



**Multiply** / Settings

# (1) ARBgen : **Sine** / Scope: Quick Meas - **Rise Time**

The analysis begins by **computing a *histogram*** of the waveform (wfm) data; **for example**, the histogram of a wfm transitioning in two states will contain two peaks. The analysis will attampt to identify the two clusters that contain the largest data density. Then *the most probable* state (centroids) associated with these two clusters will be computed to determine the Top and Base *reference levels*.




Once Top and Base are estimated, ***calculation* of the Rise and Fall times** is easily done. The 90% and 10% threshold levels are automatically determined by using the amplitude (ampl) parameter; the vertical interval spanned between the Base and Top line is subdivided into a percentile scale (Base = 0%, Top = 100%) to determine the vertical position of the *crossing points*.

The time *interval* separating the points on the rising or falling edges is then estimated to yield the Rise or Fall time.

**The right signal to test Rise an Fall time measurement**

**Sine waves** have a predictable shape and, theoretically, *known* timing parameters such as Rise times (and Fall times)

$$RiseTime = \frac{\arcsin(0.8)}{\pi \cdot Freq} = \frac{0.927295218}{\pi \cdot Freq} = \frac{0.2951672}{Freq} \approx 0.3 \cdot Period$$

**~ 1 us**

**0.295…MHz**

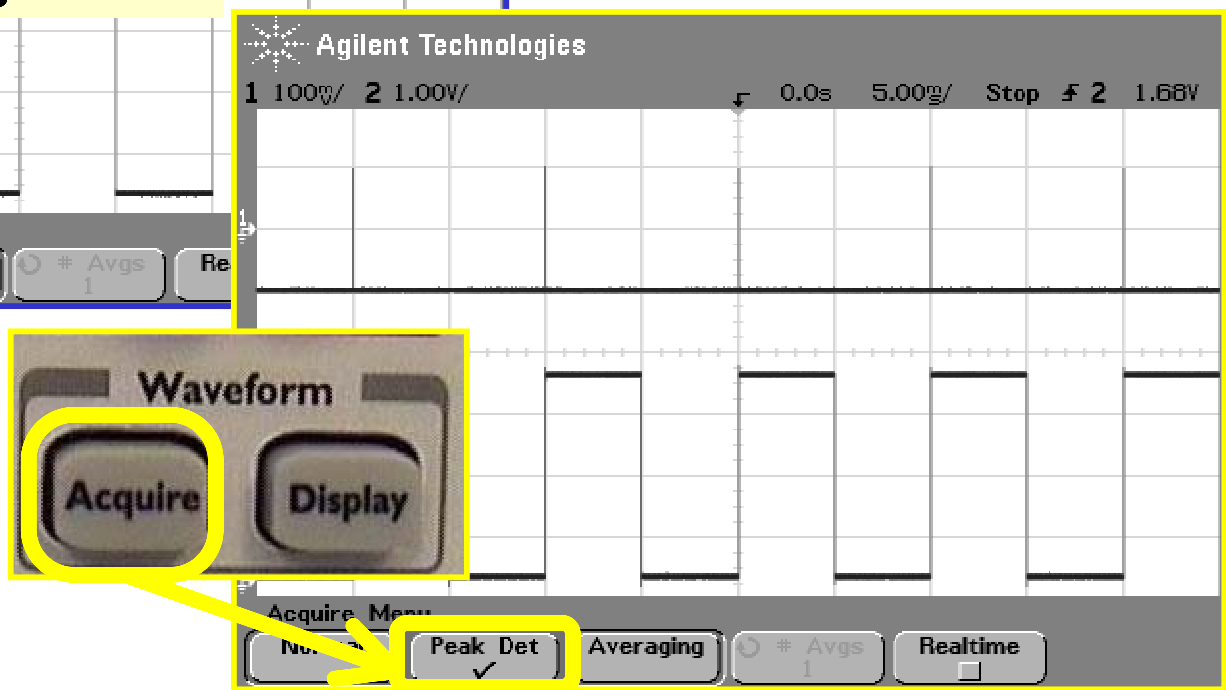
# (2) ARBgen : **Pulse** / Scope: Acquire - **Peak Det**

**5ms/DIV**


**Keskeny tüskék „lassú” jel**

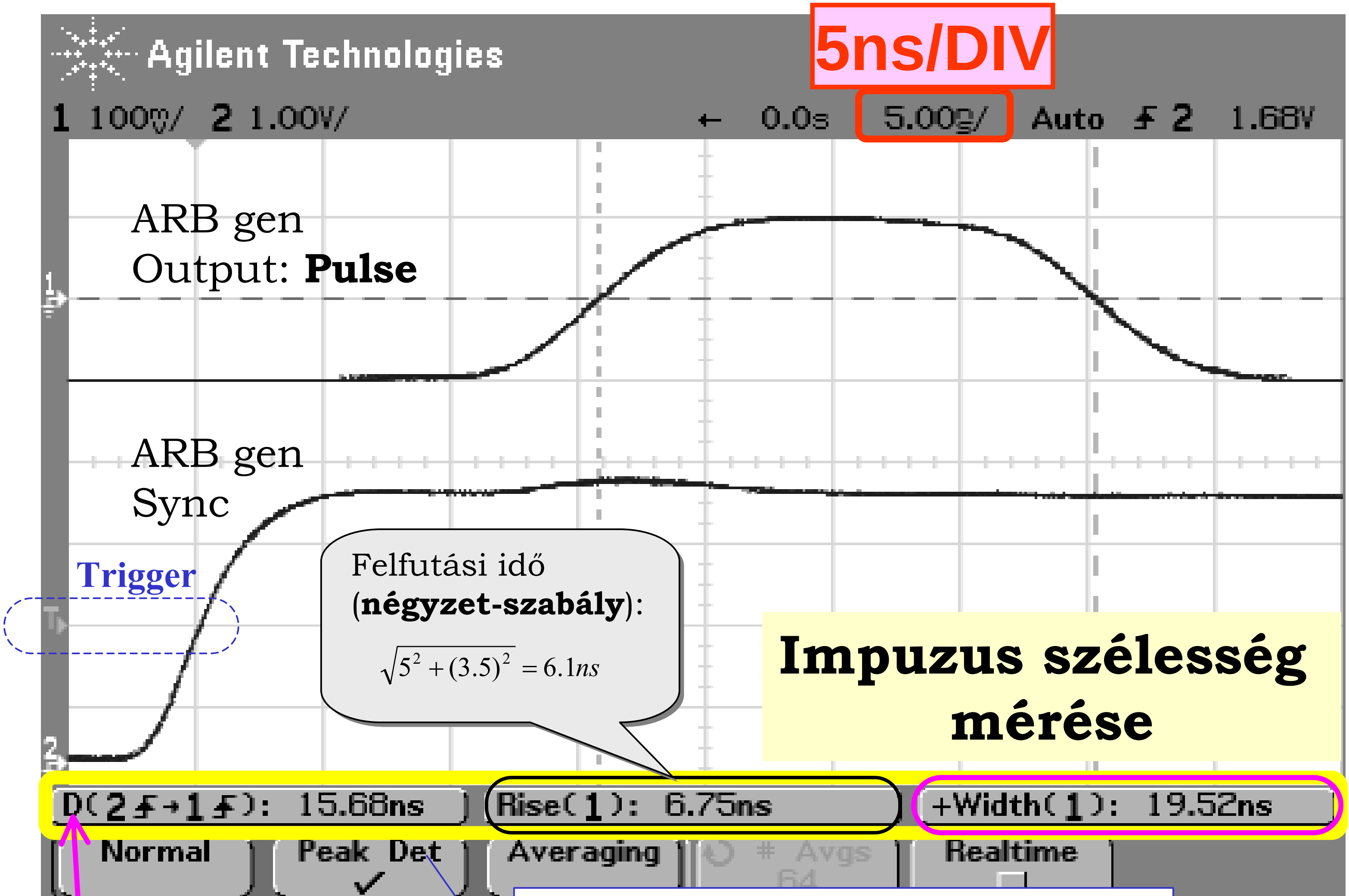
ARBgen :

**Pulse, 100Hz**
**Rise: 5ns**
**Width: 20ns**




**Scope:**

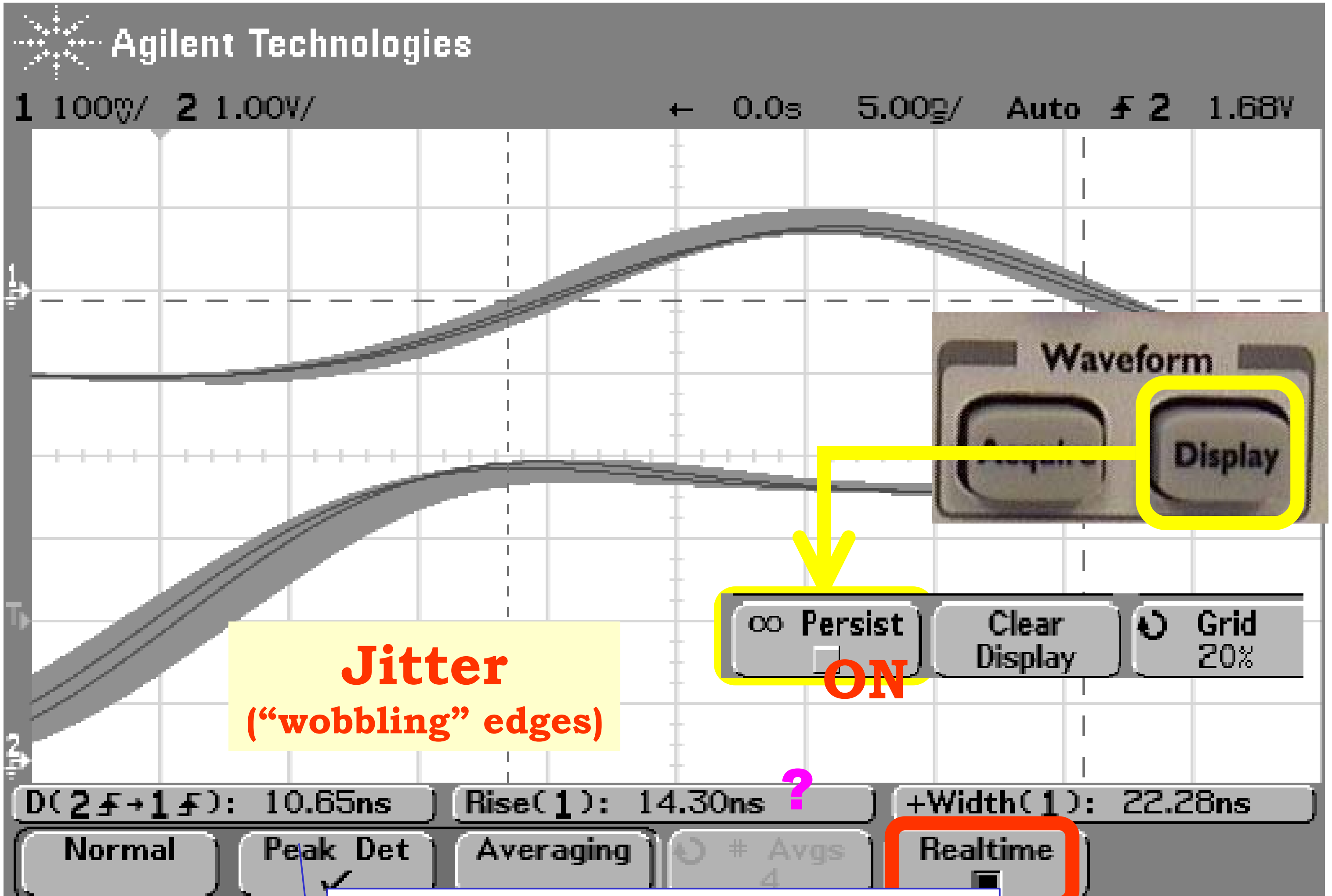
## ARBgen: **Pulse** ... folytatás — Scope: **Quick Meas**




Meas
Delay - settings

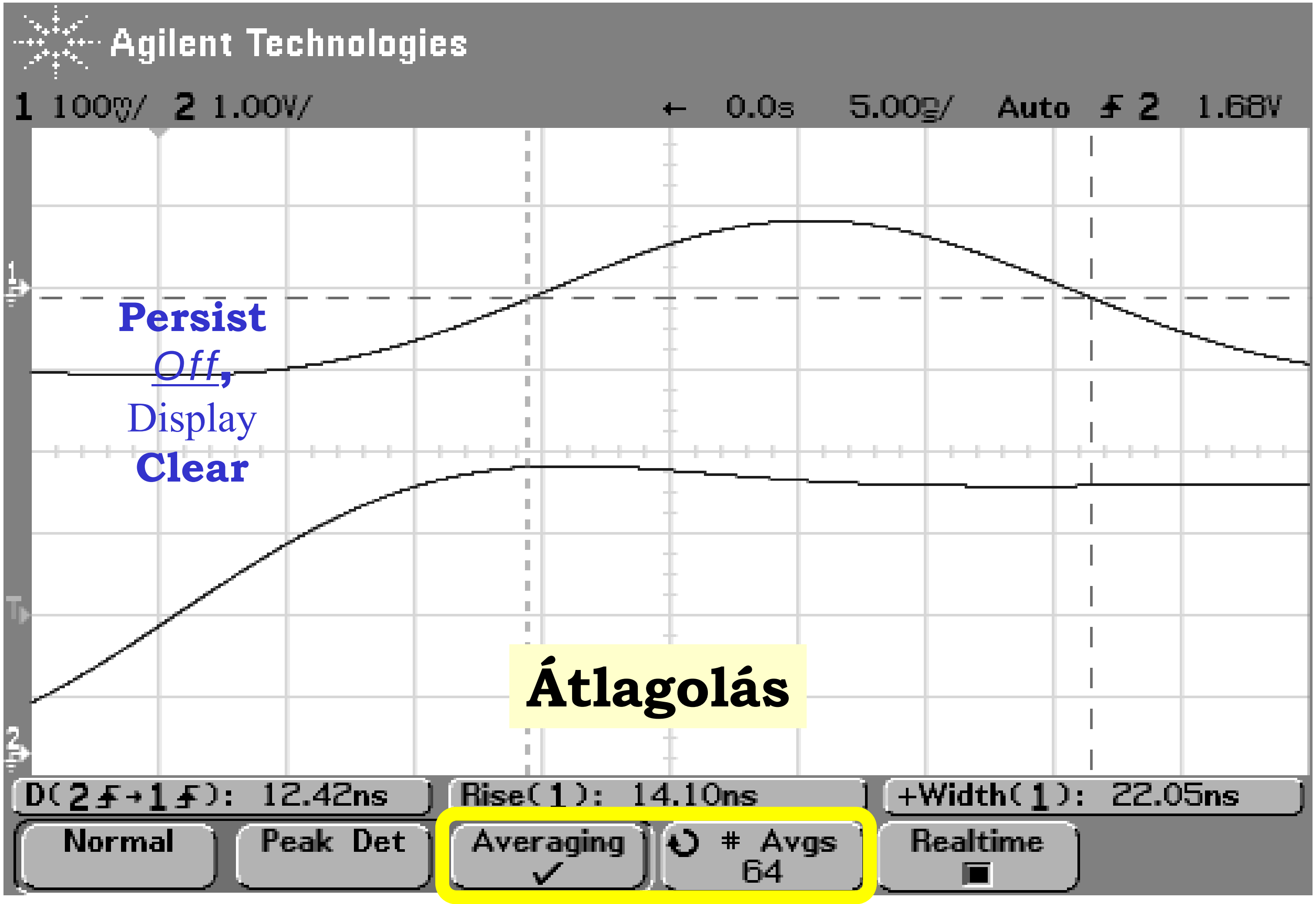
5ns/DIV sweep-nél már NEM hatásos a Peak Det üzemmód (... ezt tudja az oszcilloszkóp!)

# ARBgen: **Pulse** ... folytatás — Scope: **Realtime**




5ns/DIV sweep-nél már NEM hatásos a Peak Det üzemmód (... ezt tudja az oszcilloszkóp!)

ARBgen: **Pulse** ... folytatás — Scope: **Averaging**, **#Avgs** 64



# (3) ARBgen:

**Modulációk** *bemutatása*

Először a *vivő-t* kell kiválasztani ... pl. **Sine**

♣ Szemléltető **példa:**

- **Mod** Type: AM **...** Type: FSK
- **Sweep** (LIN)
- **Burst** (N cycle) **...** Cyc: 1, **2 ..**

Álló ábrához: Scope TRIG mode: **Holdoff**

(vizuális „élmény” – ARBgen display: **Graph** Mode)

**Store/Recall** – 4 memória hely van

„The ARBgen stores the selected **function, frequency, amplitude, dc offset, duty cycle, symmetry**, as well as any **modulation parameters** in use.
The instrument *does not* store *volatile* waveforms created in the arbitrary waveform function.”

**Utility** – / **csak** ezeket használjuk ... /

**DC** *off* | on – de 50Ω a forrás-ellenállás (!)

**Output Setup** Load/HighZ .. | (polarity) *Normal*/Invert

**Range:** *Auto* (!!) – maradjon!!

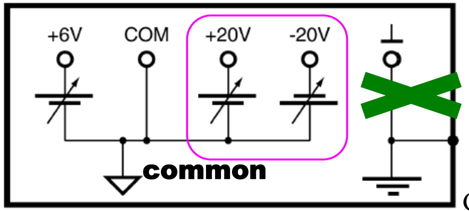
# Agilent 3630A triple-output **Power Supply**

max 6V, **2.5A**; max ± 20V **0.5A** (output tracking)

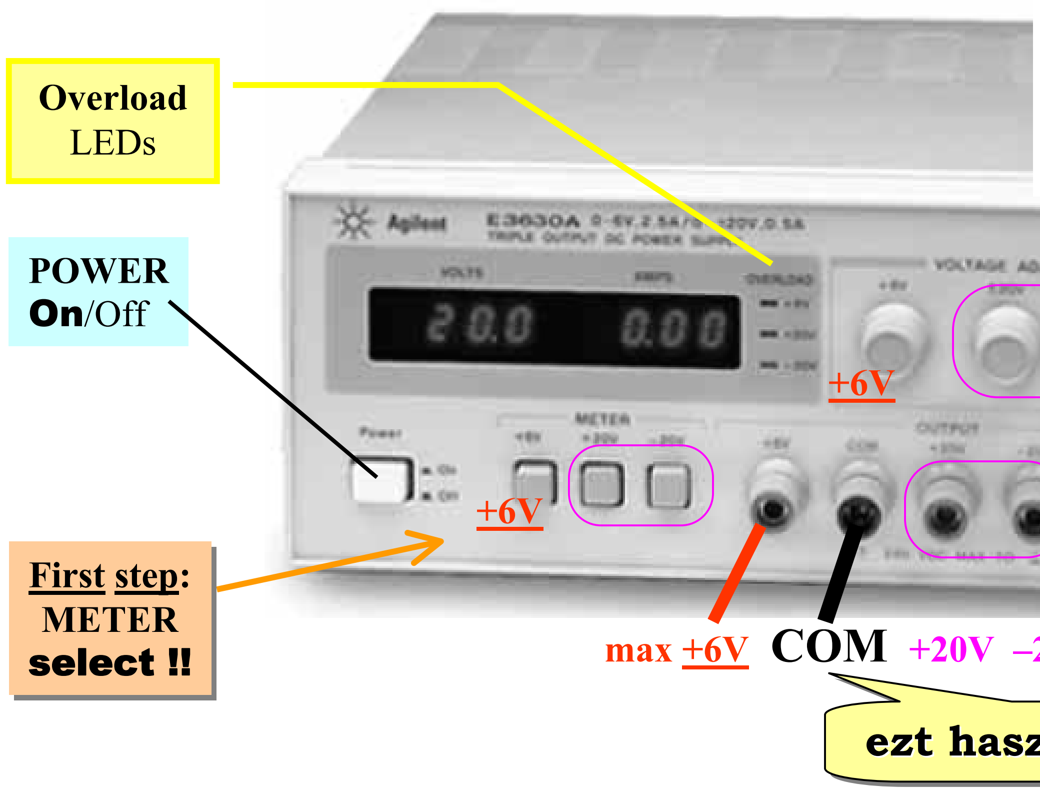
**Constant voltage** (CV)

and **current foldback** (CF, +6V) / **current limit** (CL, ±20V) modes

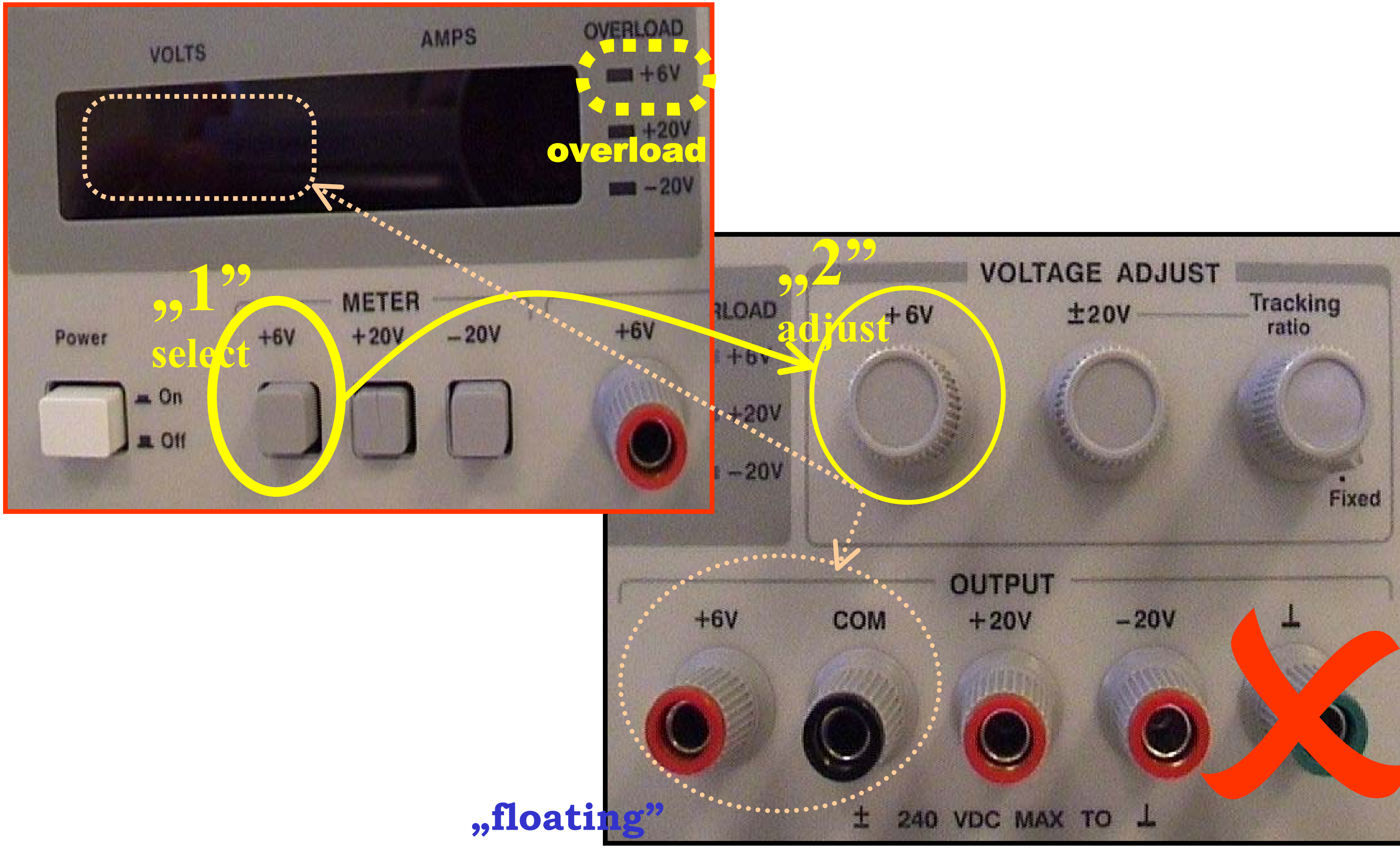
Digital voltage and current METERs




Shield (earth) Ground: **GND**



# Power Supply - **max** <u>+ 6V</u> output

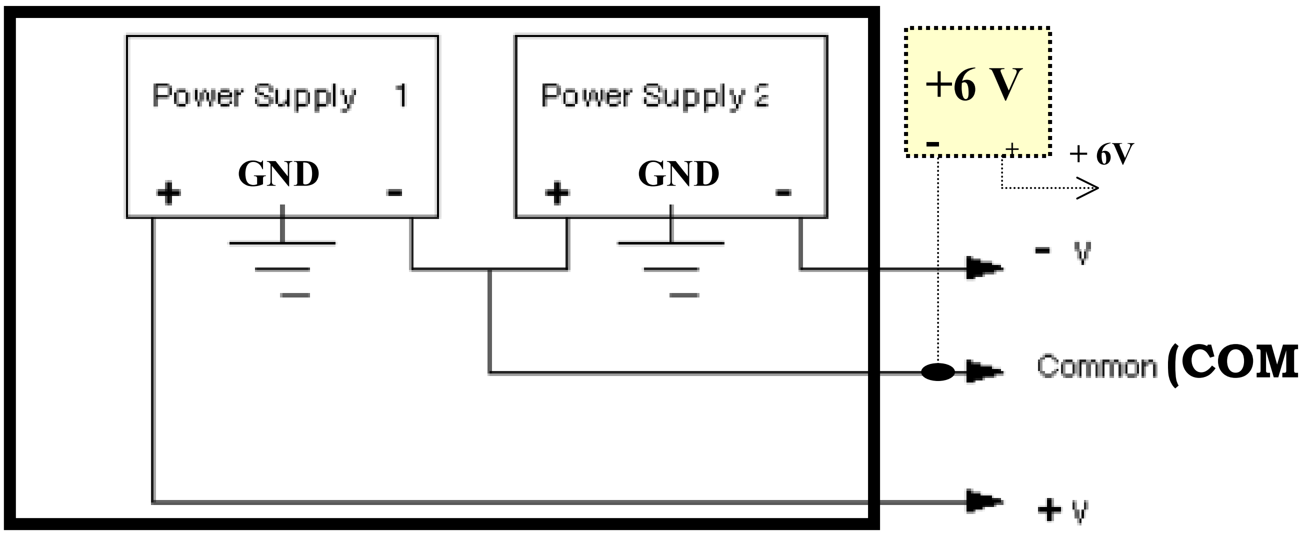


# Power Supply: ± 20V output "tracking"

- The ±20V control sets the **0 to +20V** and the **0 to -20V** outputs simultaneously. With the **Tracking ratio** control turned fully clockwise to its "**fixed**" **position**, the voltage of the negative supply tracks the positive supply within 1%, giving *balanced* positive and negative supplies.

Example: Press the +20V METER button (to display the +20V output) and adjust the ±20V control knob to set the positive supply to **+15V**. Press the -20V meter button, the METER should read **-15V**. The positive and negative supplies are *balanced* **: ±15V**

--------------
**"1" METER**
"2" ADJUST
--------------
"3" Connect
(**COM,** V )
--------------




- Turning the **Tracking ratio** control clockwise **out of its fixed position** allows you to set the voltage of the **-20V supply** to a fixed fraction (**less** than unity) of the +20V supply. Once this ratio is set, the ±20V control still controls both outputs and maintains a *constant ratio* between their voltages.

# Power Supply - Overload

(2) Voltage **ADJUST**

**Overload** LEDs

max **+6V**

max ±20V

Tracking ratio **(fixed !)**

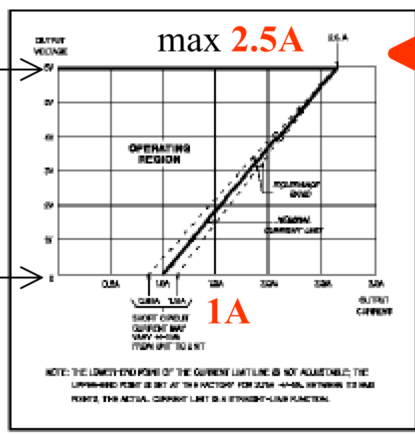
(1) **METER** select


**+6V** **COM** +20V –20V ~~(GND)~~

**ezt használjuk !!**

max 6V

0V




Current Limit Characteristic of the 6V Supply

If **overload** conditions occur, the **±20V** supplies will protect the load by limiting the current to 0.55 A and the **+6V** supply will protect the load by reducing both voltage and current simultaneously along the **foldback** locus as shown in Figure.

# Agilent **34401A** digital **Multimeter (DMM)**

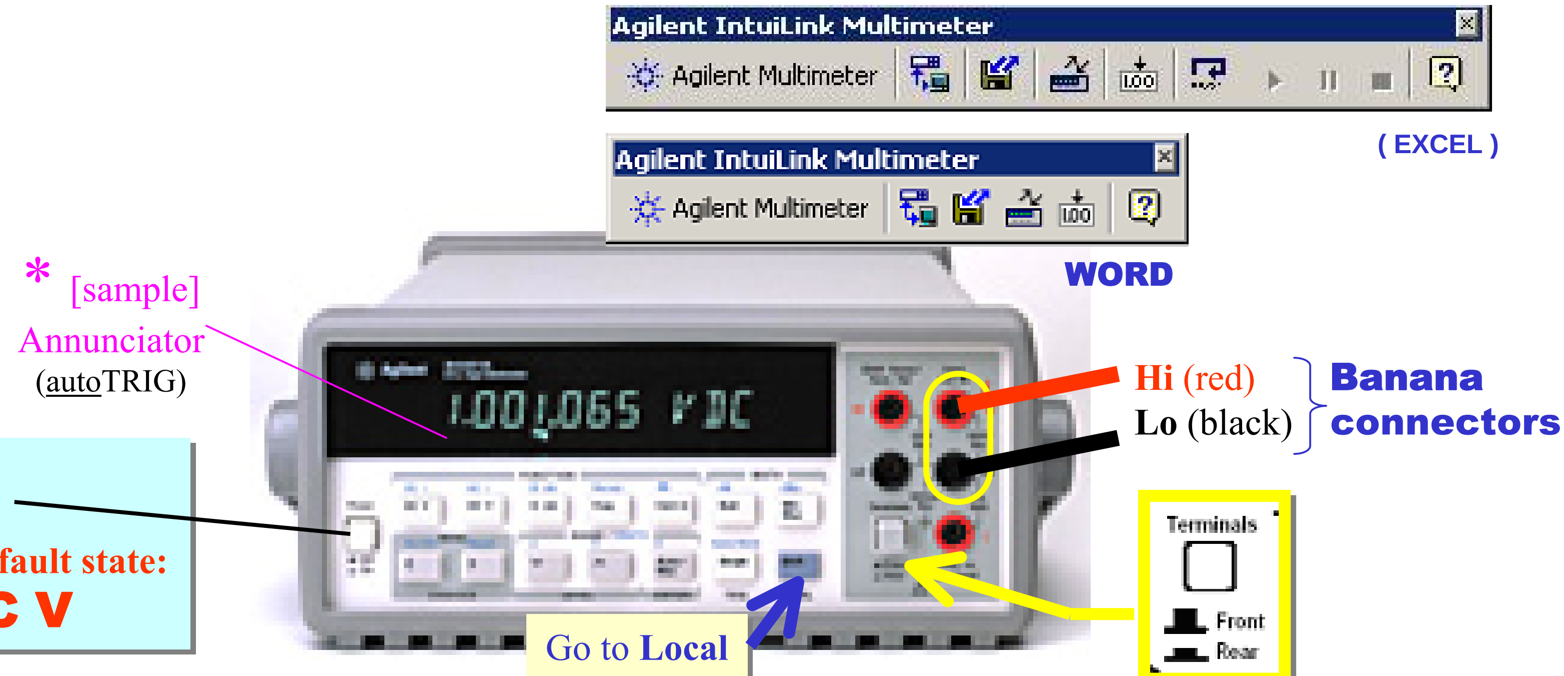
**6.5** digit resolution (**!**); autoRanging; autoTrig

**Voltage:V**, Current:I, **Resistance: Ω** ( **2Wire**, NULL feature, 4W )

**True RMS AC volt** and current (**ac coupled !**)

Frequency, period; **Math,** Data logging

**GPIB**, **IntuiLink: Toolbars**




**POWER**
**On**/Off
Pwr **on default state:**
**DC V**

# **DMM** - Front panel

## ❶ **FUNCTION** ( default sate: **DC V** )

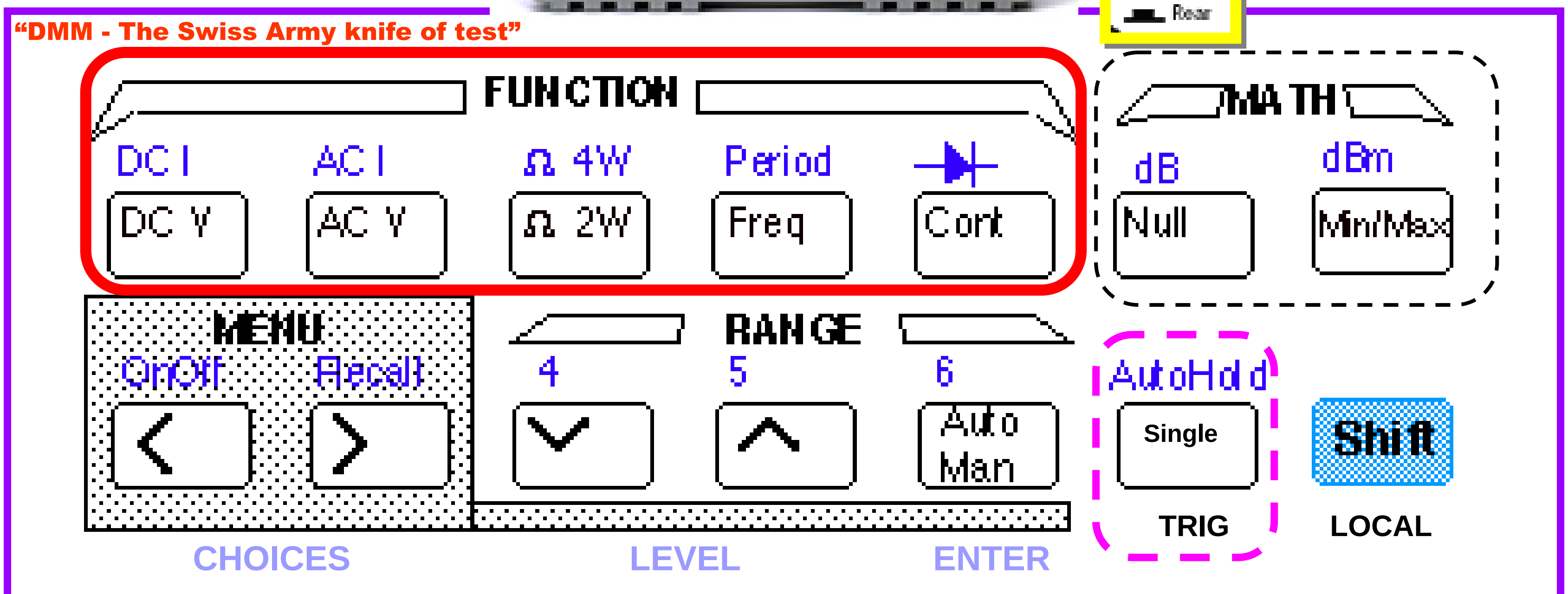
❷ **RANGE** (<u>Auto</u>/Man ∧ ∨), ❸ **DIGITS** ( **Shift 6/<u>5</u>/4**; masking: < > ), ❹ **TRIGger** ( <u>Auto</u> )

❺ *Connection*


**Hi** (red)

**Lo, COM** (black)

* [sample] annunciator



**DMM:**

# **Math** Functions

To make **null** (relative) measurement — Null

To store **min/max** readings — Min Max

To make **dB** measurements — Shift dB

**DC V or AC V only**

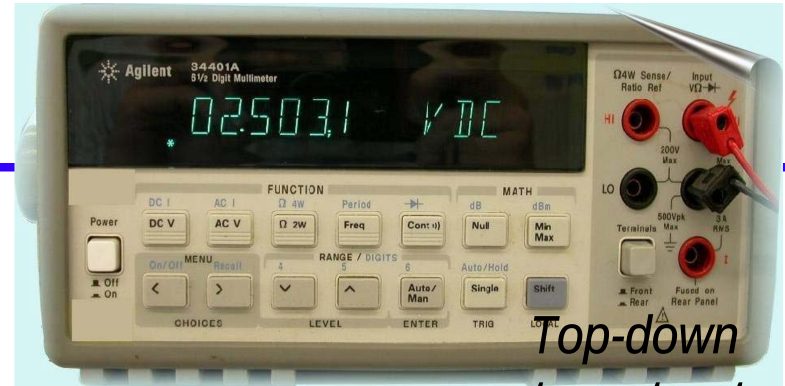
dB = *reading in dBm* **-** *relative value in dBm*

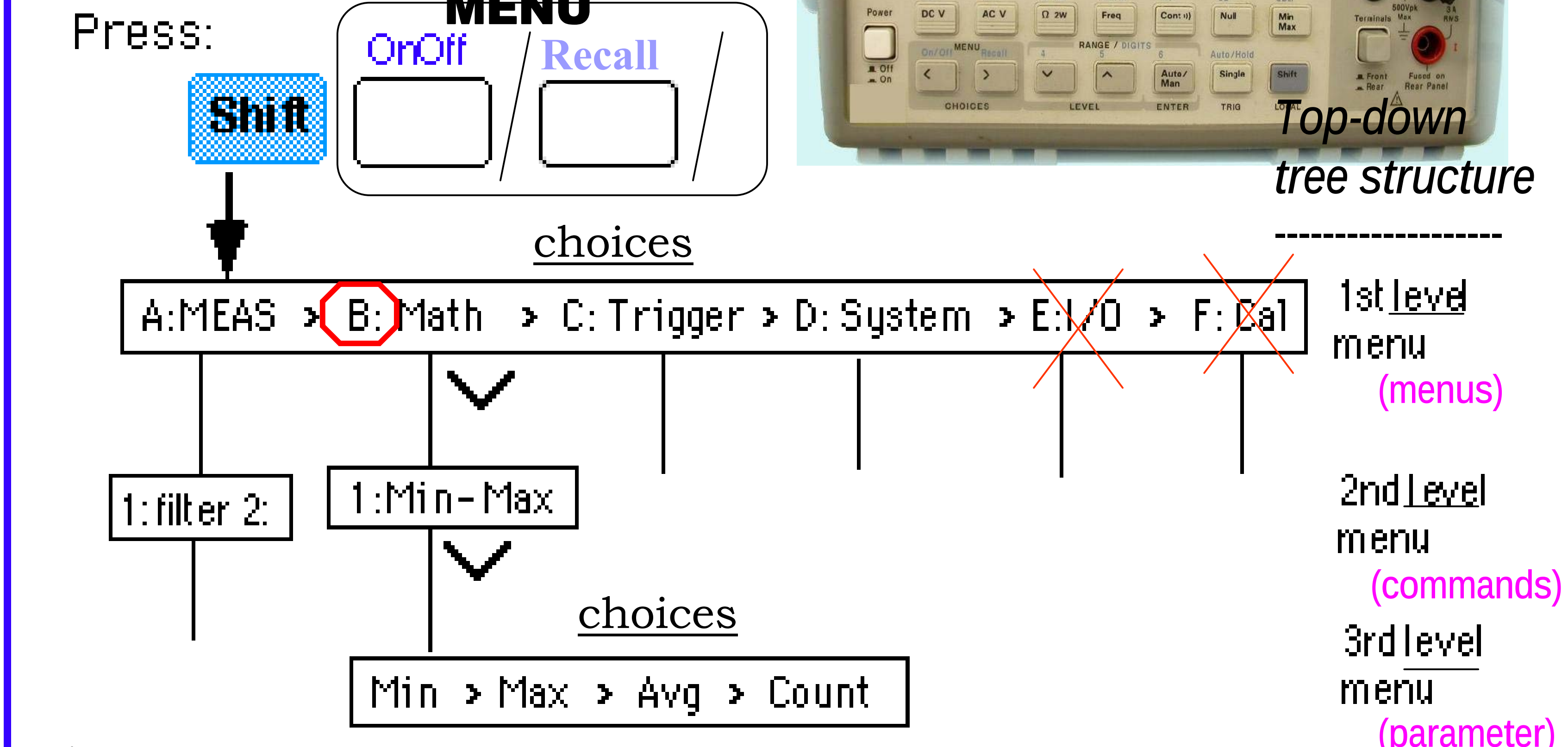
To make **dBm** measurements — Shift dBm

dBm = $10 \cdot \log_{10}$ (*reading* $^2$*/ reference resistance/ 1mW)*

**Limit** testing ( Access through **Menu** )

# DMM - Front panel menu




choices

A: MEASurement MENU

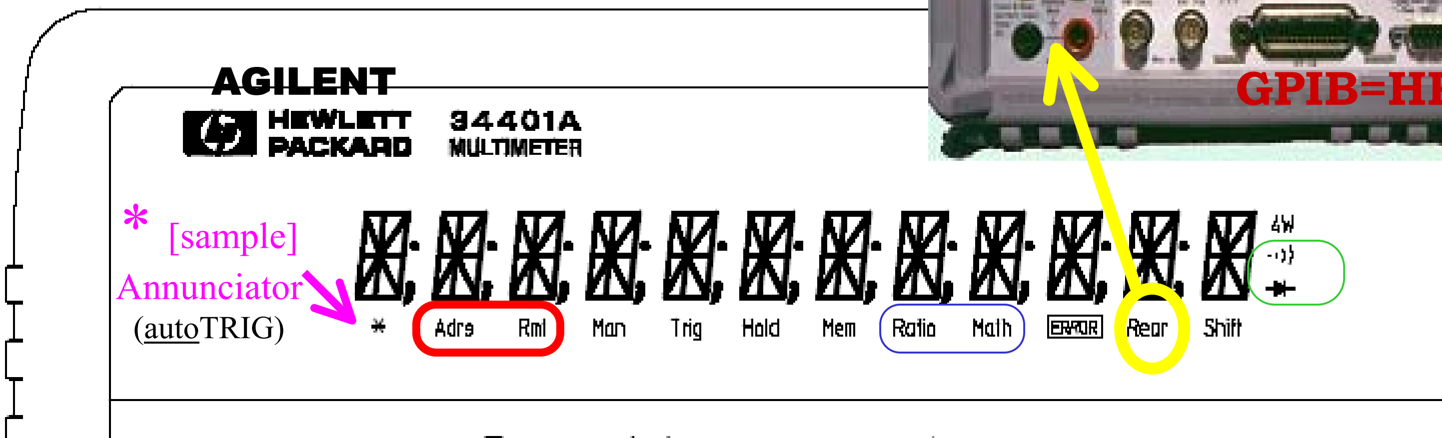
1: AC FILTER → 2: CONTINUITY → 3: INPUT R → 4: RATIO FUNC → 5: RESOLUTION

B: MATH MENU

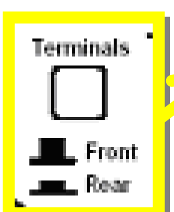
1: MIN-MAX → 2: NULL VALUE → 3: dB REL → 4: dBm REF R → 5: LIMIT TEST → 6: HIGH LIMIT → 7: LOW LIMIT

*Execute:* Enter

# DMM - Display annunciators


Go to **Local**


| | |
|---|---|
| * | Turns on during a measurement. |
| **Adrs** | Multimeter is addressed to listen or talk over the HP-IB interface. |
| **Rmt** | Multimeter is in remote mode (remote interface). |
| **Man** | Multimeter is using manual ranging (autorange is disabled). |
| **Trig** | Multimeter is waiting for a single trigger or external trigger. |
| **Hold** | Reading Hold is enabled. |
| **Mem** | Turns on when reading memory is enabled. |
| **Ratio** | Multimeter is in dcv:dcv ratio function. |
| **Math** | A math operation is enabled (null, min-max, dB, dBm, or limit test). |
| **ERROR** | Hardware or remote interface command errors are detected. |
| **Rear** | Rear input terminals are selected. |
| **Shift** | "Shift" key has been pressed. *Press "Shift" again to turn off.* |
| **4W** | Multimeter is in 4-wire ohms function. |
| ·›)) | Multimeter is in continuity test function. |
| ⊣▶⊢ | Multimeter is in diode test function. |

**MENU**

# DMM - Basic functions

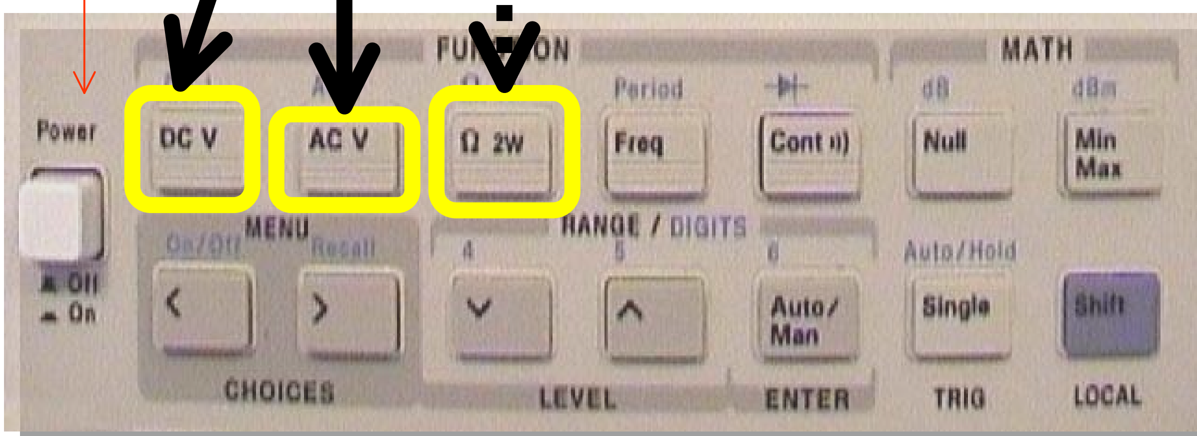
Egyenkomponens

**DC:** „direct current”
**AC:** ”alternating current”
**V: volt (!!)**

**POWER** ( Pwr **on**: **default state: DC V** )

Egyenkomponens nélküli váltakozó jel valódi effektív értéke

Ellenállás (2Wire)





„floating”

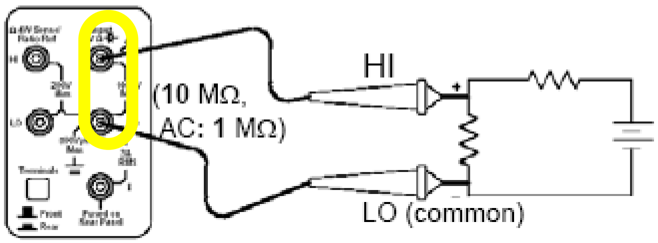
Front

“DMM - The Swiss Army knife of test”

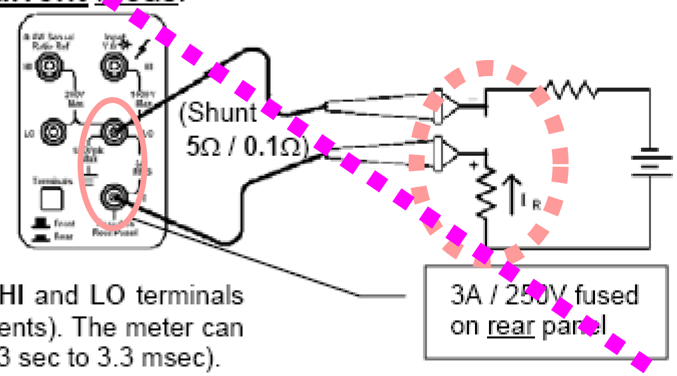
# DMM Functions – Banana connectors

**DC V, AC V:**

Voltage measurement:



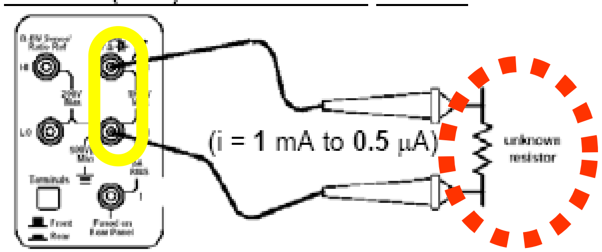

Current meas:

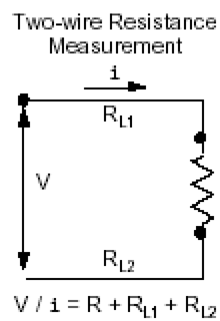



Note: to Measure **Frequency: F** (or **Period: T**) use the **HI** and **LO** terminals marked **1000 V Max** (as you would for voltage measurements). The meter can measure frequency from 3 Hz to **300 kHz** (period from 0.33 sec to 3.3 msec).

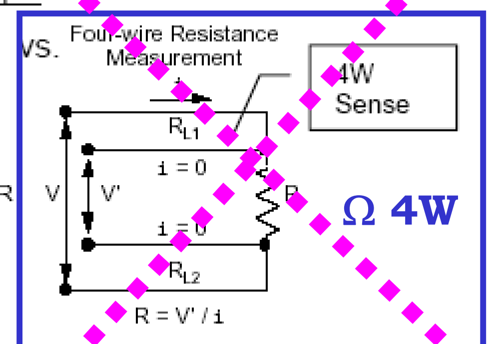
For frequency and period measurements, **ranging** applies to the signal's input *voltage*, not its frequency!

**Ω 2W:** **2 wire** (2W) **Resistance** meas:




vs.




NOTE: the measurement portion of DMM is **ISOLATED** from chassis (earth) ground !!

**Üzemmód váltás előtt: vezetéket bontani (kivéve: DC V, AC V)**

# DMM - DC V ( dc coupled )

Range (DIGITS) vs. Integration ( AVG ) time in PLCs

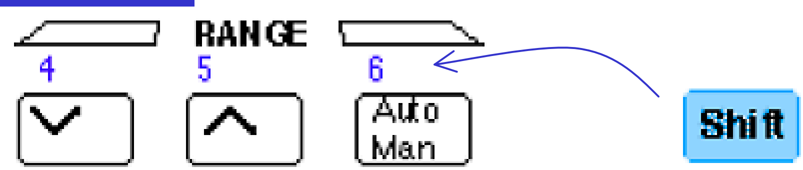
| Resolution Choices | Integration Time |
|---|---|
| Fast 4 Digit | 0.02 PLC |
| * Slow 4 Digit | 1 PLC |
| Fast 5 Digit | 0.2 PLC |
| * Slow 5 Digit *(default)* | 10 PLC |
| * Fast 6 Digit | 10 PLC |
| Slow 6 Digit | 100 PLC |

***Fastest,*** least accurate

Do not provide power-line noise rejection

Slowest, ***most accurate***

* These settings configure the multimeter just as if you had pressed the corresponding "DIGITS" keys from the front panel.




Integration time is specified in *number of power line cycles* (NPLCs). The choices are 0.02, 0.2, 1, **10**, or 100 power line cycles. *The default is 10 PLCs.*

# Power Supply / DMM - DC V:


♣ Szemléltető **példa:** a tápegység előzőleg beállított értékeit mérjük (*piros*, fekete mérővezeték)

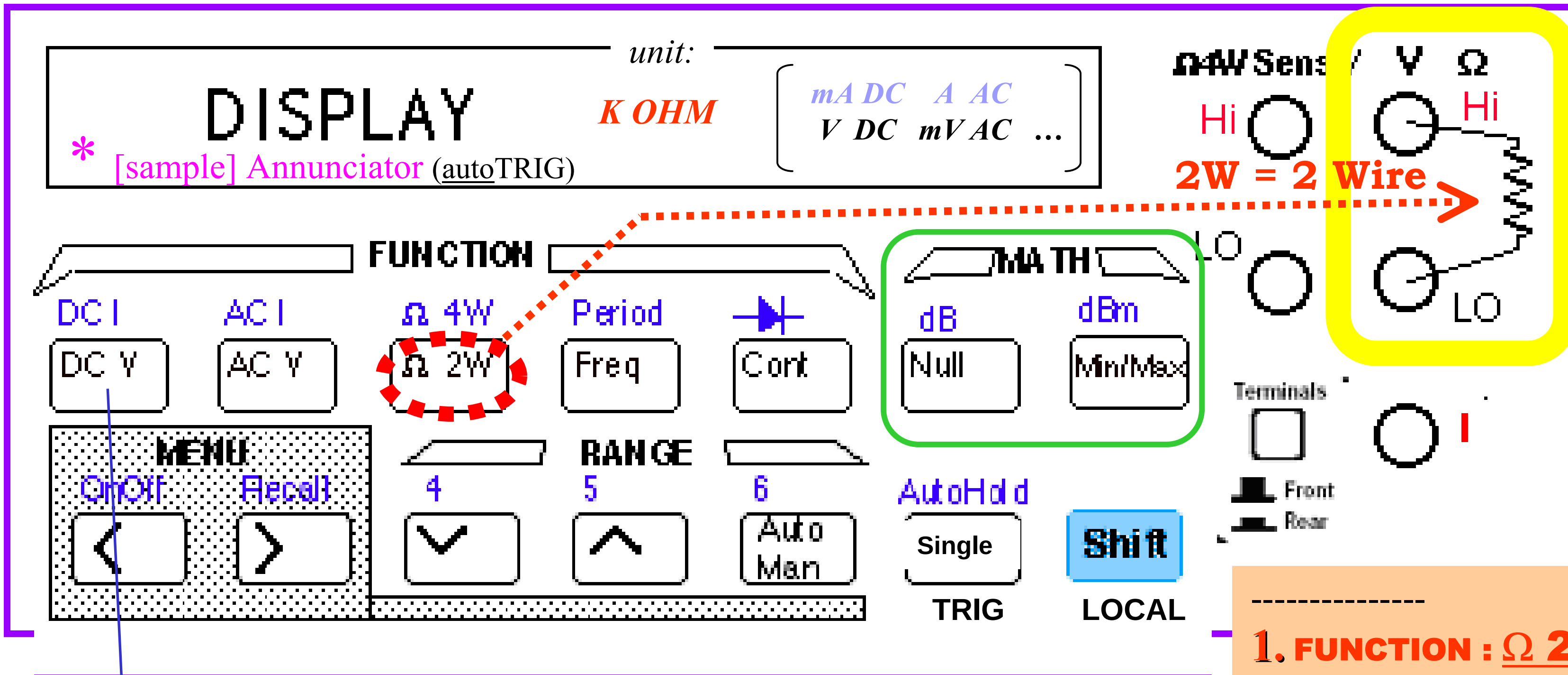
Vessük össze a **Tápegység** indikátor és a **Multiméter** adatait!

- Tápegység +6V out mérése, → Méréshatár: „Auto/**Man**” (**Man** annunciator turns on), ezután „ ∨ ” **… OVLD** [display] , „ ∧ ”(*optimális* tartomány!)
  *Megtartva* ezt a beállítást, +20V out mérése: **OVLD,** → Range: „**Auto**/Man” (Man annunciator turns off) **…** a továbbiakban célszerű **auto** Range
- Felbontás módosítás: „(*shift*) 6 / 4 / **5**” (figyeljük meg * [sample] annunciator gyakoriságának változását!) ill. a digit „maszkolás” (“ < ” , “ > ”) hatása
- Mérés indítás (TRIG): „Single” [9] (**Trig** annunciator turns on), → „(*shift*) **Auto** | Hold” (Trig annunciator turns off) **…** célszerű **auto** TRIGger

Megjegyzés: Hold állapotban (**Hold** annunciator turns on) **„befagy” a kijelzés (!)**, és új érték (sípolva) csak akkor jelenik meg, ha a rögzített érzékenységi-sávon [10] belül, egymást-követően *három* mérési adat fordul elő.
**Például,** *kapcsoljuk be* [11] a **Hold** állapotot, majd +6V out mérése, majd ismét +20V out mérése; ezután *kapcsoljuk ki* : „(*shift*) **Auto** | Hold”

[9] one reading: press **Single**
[10] default state: 0.1% of reading (→ Trig MENU)
[11] **(shift) Auto/Hold** toggles between **auto TRIG** and reading **Hold**

# DMM - Ω 2W meas




---------------

**1. FUNCTION : Ω 2W**

---------------

- RANGE ( *auto* )
- Digits ( **Shift** 4/5/6 )
- TRIGger ( *auto* )

---------------

**2. Connection**

---------------

**BEkapcsolásnál**
**ez aktív: DC V**
**( most meg kell változtatni !! )**

**a BEkapcsolási alaphelyzet maradjon !!**

## ♣ DMM - Szemléltető **példa**: Ω **2W**

**1.** Két *összekötött* mérővezeték ellenállásának mérése ... (≈ 45 mΩ),

ezután

Math: **Null** ( ***Math*** annunciator turns on ):
Ω **2W** mérésnél a mérővezeték hatásának kompenzálása

( **2.** Saját *test ellenállás* mérése ... )

**3. Dokumentálás:** e-Jegyzőkönyv ( **Word** )

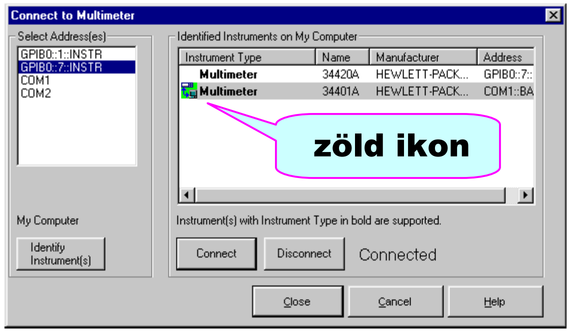
**egyszerűbb KÉZZEL begépelni az adatot ...**

## DMM - WORD: Tools | Templates and Add-Ins... AgtMMtb.dot

( ha nem látszik → **View** | Toolbars : √ )

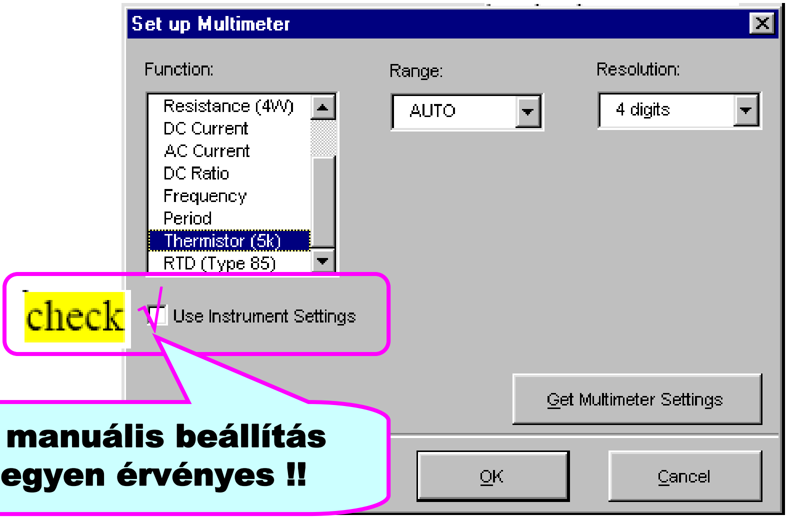

**Agilent MultiMeter toolbar**

### Connect to Multimeter




GPIB address - 22

### Set Multimeter Functions for single readings,




### Get Single Measurement

check **'With Engineering units'**,
do **NOT** check 'Do not show this dialog' !!

**WORD**
Save as … **G: drive !!**

## DMM - üzemmód váltás

**Feszültség (V) mérésen kívül ...**

**Eltérő üzemmód** kiválasztáshoz először *szüntessük meg* a kapcsolatot a mérendővel (összekötés bontás!), csakis ezután váltsunk üzemmódot.

**"The Swiss Army knife of test"**

Univerzalitás: **áram (I)**, **ellenállás (Ω**, 2Wire / 4W), **Freq**, **T** (= 1/F, Period) ...

**FIGYELEM:** **I :** meg kell szakítani az áramkört ( ... biztosíték!)

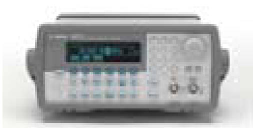
**Ω :** szeparálni kell az alkatrészt

- **I, Ω** üzemmódban **NE** kapcsoljunk rá feszültséget !!

**( Banana** in**! )**

**ARBgen**

**( BNC** out**! )**



**F (T) :** a HI / LO -ra kapcsolt feszültség frekvenciáját ( ill. periódusát ) méri – „reciprocal Counter"

- **F (T)** módban RANGE a feszültség tartományt állítja!

**AC** mérés (V, I): AC csatolt **igazi** RMS érték („AC coupling **true** RMS")

MEAS **menu** : AC coupling FILTER: 3 Hz [slow], **20 Hz [medium],** 200 Hz [fast]

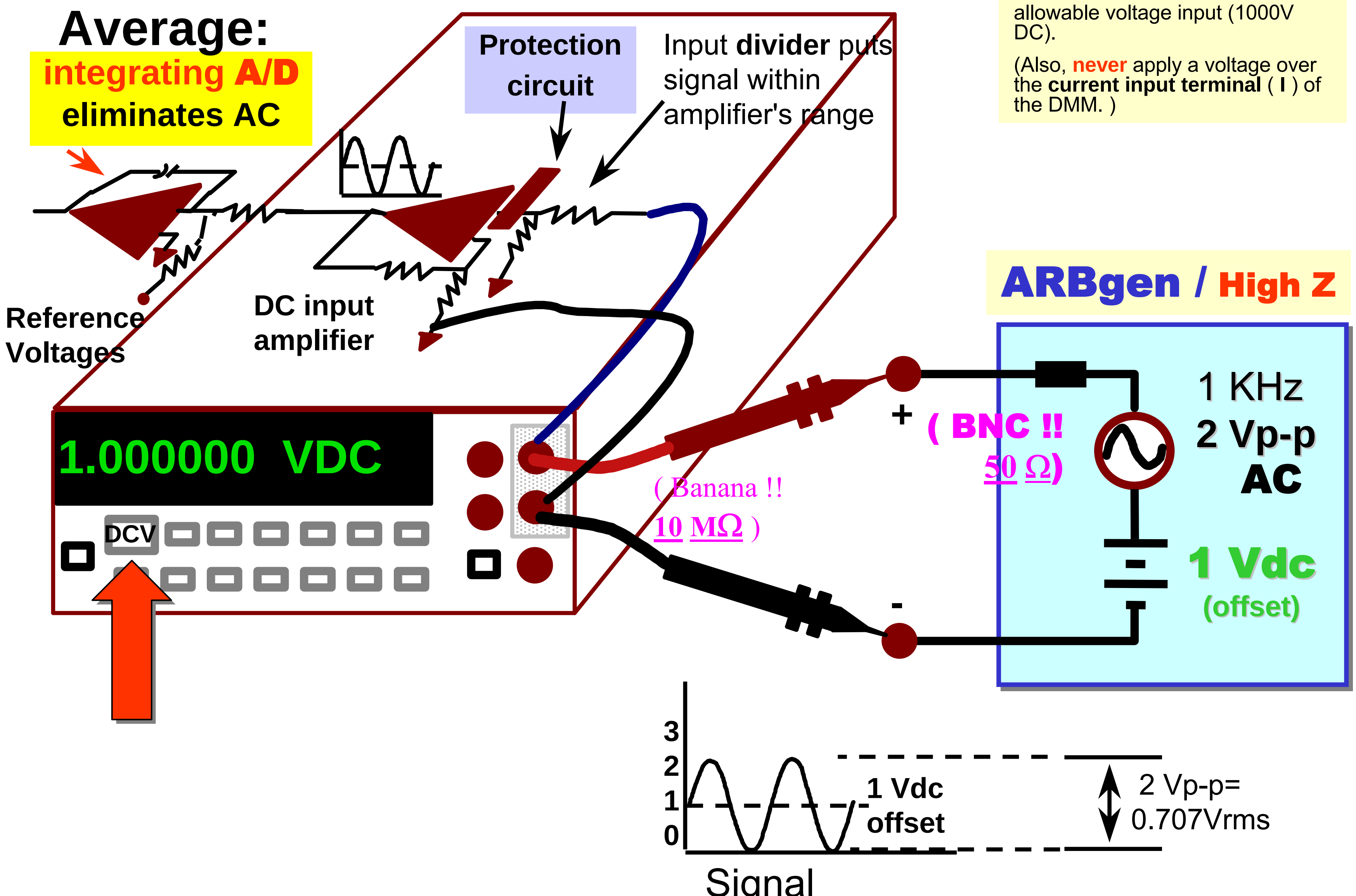
(DC offset up to 400V; **CF:** crest factor max 5:1 @ full scale)

# ARB gen / DMM (1): Measuring **DCV** (dc coupled)

**CAUTION:**

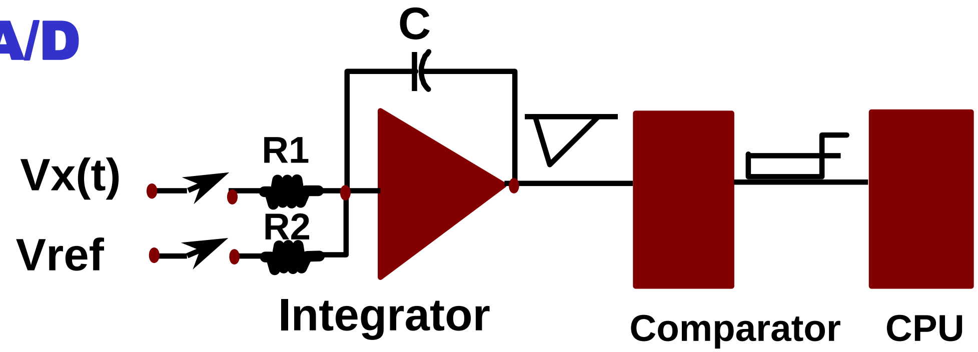
Do not exceed the **maximum** allowable voltage input (1000V DC).

(Also, **never** apply a voltage over the **current input terminal** ( **I** ) of the DMM. )



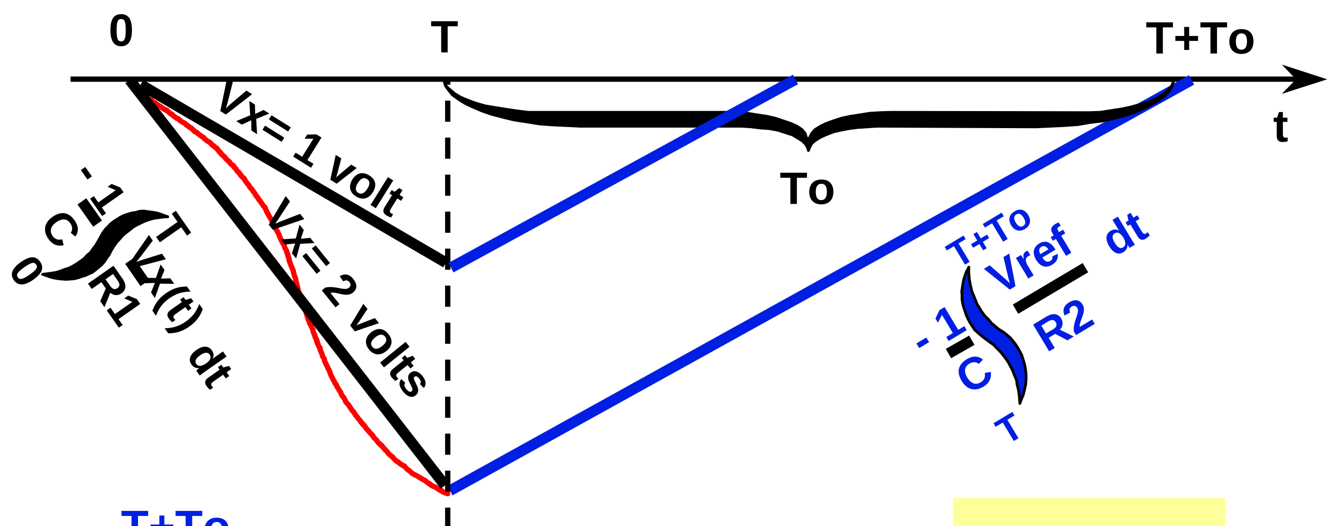
# DMM: Integrating (dual slope) A/D

**1) Converts voltage to time to digits**
**2a) Integrator is a line-frequency filter**
**2b) Integrator is a low-pass filter**




**Integrator:**

$$Vout = -\frac{1}{C}\int_0^T i(t)\,dt$$




$$\text{If } R1=R2 \Rightarrow \int_0^T Vx\,dt = \int_T^{T+To} -Vref\,dt \Rightarrow T{*}Vx = To{*}(-Vref) \Rightarrow \frac{Vx}{-Vref} = \frac{To}{T}$$

**T is fixed at one cycle** of 50 Hz or 60 Hz to *eliminate* power line noise;
**Vref** is fixed; R, C and Time are all *ratioed*, so **accuracy** is **excellent**.

# DMM - **DC V** ( dc coupled )

## Range (DIGITS) **vs.** Integration ( **AVG** ) time in PLCs

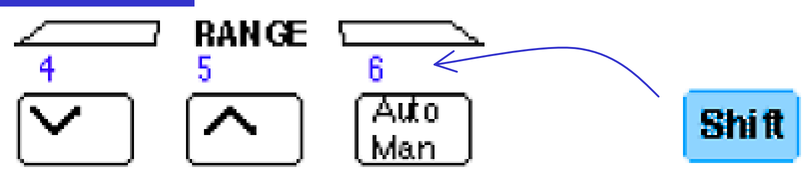
| Resolution Choices | Integration Time |
|---|---|
| Fast 4 Digit | 0.02 PLC |
| * Slow 4 Digit | 1 PLC |
| Fast 5 Digit | 0.2 PLC |
| * Slow 5 Digit *(default)* | 10 PLC |
| * Fast 6 Digit | 10 PLC |
| Slow 6 Digit | 100 PLC |

0.02 PLC: ***Fastest,*** least accurate

100 PLC: Slowest, ***most accurate***

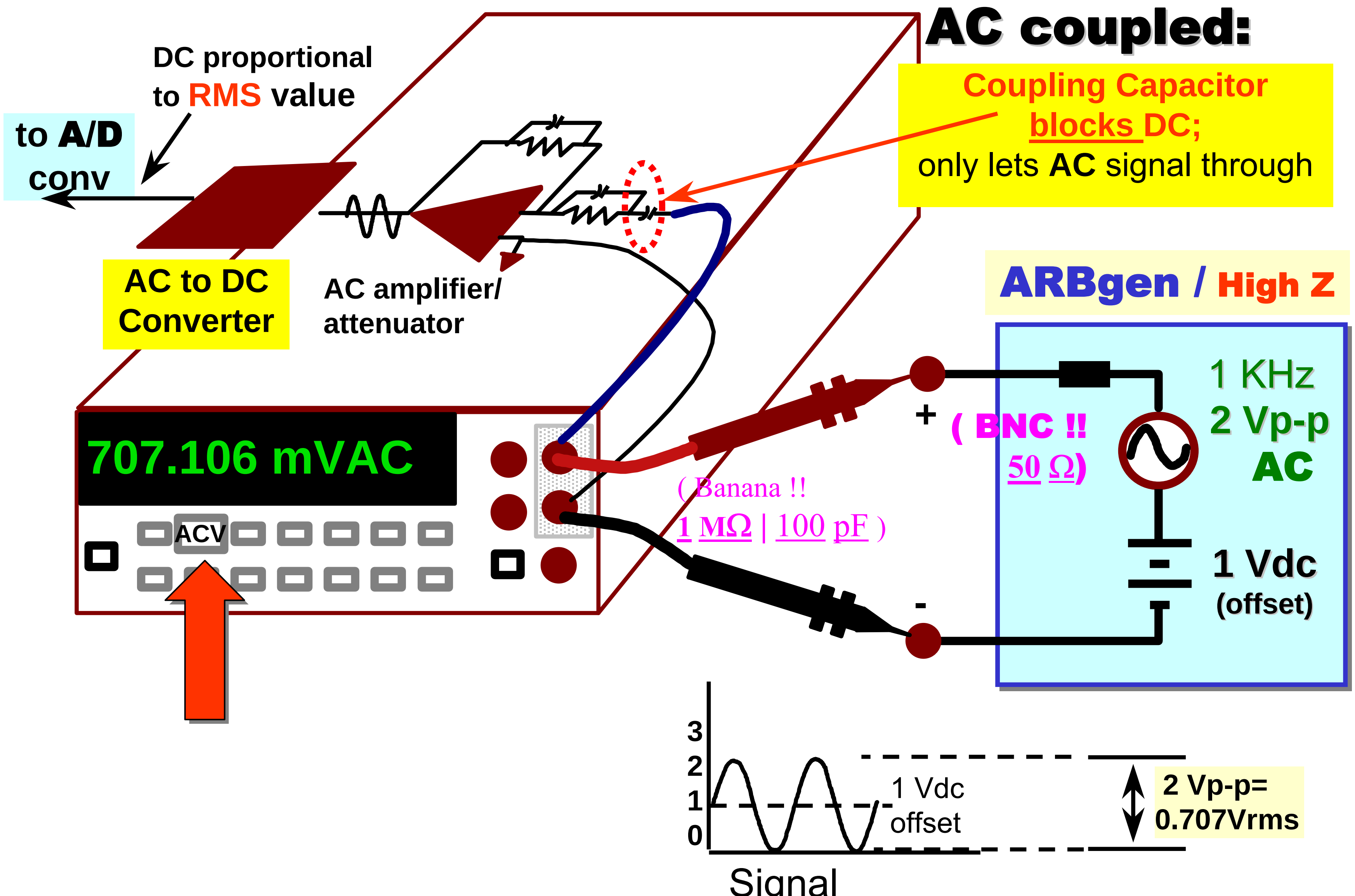
0.02 PLC and 0.2 PLC: Do not provide power-line noise rejection

* These settings configure the multimeter just as if you had pressed the corresponding "DIGITS" keys from the front panel.




Integration time is specified in *number of power line cycles* (NPLCs). The choices are 0.02, 0.2, 1, **10**, or 100 power line cycles. *The default is 10 PLCs.*

# ARBgen / DMM (2): Measuring ACV (true RMS, ac coupled)

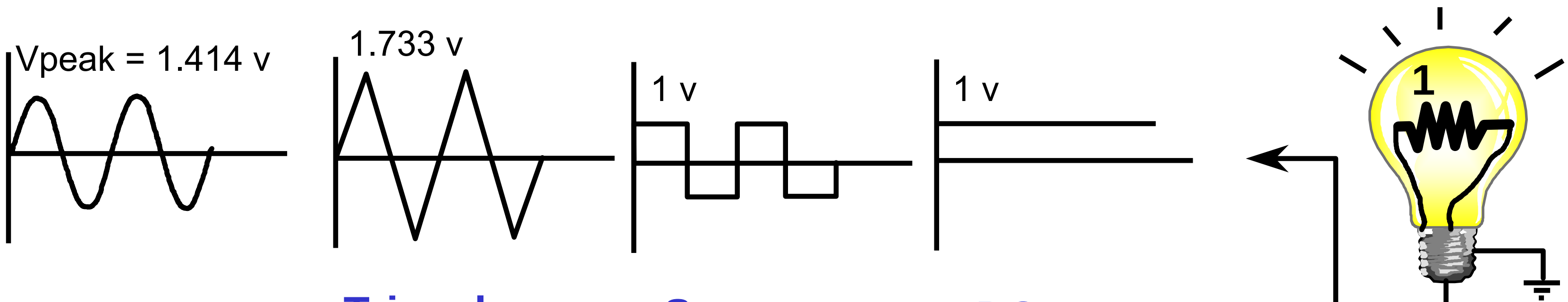


# DMM - AC V (true RMS: Root-Mean-Square, ac coupled)

* RMS is a measure of a signal's average power $$V_{rms} = \sqrt{\frac{1}{T}\int_0^T V^2(t)dt} = \sqrt{AVG(v^2)}$$

- **An AC Voltage with a given RMS value has the same heating (power) effect as a DC Voltage (with that same value)**

- All the following voltage waveforms (wfm's) have the *same* RMS value: 1.000 VAC on an RMS meter




| Sine | Triangle | Square | DC | wfm |
|---|---|---|---|---|
| 1.414 | 1.733 | 1 | 1 | Vpeak |
| 1 | 1 | 1 | 1 | Vrms |

All = 1 WATT

# Mérőhely kikapcsolás

1. **Műszer(ek)** – *KI* kapcs.
2. **Számítógép** (Win2K) – ***Shut Down …***

   … és **megvárjuk (!)** , amíg az
   *aut.* kikapcsolás lefut
3. Mérőhely **táp-elosztó** – *KI*

… és rendet rakunk (kábelek, stb.)

A **mérőkártyák adapterei NE** **maradjanak a konnektorban a mérés után (ne melegedjen a trafó)** **(!)**

*"I hear…I forget; I see…I remember; I do…I understand."* – Confucius, c. 500 BC

# In theory, there is no difference between theory and practice.

# But, in practice, there is.

*Jan L. A. van de Snepscheut*

Here is a mnemonic for the *decimal expansion* of π.
Each successive digit is the number of letters in the corresponding word.

***How I want a drink, alcoholic(?) of course, after the heavy lectures …***

***π = 3.14159265358 …***