

Ukladanie údajov – USB, pamäťové karty

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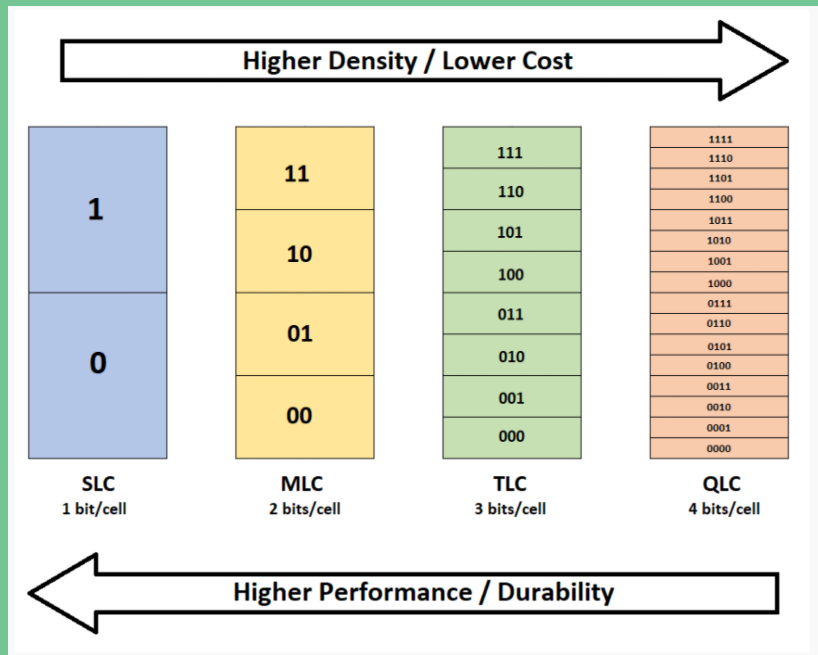
2. ročník, 2025/2026

Pamäť FLASH

- Energeticky nezávislá polovodičová pamäť (non-volatile, uchováva údaje aj po odpojení napájania)
- Výrazne rýchlejšie mazanie údajov ako predchodca (EEPROM) — preto názov FLASH
- Počiatky — 80. roky 20. storočia, Toshiba
- Hlavné architektúry:
 - **NOR** — pamäťové bunky zapojené paralelne, rýchle náhodné čítanie, najmä firmware, BIOS
 - **NAND** — pamäťové bunky zapojené sériovo, rýchlejší sekvenčný zápis, nižšie náklady

NAND FLASH

- Operácie: čítanie, programovanie (zápis), vymazanie
- 2D NAND (planárna) vs. 3D NAND
- Podľa počtu bitov v pamäťovej bunke: SLC, MLC, TLC, QLC, PLC
- Obmedzený počet P/E cyklov (program/erase)



Obr. 1: Vzťah medzi počtom bitov v pamäťovej bunke a cenou, výkonom a výdržou.

<https://www.thessdreview.com/ssd-guides/learning-to-run-with-flash-2-0/understanding-slc-mlc-tlc-and-qlc-nand-flash-learning-to-run-with-flash-2-0/>



Obr. 2: Vzťah medzi počtom bitov v pamäťovej bunke a výdržou (počtom P/E cyklov).

<https://www.kingston.com/en/blog/pc-performance/difference-between-slc-mlc-tlc-3d-nand>

Radič (Memory Controller)

- Integrovaný riadiaci čip, ktorý organizuje a spravuje dáta. Obsahuje firmware.
- Zabezpečuje správne ukladanie a čítanie dát medzi PC a NAND flash pamäťou.
- Funkcie:
 - **Error correction (ECC):** opravuje bitové chyby v pamäti.
 - **Wear leveling:** vyrovnáva opotrebenie buniek.
 - **Flash Translation Layer (FTL):** spravuje mapovanie logických blokov na fyzické bloky.
 - **Garbage collection:** uvoľňuje efektívne miesto pre nové dáta.
 - **Health monitoring:** sleduje stav pamäte a životnosť.

USB — Universal Serial Bus

- Štandard pre výmenu dát a napájanie medzi elektronickými zariadeniami (<https://www.usb.org/>)
- Predtým: paralelné, sériové, game, PS/2, SCSI a rôzne proprietárne porty
- Verzie: USB 1.0 – USB4
- Konektory: USB-Type A, USB-Type B, USB-Type C
- Plug and play

ÜCMFPV

Standard	Also Known As	Logo	Year Introduced	Connector Types	Max. Data Transfer Speed	Cable Length**
USB 1.1	Full Speed USB		1998	USB-A USB-B	12 Mbps	3 m
USB 2.0	Hi-Speed USB		2000	USB-A USB-B USB Micro A USB Micro B USB Mini A USB Mini B USB-C*	480 Mbps	5 m
USB 3.2 Gen 1	USB 3.0 USB 3.1 Gen 1 SuperSpeed		2008 (USB 3.0) 2013 (USB 3.1)	USB-A USB-B USB Micro B USB-C*	5 Gbps	3 m
USB 3.2 Gen 2	USB 3.1 USB 3.1 Gen 2 SuperSpeed+ SuperSpeed 10Gbps		2013 (USB 3.1)	USB-A USB-B USB Micro B USB-C*	10 Gbps	3 m
USB 3.2 Gen 2x2	USB 3.2 SuperSpeed 20Gbps		2017 (USB 3.2)	USB-C*	20 Gbps	3 m
USB 4	USB4 Gen 2x2 USB4 20Gbps		2019	USB-C*	20 Gbps	0.8 m
USB 4	USB4 Gen 3x2 USB4 40Gbps		2019	USB-C*	40 Gbps	0.8 m

* USB-C is more accurately known as Type C or USB Type C

** Cable length is the length covered by the specification. Longer lengths can be achieved using active cables and in some cases, longer passive cables

Obr. 3: Prehľad USB štandardov.

<https://tripplite.eaton.com/products/usb-connectivity-types-standards>

USB kľúče

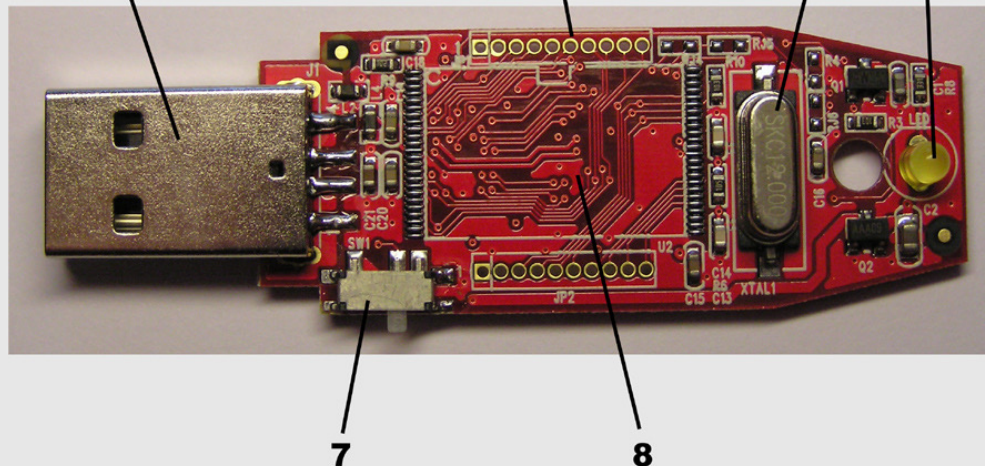
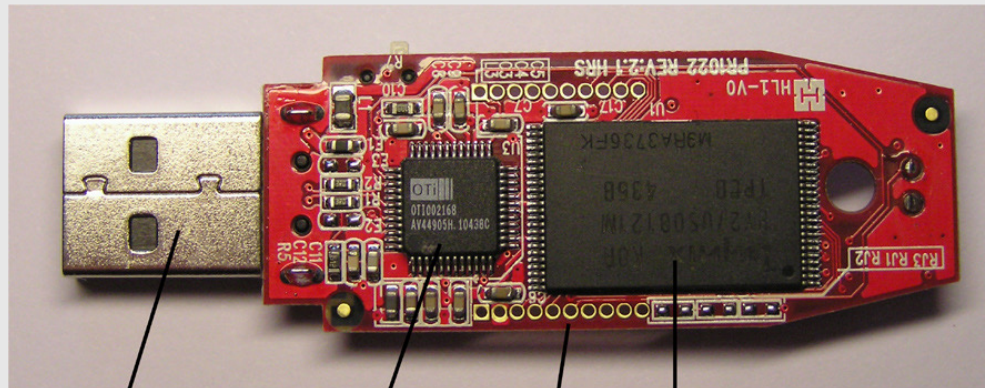
- Prenosné dátové úložisko, využívajúce flash pamäť typu NAND a zbernicu USB
- Malé rozmery, odolnosť, rýchlosť čítania a zápisu, nízka spotreba energie
- Prvý USB kľúč: 1999, DiskOnKey, M-Systems a IBM, 8 MB
- Súčasné kapacity: 16 GB – 2 TB
- Neexistujú výkonnostné triedy
- Jednotlivé modely môžu mať výrazne odlišný výkon — jednotky až stovky MB/s
- Konektory: A, micro B, C
- OTG: umožňuje priame pripojenie USB zariadenia (USB kľúč, klávesnica...) k mobilnému telefónu či tabletu.



Obr. 4: Prvý USB kľúč.

lanturo (<https://commons.wikimedia.org/wiki/File:USB-IBM-DiskonKey.jpg>), <https://creativecommons.org/licenses/by-sa/4.0/legalcode>

USB klúče



1. USB konektor
2. Radič
3. Testovacie kontakty
4. Flash pamäť
5. Oscilátor
6. LED
7. Zámok
8. Miesto pre druhý pamäťový modul

Obr. 5: Komponenty USB klúča.

anonymous (https://commons.wikimedia.org/wiki/File:Usbkey_internals.jpg), „Usbkey internals“, <https://creativecommons.org/licenses/by-sa/3.0/legalcode>

Pamäťové karty SD

SD Association: <https://www.sdcard.org>

SD (Secure Digital)

- 1999 — SanDisk, Panasonic, Toshiba → SD Card Association
- 128 MB – 2 GB
- FAT 12, FAT 16
- Rozmery: 24,0 × 32,0 × 2,1 mm

SDXC (Secure Digital Extended Capacity)

- 2009
- 64 GB – 2 TB
- exFAT

SDUC (Secure Digital Ultra Capacity)

- 2018
- do 128 TB
- exFAT

SDHC (Secure Digital High Capacity)

- 2006
- 4 GB – 32 GB
- FAT 32

SD Express

- 2023
- PCIe/NVMe
- Spätná kompatibilita s UHS-I
- Nový štandard, vysoké rýchlosti (do 985 MB/s (SD 7), do 3940 MB/s (SD 8))



Obr. 6: Pamäťová karta typu SD.
<https://www.sandisk.com>

Pamäťové karty SD

microSD / microSDHC / microSDXC / microSDUC / microSD Express

- 2005, SanDisk
- Najmenšia veľkosť pamäťovej karty aktuálne na trhu (11,0 × 15,0 × 1,0 mm)



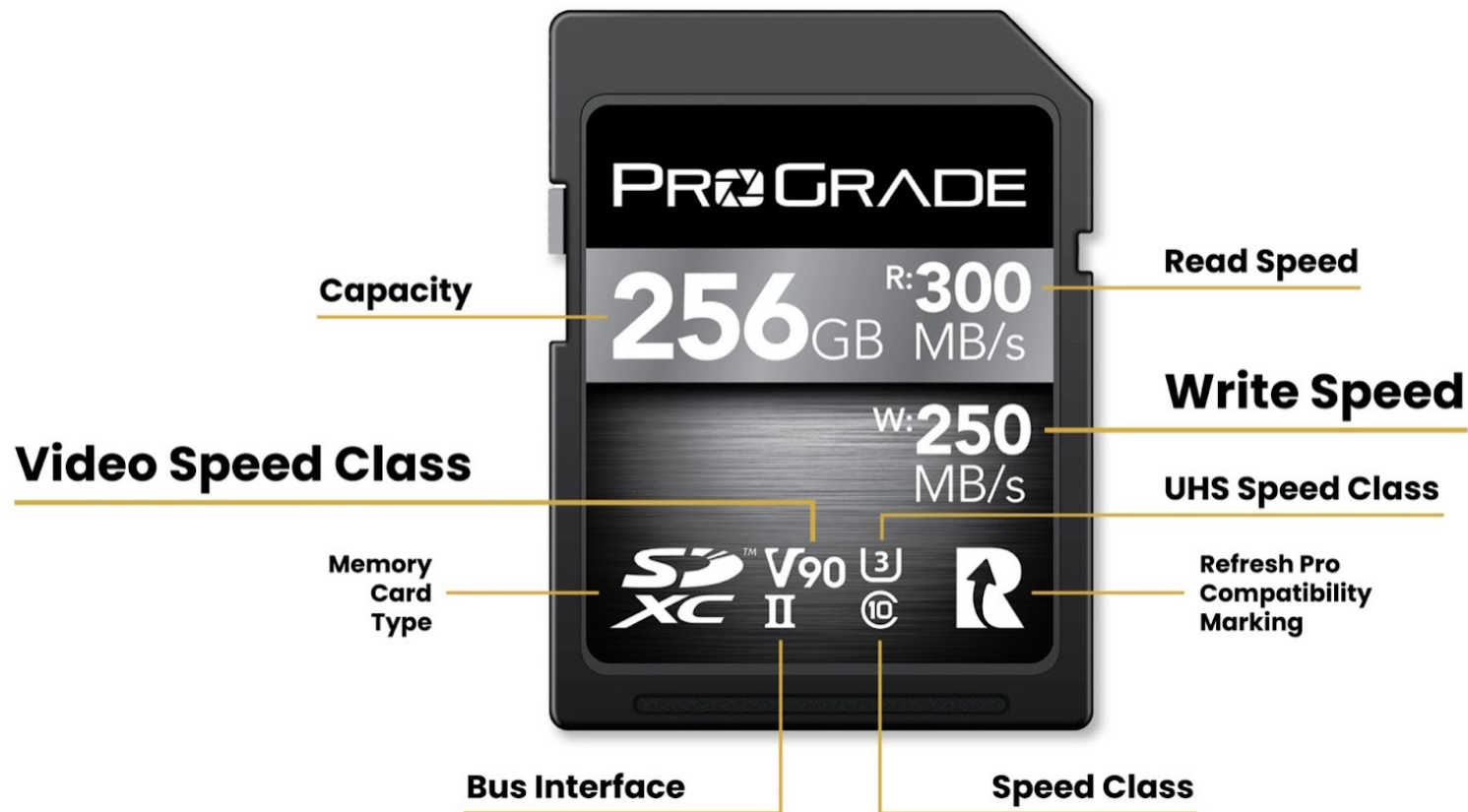
Obr. 7: Pamäťová karta typu microSD.
<https://www.sandisk.com>

Pamäťové karty SD – značenie

- **Zbernice:** High Speed, UHS-I, UHS-II, UHS-III, EX
- **Rýchlostná trieda:** C2, C4, C6, C10
- **UHS rýchlostná trieda:** U1, U3
- **Video rýchlostná trieda:** V6, V10, V30, V60, V90
- **Aplikačná trieda:**
 - A1 — R: 1500 IOPS, W: 500 IOPS, trvalý sekvenčný zápis: 10 MB/s
 - A2 — R: 4000 IOPS, W: 2000 IOPS, trvalý sekvenčný zápis: 10 MB/s

Minimum Sequential Write Speed	Speed Class			Corresponding Video Format
	Speed Class	UHS Speed Class	Video Speed Class	
Card Image				The necessary speed varies by each recording/playback device condition. in the same format.
90MB/sec			V90	8K Video 4K Video HD/Full HD Video Standard Video
60MB/sec			V60	
30MB/sec		U3	V30	
10MB/sec	10	U1	V10	
6MB/sec	6		V6	
4MB/sec	4			
2MB/sec	2			

Pamäťové karty SD – značenie

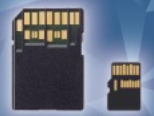
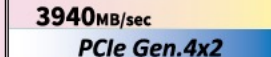
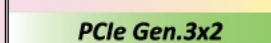
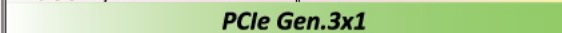
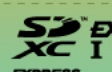


Obr. 9: Vysvetlenie značenia SD kariet.
<https://progradedigital.com/symbols-on-sd-cards-explained/>



Obr. 10: Ukážka microSD express karty s uvedením APC.
<https://www.sandisk.com>

Pamäťové karty SD – zhrnutie

	SD Memory Card				SD Express Memory Card	
Pin Layout						
PCIe Bus Interface					 3940MB/sec PCIe Gen.4x2	
					 1970MB/sec PCIe Gen.3x2	
					 985MB/sec PCIe Gen.4x1	 985MB/sec PCIe Gen.3x1
SD Bus Interface	25MB/sec	104MB/sec	312MB/sec	624MB/sec		
		UHS-I	UHS-II			
			UHS-III			
	High Speed		High Speed		High Speed	
Capacity (file system)						
Ultra Capacity Up to 128TB (exFAT)						
Extended Capacity Up to 2TB (exFAT)						
High Capacity Up to 32GB (FAT32)						

Obr. 11: Kompletný prehľad technológií SD kariet.

<https://www.sdcard.org/consumers/about-sd-memory-card-choices/bus-interface-speed-standards-for-large-size-data-transfer/>

Pamäťové karty CF

CompactFlash Association: <https://compactflash.org>

CFexpress

- 2017
- PCIe + NVMe
- CFexpress 1.0, CFexpress 2.0, CFexpress 4.0
- Až 8 GB/s
- Type A, Type B, Type C
- Pravdepodobne budúcnosť pre nasledujúce generácie fotoaparátov a kamier



Obr. 12: Porovnanie CFexpress kariet typu A a typu B.

<https://progradedigital.com/cfexpress-memory-card-guide-understanding-symbols-types-and-performance-metrics/>

Type A: 20 × 28 × 2.8 mm, **Type B:** 29.8 × 38.5 × 3.8 mm, **Type C:** 54 × 74 × 4.8 mm

Pamäťové karty CF

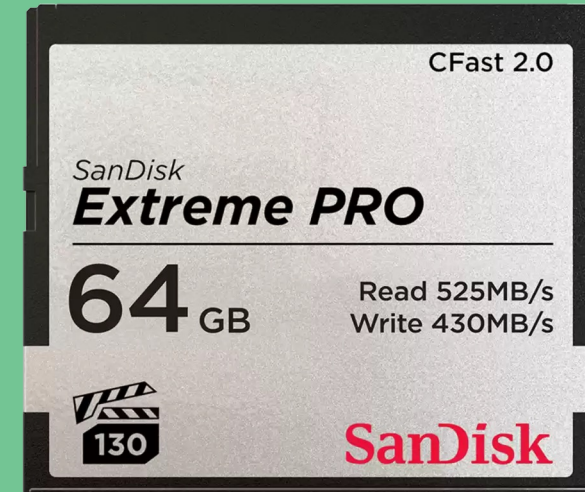
- **CompactFlash Type I (CF-I)**
 - 1995, prvá pamäťová karta s pamäťou typu flash
- **CompactFlash Type II (CF-II)**
- **CFast, CFast 2.0**
- **XQD**



Obr. 13: Pamäťová karta CompactFlash.
<https://www.sandisk.com>

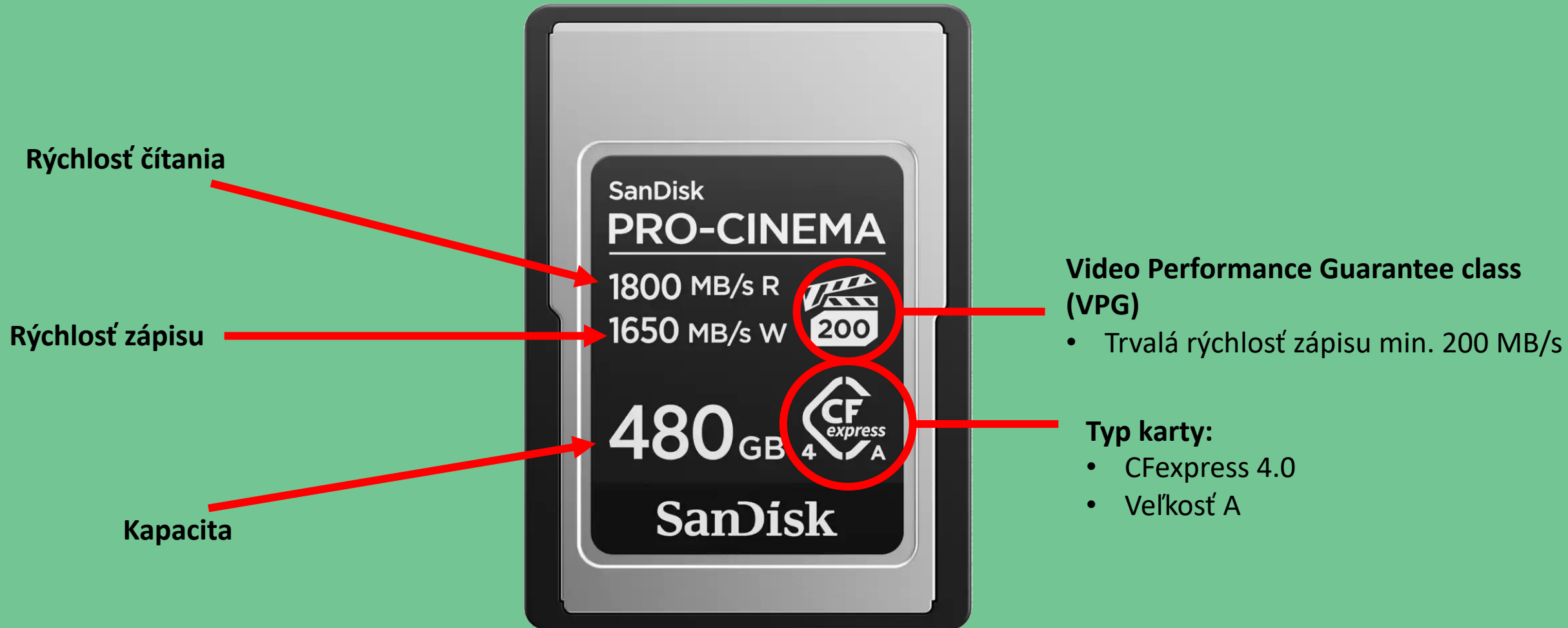


Obr. 15: Pamäťová karta XQD.
<https://www.nikon.sk>



Obr. 14: Pamäťová karta CFast 2.0.
<https://www.sandisk.com>

Pamäťové karty CFexpress – značenie



Obr. 16: Vysvetlenie značenia CFexpress kariet.
<https://www.sandisk.com>

Pamäťové karty CF – zhrnutie

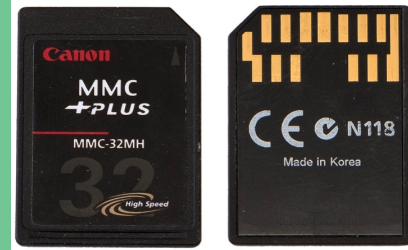
CFA STANDARD	VERSION	YEAR ANNOUNCED	INTERFACE	MAX. THEORETICAL THROUGHPUT	LOGO
CFexpress	v4.0	2023	PCIe Gen4	Type A = 2 GB/s Type B = 4 GB/s Type C = 8 GB/s	
	v2.0	2019	PCIe Gen3	Type A = 1 GB/s Type B = 2 GB/s Type C = 4 GB/s	
	v1.0	2017	PCIe Gen3	Type B = 2 GB/s	
XQD	v1.0	2011	PCIe Gen2	500 MB/s	
CFast	v2.0	2012	SATA 3.0	600 MB/s	
	v1.0	2009	SATA 2.0	300 MB/s	
CompactFlash	v6.0	2010	PATA UDMA Mode 7 (UDMA 167)	167 MB/s	
	v5.0	2010	PATA UDMA Mode 6 (UDMA 133)	133 MB/s	
	v4.0	2006	PATA UDMA Mode 6 (UDMA 133)	133 MB/s	
	v3.0	2004	PATA UDMA Mode 4 (UDMA 66)	66 MB/s	
	v2.0	2003	PIO Mode 4	16.7 MB/s	
	v1.0	1995	PIO Mode 2	8.3 MB/s	

Obr. 17: Prehľad technológií CF kariet.
<https://compactflash.org/card-types/>

Pamäťové karty – ostatné (zastarané)

MultiMediaCard (MMC)

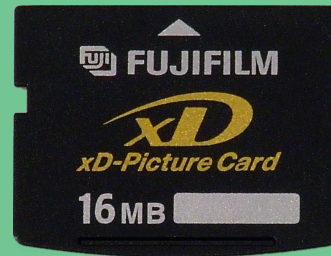
- 1997
- SanDisk, Siemens, Nokia
- Predchodca SD
- 32 × 24 × 1,4 mm



Obr. 18: Pamäťová karta MMC.
<https://en.wikipedia.org/wiki/File:15-04-29-MMC-Karte-RalfR-dscf4734-d.jpg>

xD-Picture Card

- 2002 – 2009
- Olympus + Fujifilm
- 20 × 25 × 1.78 mm
- Do 2 GB



Obr. 19: Pamäťová karta xD-Picture.
https://en.wikipedia.org/wiki/File:XD_card_16M_Fujifilm_front.png

Memory Stick

- Sony
- Mnoho verzií/formátov:
 - Memory Stick / Memory Stick PRO
 - Memory Stick Duo / PRO Duo / PRO-HG Duo
 - Memory Stick Micro (M2)
 - Memory Stick XC



Obr. 20: Rôzne pamäťové karty Memory Stick.
https://en.wikipedia.org/wiki/File:MSst_duo_m2.jpg

Nástroje

f3 — Fight Flash Fraud

- Testovanie, kapacity a výkonu
- Open source alternatíva k **H2testw** (<https://h2testw.org>), ktorý je len pre Windows
- <https://fight-flash-fraud.readthedocs.io/en/latest/index.html>

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