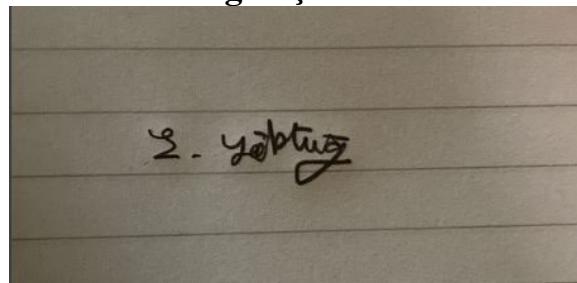


October 24, 2025

**EE 4065 – Embedded Digital Image Processing  
Homework 1**

**Due: November 7, 2025. 23:59 pm**

**Sertan Göktuğ Başarıcı – 150722841**



**Orçun Sargin - 150722824**



- Form a GitHub repository for the course with your course partner. Do not share it with your friends.
- You will post your homework documents (report, codes, results) via this repository for grading.

Q1-) (40 points) Use the available code in the repository below (with appropriate modifications) for this question.

[https://www.dropbox.com/scl/fi/16yvqgqonjd89ucfgntrs/Embedded-System-Design-with-Arm-Cortex-M-Microcontrollers-supplementary\\_material\\_zipped.rar?rlkey=flp9fefjly9jshi4ll8uyp3mz&dl=0](https://www.dropbox.com/scl/fi/16yvqgqonjd89ucfgntrs/Embedded-System-Design-with-Arm-Cortex-M-Microcontrollers-supplementary_material_zipped.rar?rlkey=flp9fefjly9jshi4ll8uyp3mz&dl=0)

- a- Form a grayscale image of your choice with appropriate size on PC. Store it as a header file. Then, add this header file to your new project and display some of the image entries in the memory of your microcontroller.

Q2-) (60 points) Apply the intensity transformations below to your image.

- a- Negative image.
- b- Thresholding the image
- c- Gamma correction with gamma being 3 and 1/3.
- d- Piecewise linear transformations for the part in b.

Check and your results by observing memory locations via the memory window under STM32CubeIDE.

## Q1(a) – Image Data Observation on MCU

A grayscale image of size  $64 \times 64$  was converted into a header file and added to the STM32 project. The image data was loaded into the microcontroller's RAM by copying the array from Flash memory. Using STM32CubeIDE's Debug mode and the Memory Window, the image entries were successfully observed at the address `&in_img[0][0]`, confirming that the grayscale pixel values (0–255) were correctly stored in the MCU memory.

Address	0 - 3	4 - 7	8 - B	C - F
20014090	851365113	3339744534	1045904983	3564759784
200140A0	1425051782	605307945	4151711425	1734308729
200140B0	1839766804	2489485738	2128125061	1160649472
200140C0	3806317798	1091112527	4095299034	3808118697
200140D0	2769863419	2480972167	4226260351	1842446941
200140E0	3485078631	2783330917	2983927247	2252339206
200140F0	3719982101	1272097545	348474045	3279294528
20014100	1004773743	3549444989	2558513060	1122285299
20014110	3137947831	3813679818	536779693	2219201251
20014120	3270972473	2788625154	788128423	1526611523
20014130	4121957049	1433914056	2791508552	2735321362
20014140	990339771	51979363	4186332158	977522003
20014150	2163117614	393043969	4291504055	2685470579
20014160	1006377773	3586451510	18087163	3465328147
20014170	4149804735	4068086252	2771550301	1248126387
20014180	3450109895	1804747505	1712171682	738496544
20014190	2810952143	84551839	1820968559	2149462114
200141A0	783179250	3775496290	2003155076	2961319457
200141B0	3542358423	1797967735	3812134073	684066571
200141C0	3123391932	1980201167	2644499498	3876594806
200141D0	2934437948	656923965	385185262	2887844791
200141E0	1501133784	1378673212	2782146437	160316359
200141F0	1127631929	2855357033	3511694937	42795970

Address	0 - 3	4 - 7	8 - B	C - F
200141F0	1127631929	2855357033	3511694937	42795970
20014200	2476456302	135234782	4287994513	3331379326
20014210	3354634687	227687010	1387053020	2755649776
20014220	1459343189	3596858690	1362613684	3679084872
20014230	1575019018	1297704026	3311611511	3124902726
20014240	1060995710	850924941	2125315719	3434959019
20014250	699986815	1074769332	428791509	941695267
20014260	4260097723	2203960912	4150062013	850079728
20014270	2570642285	2572556910	3377361351	195249857
20014280	2042166141	2085327385	3793403117	3334996490
20014290	3069205369	1020134113	1977439169	1534594827
200142A0	3177427154	3198265924	289665475	1920506064
200142B0	4146005474	2493820996	1701064540	41668240
200142C0	4269271623	789312790	3921542602	2295763340
200142D0	2890504921	2160134177	417150473	584061800
200142E0	343314558	2421689869	2847555525	1184974762
200142F0	3630870399	1423993131	647206802	3093265403
20014300	3609855679	3477216611	3579557022	3100279373
20014310	2452524332	277770978	3155412533	1677802913
20014320	3699372507	911855516	3888561212	111654273
20014330	2195099899	1869017844	2809634548	412291492
20014340	1537897849	806268404	2664709627	538953738
20014350	1281870634	1750563451	3718572027	1530957495

- 1. `sat8(int v)` – Saturation helper

This function keeps a value within the valid grayscale range (0–255).

If the result of a calculation is below 0, it returns 0; if above 255, it returns 255.  
It prevents overflow or underflow in image operations.

## 2. img\_negative() – Negative transformation

Each pixel value is inverted using the formula  $y = 255 - x$ .

Dark pixels become bright and bright pixels become dark, creating a photographic negative effect.

## 3. img\_threshold() – Thresholding

For each pixel, if the intensity is greater than a chosen threshold T, it is set to 255 (white); otherwise, it is set to 0 (black).

This converts a grayscale image into a binary black–white image.

## 4. img\_gamma() – Gamma correction

This applies a nonlinear intensity adjustment defined by  $y = 255 * (x / 255)^\gamma$ .

When  $\gamma > 1 \rightarrow$  the image becomes darker.

When  $\gamma < 1 \rightarrow$  the image becomes brighter.

A lookup table (LUT) is used to make the operation faster.

## 5. img\_piecewise() – Piecewise linear transformation

The image is modified using two different linear slopes around a threshold value T:

For  $x \leq T$ :  $y = a1 * x$

For  $x > T$ :  $y = a2 * (x - T) + a1 * T$

This method enhances contrast by compressing dark regions and stretching bright regions, while keeping continuity at T.

## A) Negative

Address	0 - 3	4 - 7	8 - B	C - F
2001DFE0	3205523962	1727662166	2491464673	3316261400
2001DFF0	176790838	2511344461	1308074737	1211794819
2001E000	1867482873	1582737698	2136140056	1906522788
2001E010	2564261093	488436870	3419914878	221567197
2001E020	3093406323	75892529	3078312560	278922572
2001E030	2628221343	201752973	3938137915	1821655059
2001E040	430953034	2253520916	1565482798	1077919841
2001E050	3005631507	1048717202	1204401693	16781319
2001E060	3436912158	2190405324	1631023742	416180532
2001E070	520039413	2151679024	3615573623	1768425561
2001E080	3177382615	342109572	4069074411	153982484
2001E090	2109561641	1443007040	2075455359	2888961448
2001E0A0	2348525985	25283492	1894424990	134765586
2001E0B0	1324176273	2023751794	2830918765	337398473
2001E0C0	1677476010	1217215492	1869685973	1612940298
2001E0D0	1471784355	100681240	1608496572	2520064246
2001E0E0	3723882227	2378269954	989615774	1057806345
2001E0F0	3452665222	2466283881	423612299	8916835
2001E100	2811734755	70192930	2941435281	1631887910
2001E110	1586289917	674361984	101252583	1097324088
2001E120	3560429747	12799299	1954485414	79318368
2001E130	3950649814	539596190	1267654608	1442843087
2001E140	512158617	2729758514	1006517025	3517362535
2001E150	262977819	568883108	465002923	1305512976

2001E150	262977819	568883108	465002923	1305512976
2001E160	3954992349	100277243	1458302679	224668461
2001E170	3266462201	539267193	2964802152	3831378533
2001E180	3949254491	3767479850	928676710	138547505
2001E190	3942554282	213180964	521834179	873221196
2001E1A0	3890136171	3311274624	1018996123	960514155
2001E1B0	2264557140	1675763302	1475879409	854985433
2001E1C0	1245207113	186009742	3447419313	2845712254
2001E1D0	4093357997	1505634895	2289985150	1250284710
2001E1E0	2682877813	266668172	3606831144	627327944
2001E1F0	3547111380	1557469616	4062821225	2222206561
2001E200	3997629017	2353661385	1585297376	482566965
2001E210	3996892885	791538689	4210593388	3119124177
2001E220	2412362627	2028282953	3083781760	1396624274
2001E230	3791338653	1045568915	3902736721	1243333729
2001E240	3738940156	3476333313	3838353678	2324300598
2001E250	2214346751	706756131	1100693281	679488458
2001E260	7064766661	126792879 0x2001E254	1071968736	3376963848
2001E270	3199976873	1605852011	1323356938	1502388976
2001E280	3086840395	1282572316	2475210635	184637141
2001E290	1340546965	1499784215	2104092134	73184939
2001E2A0	3957231828	1125476974	4193434331	3260726051
2001E2B0	3455954328	170398027	1821400559	4227924242
2001E2C0	3418483261	2090605754	3162441630	1630813729

## B) Threshold

Address	0 - 3	4 - 7	8 - B	C - F
2001CFE0	2646817190	2844041399	2137631913	2971746818
2001CFF0	3959350294	156437481	2481582437	1291356376
2001D000	1158647157	10850972	578385177	808749290
2001D010	2666780901	2156703553	356455254	1843424739
2001D020	2583582872	2284230607	493223739	1301243282
2001D030	3944815350	1912936821	1031063481	1148365969
2001D040	254478582	3641369104	1177942394	407245512
2001D050	3697222330	1087658724	3132798940	3371342917
2001D060	1083634622	219414582	3840857349	3930338274
2001D070	2015853031	606176879	1313892729	3500169392
2001D080	3731696634	571050098	3365985995	2220893209
2001D090	496875561	399300363	1694250249	2366904418
2001D0A0	2394161151	76777159	4242548434	4036952597
2001D0B0	2088666201	216105288	3669127694	170979455
2001D0C0	3846123657	3114862797	4024254302	451711153
2001D0D0	3938504082	1504203508	2075056825	420485699
2001D0E0	608137547	1745001632	3959322605	2221719561
2001D0F0	825143046	473334050	3080019081	113845329
2001D100	3889372064	1881878537	3753857020	395742692
2001D110	2788646748	2175461025	1967084088	3160192081
2001D120	1221514473	1699504756	989753251	3141764489
2001D130	4270939360	946077954	3634640603	219035456
2001D140	1607153659	626817	3654883072	2182380037
2001D150	3751303897	717269027	2120408253	2974319169

Address	0 - 3	4 - 7	8 - B	C - F
2001D150	3751303897	717269027	2120408253	2974319169
2001D160	3464955873	1624574796	3761194295	2755222996
2001D170	3705699551	1099157171	3553310723	708858097
2001D180	4240412650	170951330	3468266448	567431364
2001D190	2510697415	558069591	3694378655	1467617284
2001D1A0	4260427754	2928458837	3761886431	2307226226
2001D1B0	3391776687	1884714184	2134888387	2204867681
2001D1C0	4192055547	84984265	930045950	2995147676
2001D1D0	3740259983	3712876832	3461754793	3036528758
2001D1E0	2598973361	751453745	1630709563	2500496611
2001D1F0	2522496226	1713700902	1600910233	2202220586
2001D200	1584653463	1019349362	4159429899	2868920499
2001D210	3757780991	1825317456	4189974186	3893832724
2001D220	4258987762	80065291	1936269594	136270728
2001D230	4021204650	3290699577	1247329411	2450528818
2001D240	3157828849	296935473	244953643	151729317
2001D250	3429526459	625624464	1704961674	2840611394
2001D260	2262664932	4021420334	3288069326	683448574
2001D270	950784578	1429274898	2038037974	1225133058
2001D280	3836066675	3326754847	1756544445	2169035520
2001D290	3214007895	604811698	2739862251	862543984
2001D2A0	4001362483	3886875256	2884692438	1485062336
2001D2B0	2912615677	688001346	2999082524	2459474000
2001D2C0	3755942890	1088592954	3469890734	268975266

## C) Gamma Correction With Gamma = 3

Address	0 - 3	4 - 7	8 - B	C - F
2001BFEO	1967838925	78731851	4007062445	3463010322
2001BFF0	3954125960	3476104235	3343990763	915950657
2001C000	2130296614	94408452	3925391730	1794953733
2001C010	2078536539	312227537	4025441144	2908967685
2001C020	3754781800	1695137109	3963277247	363405739
2001C030	2107596823	1098908937	2615601812	3305291737
2001C040	1284882233	12948781	242871637	2427793633
2001C050	4055738189	2736143297	2949704317	1418856684
2001C060	2684058987	210998316	3110924335	1545071469
2001C070	2114823606	3491369785	1560204164	1216377897
2001C080	517902333	562725892	313725820	3693617300
2001C090	1733767070	2832960290	434915297	495005878
2001C0A0	4104748187	2848459125	380393023	2581037375
2001C0B0	3055516440	3771437204	1558688147	3876068947
2001C0C0	2935927530	2455011410	789926839	2406522241
2001C0D0	2532945527	1680485418	1061778922	503345235
2001C0E0	3992233465	1544476688	3716128345	1433718022
2001C0F0	4288317685	3326120789	401150641	2641490076
2001C100	2914332389	105393	1762833510	186664482
2001C110	1944498648	778423464	3661626666	3933286510
2001C120	3554780626	1091630656	1422783703	23232553
2001C130	1237571389	2232623043	94321599	2448739401
2001C140	1030523881	9022937	2078960834	2983275267
2001C150	3420358547	2993966712	3982761002	1623493236

Address	0 - 3	4 - 7	8 - B	C - F
2001C150	3420358547	2993966712	3982761002	1623493236
2001C160	2515248519	4062559671	3387847093	865177387
2001C170	4271604525	1177290030	1579640695	1753320488
2001C180	4164907946	2716422663	671022983	2418161635
2001C190	3135338207	2363762432	4056055717	4247005184
2001C1A0	2952784947	864594569	3366869441	1348251706
2001C1B0	1793757843	1556808480	784556944	1643156430
2001C1C0	4141590201	2166907476	1169383121	149833248
2001C1D0	3579257019	1076856235	1125084576	3428911714
2001C1E0	3110500690	2987657096	2672690029	2650622248
2001C1F0	787277701	37 <sub>10</sub> x2001C1E4	2351109850	1718748896
2001C200	2666052593	102302155	1397614914	3380884098
2001C210	1440447643	3020924512	3651818350	71956496
2001C220	2646266251	755188585	2075280267	2074772427
2001C230	2055153077	3726741514	229354422	1723577905
2001C240	3030723316	3255309225	3779743310	710498320
2001C250	2005856630	19285001	3067738233	1091878608
2001C260	3759062779	1962051681	373274618	78193150
2001C270	3123424054	1779958356	2420316325	3224254000
2001C280	1740913653	1665176896	1174233931	2550861428
2001C290	4226677309	188874756	657886718	53230855
2001C2A0	3800670186	1165317610	2138016271	2289638041
2001C2B0	2671448845	1483608876	2632141608	1617446472
2001C2C0	2594674742	2888922480	3291733850	827426290

## D) Gamma Correction With Gamma = 1/3

2001A <sup>F</sup> E0	2762739747	4202430979	2932923778	2764006572
2001A <sup>F</sup> F0	2990766276	338989702	4007256941	3467921940
2001B <sup>F</sup> 00	2284139310	3696678376	307941877	1187020813
2001B <sup>F</sup> 010	261391174	3592463555	3572645439	1140990164
2001B <sup>F</sup> 020	1722804457	3667662018	1335399644	75227876
2001B <sup>F</sup> 030	2678488359	2295752781	637317225	3849104993
2001B <sup>F</sup> 040	2102408380	737347244	3685668429	1758111751
2001B <sup>F</sup> 050	4243959892	3590365842	2641323255	2896745579
2001B <sup>F</sup> 060	1299860496	2931331214	299687850	1183643671
2001B <sup>F</sup> 070	2391896853	3839398464	1337130568	2225873801
2001B <sup>F</sup> 080	3948894267	2883961429	2243356733	1814554771
2001B <sup>F</sup> 090	4168597169	3212241626	2866236752	1559243957
2001B <sup>F</sup> A00	347910487	351305980	3419020543	1790451844
2001B <sup>F</sup> B00	4102963734	3117473952	1768776431	1948723882
2001B <sup>F</sup> C00	2223789965	1591095414	1471220793	1518405703
2001B <sup>F</sup> D00	3560697327	46574510	349351155	1028113939
2001B <sup>F</sup> E00	1538186879	3136665578	436624741	2765444372
2001B <sup>F</sup> F00	3071148622	1774004459	2787124630	1756628530
2001B <sup>F</sup> 100	1494519550	2728235245	4197240376	3426073289
2001B <sup>F</sup> 110	1345257615	1994491658	2077396000	878116979
2001B <sup>F</sup> 120	667435985	3645821145	4010586261	2161801933
2001B <sup>F</sup> 130	3571319296	1118591680	2415606993	948844176
2001B <sup>F</sup> 140	3781076404	3625532584	3681188051	576826377
2001B <sup>F</sup> 150	425284056	1444714373	408891702	3590982721

2001AFE0	2762739747	4202430979	2932923778	2764006572
2001AFF0	2990766276	338989702	4007256941	3467921940
2001B000	2284139310	3696678376	307941877	1187020813
2001B010	261391174	3592463555	3572645439	1140990164
2001B020	1722804457	3667662018	1335399644	75227876
2001B030	2678488359	2295752781	637317225	3849104993
2001B040	2102408380	737347244	3685668429	1758111751
2001B050	4243959892	3590365842	2641323255	2896745579
2001B060	1299860496	2931331214	299687850	1183643671
2001B070	2391896853	3839398464	1337130568	2225873801
2001B080	3948894267	2883961429	2243356733	1814554771
2001B090	4168597169	3212241626	2866236752	1559243957
2001B0A0	347910487	351305980	3419020543	1790451844
2001B0B0	4102963734	3117473952	1768776431	1948723882
2001B0C0	2223789965	1591095414	1471220793	1518405703
2001B0D0	3560697327	46574510	349351155	1028113939
2001B0E0	1538186879	3136665578	436624741	2765444372
2001B0F0	3071148622	1774004459	2787124630	1756628530
2001B100	1494519550	2728235245	4197240376	3426073289
2001B110	1345257615	1994491658	2077396000	878116979
2001B120	667435985	3645821145	4010586261	2161801933
2001B130	3571319296	1118591680	2415606993	948844176
2001B140	3781076404	3625532584	3681188051	576826377
2001B150	425284056	1444714373	408891702	3590982721

## E) Piecewise Linear Transformations for the Part in B.

2001A100	456155091	2848623642	392583649	505686230
2001A110	2532110093	1128295333	3080167420	1662437140
2001A120	2973353594	931253526	2978848705	728940780
2001A130	571859655	2597589199	184861907	1099450262
2001A140	1604090847	3021551182	3293036798	2484839783
2001A150	3186634715	3639390902	3948666648	605031899
2001A160	1335683321	1722520974	2139139663	962384205
2001A170	3396549279	1287789802	1531012467	1680160217
2001A180	2112644846	2367523212	934747441	984061145
2001A190	4160154588	1336707882	1797592469	615190842
2001A1A0	3381901786	2717671145	1800203858	570773780
2001A1B0	873761364	450211887	14238319	327620163
2001A1C0	3926280957	2518273796	4122582916	1899335736
2001A1D0	4124397275	1671221018	1275386482	2478276932
2001A1E0	3135173694	4098293642	2807715985	2306584590
2001A1F0	3999812456	1456555150	559020132	3805610310
2001A200	4154418547	109964384	972438503	1685100736
2001A210	2649867924	160627807	4184292429	3290039448
2001A220	486121689	1776997431	2706819008	2316476685
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