



ΜΑΘΗΜΑ

ΕΡΓΑΣΤΗΡΙΟ ΜΙΚΡΟΪΠΟΛΟΓΙΣΤΩΝ (ΡΟΗ Υ)

ΕΡΓΑΣΙΑ

1^Η ΕΡΓΑΣΤΗΡΙΑΚΗ ΑΣΚΗΣΗ

ΣΠΟΥΔΑΣΤΕΣ

ΚΑΡΑΜ ΚΩΝΣΤΑΝΤΙΝΟΣ

ΚΟΛΙΟΣ ΑΠΟΣΤΟΛΟΣ

2022-23

Ζήτημα 1.1 (Lab1_1.asm)

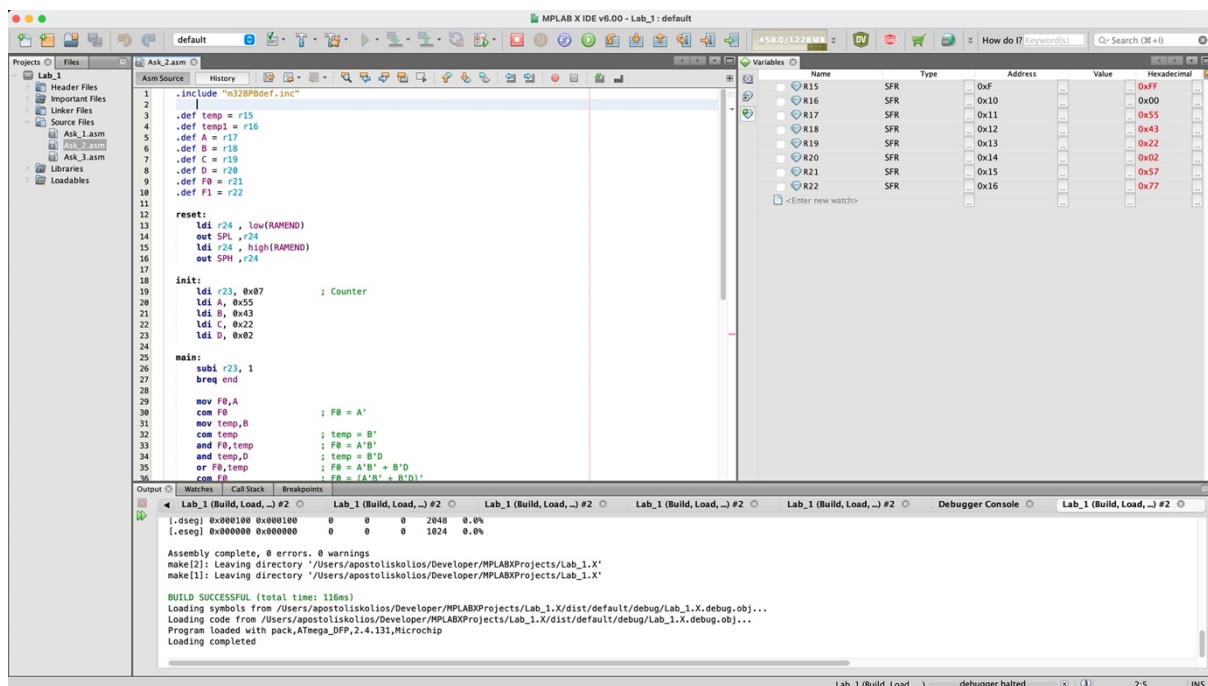
Ο κώδικας μαζί με αναλυτικά σχόλια και ένα στιγμιότυπο εκτέλεσης για 2000 msec φαίνονται παρακάτω:

The screenshot shows the MPLAB X IDE v6.00 interface. The main window displays the assembly code for Lab1_1.asm. The code includes a reset routine to initialize the stack pointer and a main routine that calls a 2000 msec delay function. The delay function is implemented using a loop that calls a wait_usec function 125 times. The wait_usec function is implemented using a loop that calls a wait_n_usec function 8 times. The wait_n_usec function is implemented using a loop that calls a wait_1_usec function n times. The wait_1_usec function is implemented using a loop that calls a wait_1_2_usec function 1 or 2 times. The wait_1_2_usec function is implemented using a loop that calls a wait_1_4_usec function 1 or 4 times. The wait_1_4_usec function is implemented using a loop that calls a wait_1_8_usec function 1 or 8 times. The wait_1_8_usec function is implemented using a loop that calls a wait_1_16_usec function 1 or 16 times. The wait_1_16_usec function is implemented using a loop that calls a wait_1_32_usec function 1 or 32 times. The wait_1_32_usec function is implemented using a loop that calls a wait_1_64_usec function 1 or 64 times. The wait_1_64_usec function is implemented using a loop that calls a wait_1_128_usec function 1 or 128 times. The wait_1_128_usec function is implemented using a loop that calls a wait_1_256_usec function 1 or 256 times. The wait_1_256_usec function is implemented using a loop that calls a wait_1_512_usec function 1 or 512 times. The wait_1_512_usec function is implemented using a loop that calls a wait_1_1024_usec function 1 or 1024 times. The wait_1_1024_usec function is implemented using a loop that calls a wait_1_2048_usec function 1 or 2048 times. The wait_1_2048_usec function is implemented using a loop that calls a wait_1_4096_usec function 1 or 4096 times. The wait_1_4096_usec function is implemented using a loop that calls a wait_1_8192_usec function 1 or 8192 times. The wait_1_8192_usec function is implemented using a loop that calls a wait_1_16384_usec function 1 or 16384 times. The wait_1_16384_usec function is implemented using a loop that calls a wait_1_32768_usec function 1 or 32768 times. The wait_1_32768_usec function is implemented using a loop that calls a wait_1_65536_usec function 1 or 65536 times. The wait_1_65536_usec function is implemented using a loop that calls a wait_1_131072_usec function 1 or 131072 times. The wait_1_131072_usec function is implemented using a loop that calls a wait_1_262144_usec function 1 or 262144 times. The wait_1_262144_usec function is implemented using a loop that calls a wait_1_524288_usec function 1 or 524288 times. The wait_1_524288_usec function is implemented using a loop that calls a wait_1_1048576_usec function 1 or 1048576 times. The wait_1_1048576_usec function is implemented using a loop that calls a wait_1_2097152_usec function 1 or 2097152 times. The wait_1_2097152_usec function is implemented using a loop that calls a wait_1_4194304_usec function 1 or 4194304 times. The wait_1_4194304_usec function is implemented using a loop that calls a wait_1_8388608_usec function 1 or 8388608 times. The wait_1_8388608_usec function is implemented using a loop that calls a wait_1_16777216_usec function 1 or 16777216 times. The wait_1_16777216_usec function is implemented using a loop that calls a wait_1_33554432_usec function 1 or 33554432 times. The wait_1_33554432_usec function is implemented using a loop that calls a wait_1_67108864_usec function 1 or 67108864 times. The wait_1_67108864_usec function is implemented using a loop that calls a wait_1_134217728_usec function 1 or 134217728 times. The wait_1_134217728_usec function is implemented using a loop that calls a wait_1_268435456_usec function 1 or 268435456 times. The wait_1_268435456_usec function is implemented using a loop that calls a wait_1_536870912_usec function 1 or 536870912 times. The wait_1_536870912_usec function is implemented using a loop that calls a wait_1_1073741824_usec function 1 or 1073741824 times. The wait_1_1073741824_usec function is implemented using a loop that calls a wait_1_2147483648_usec function 1 or 2147483648 times. The wait_1_2147483648_usec function is implemented using a loop that calls a wait_1_4294967296_usec function 1 or 4294967296 times. The wait_1_4294967296_usec function is implemented using a loop that calls a wait_1_8589934592_usec function 1 or 8589934592 times. The wait_1_8589934592_usec function is implemented using a loop that calls a wait_1_17179869184_usec function 1 or 17179869184 times. The wait_1_17179869184_usec function is implemented using a loop that calls a wait_1_34359738368_usec function 1 or 34359738368 times. The wait_1_34359738368_usec function is implemented using a loop that calls a wait_1_68719476736_usec function 1 or 68719476736 times. The wait_1_68719476736_usec function is implemented using a loop that calls a wait_1_137438953472_usec function 1 or 137438953472 times. The wait_1_137438953472_usec function is implemented using a loop that calls a wait_1_274877906944_usec function 1 or 274877906944 times. The wait_1_274877906944_usec function is implemented using a loop that calls a wait_1_549755813888_usec function 1 or 549755813888 times. The wait_1_549755813888_usec function is implemented using a loop that calls a wait_1_1099511627776_usec function 1 or 1099511627776 times. The wait_1_1099511627776_usec function is implemented using a loop that calls a wait_1_2199023255552_usec function 1 or 2199023255552 times. The wait_1_2199023255552_usec function is implemented using a loop that calls a wait_1_4398046511104_usec function 1 or 4398046511104 times. The wait_1_4398046511104_usec function is implemented using a loop that calls a wait_1_8796093022208_usec function 1 or 8796093022208 times. The wait_1_8796093022208_usec function is implemented using a loop that calls a wait_1_17592186044416_usec function 1 or 17592186044416 times. The wait_1_17592186044416_usec function is implemented using a loop that calls a wait_1_35184372088832_usec function 1 or 35184372088832 times. The wait_1_35184372088832_usec function is implemented using a loop that calls a wait_1_70368744177664_usec function 1 or 70368744177664 times. The wait_1_70368744177664_usec function is implemented using a loop that calls a wait_1_140737488355328_usec function 1 or 140737488355328 times. The wait_1_140737488355328_usec function is implemented using a loop that calls a wait_1_281474976710656_usec function 1 or 281474976710656 times. The wait_1_281474976710656_usec function is implemented using a loop that calls a wait_1_562949953421312_usec function 1 or 562949953421312 times. The wait_1_562949953421312_usec function is implemented using a loop that calls a wait_1_1125899906842624_usec function 1 or 1125899906842624 times. The wait_1_1125899906842624_usec function is implemented using a loop that calls a wait_1_2251799813685248_usec function 1 or 2251799813685248 times. The wait_1_2251799813685248_usec function is implemented using a loop that calls a wait_1_4503599627370496_usec function 1 or 4503599627370496 times. The wait_1_4503599627370496_usec function is implemented using a loop that calls a wait_1_9007199254740992_usec function 1 or 9007199254740992 times. The wait_1_9007199254740992_usec function is implemented using a loop that calls a wait_1_18014398509481984_usec function 1 or 18014398509481984 times. The wait_1_18014398509481984_usec function is implemented using a loop that calls a wait_1_36028797018963968_usec function 1 or 36028797018963968 times. The wait_1_36028797018963968_usec function is implemented using a loop that calls a wait_1_72057594037927936_usec function 1 or 72057594037927936 times. The wait_1_72057594037927936_usec function is implemented using a loop that calls a wait_1_144115188075855872_usec function 1 or 144115188075855872 times. The wait_1_144115188075855872_usec function is implemented using a loop that calls a wait_1_288230376151711744_usec function 1 or 288230376151711744 times. The wait_1_288230376151711744_usec function is implemented using a loop that calls a wait_1_576460752303423488_usec function 1 or 576460752303423488 times. The wait_1_576460752303423488_usec function is implemented using a loop that calls a wait_1_1152921504606846976_usec function 1 or 1152921504606846976 times. The wait_1_1152921504606846976_usec function is implemented using a loop that calls a wait_1_2305843009213693952_usec function 1 or 2305843009213693952 times. The wait_1_2305843009213693952_usec function is implemented using a loop that calls a wait_1_4611686018427387904_usec function 1 or 4611686018427387904 times. The wait_1_4611686018427387904_usec function is implemented using a loop that calls a wait_1_9223372036854775808_usec function 1 or 9223372036854775808 times. The wait_1_9223372036854775808_usec function is implemented using a loop that calls a wait_1_18446744073709551616_usec function 1 or 18446744073709551616 times. The wait_1_18446744073709551616_usec function is implemented using a loop that calls a wait_1_36893488147419103232_usec function 1 or 36893488147419103232 times. The wait_1_36893488147419103232_usec function is implemented using a loop that calls a wait_1_73786976294838206464_usec function 1 or 73786976294838206464 times. The wait_1_73786976294838206464_usec function is implemented using a loop that calls a wait_1_147573952589676412928_usec function 1 or 147573952589676412928 times. The wait_1_147573952589676412928_usec function is implemented using a loop that calls a wait_1_295147905179352825856_usec function 1 or 295147905179352825856 times. The wait_1_295147905179352825856_usec function is implemented using a loop that calls a wait_1_590295810358705651712_usec function 1 or 590295810358705651712 times. The wait_1_590295810358705651712_usec function is implemented using a loop that calls a wait_1_1180591620717411303424_usec function 1 or 1180591620717411303424 times. The wait_1_1180591620717411303424_usec function is implemented using a loop that calls a wait_1_2361183241434822606848_usec function 1 or 2361183241434822606848 times. The wait_1_2361183241434822606848_usec function is implemented using a loop that calls a wait_1_4722366482869645213696_usec function 1 or 4722366482869645213696 times. The wait_1_4722366482869645213696_usec function is implemented using a loop that calls a wait_1_9444732965739290427392_usec function 1 or 9444732965739290427392 times. The wait_1_9444732965739290427392_usec function is implemented using a loop that calls a wait_1_18889465931478580854784_usec function 1 or 18889465931478580854784 times. The wait_1_18889465931478580854784_usec function is implemented using a loop that calls a wait_1_37778931862957161709568_usec function 1 or 37778931862957161709568 times. The wait_1_37778931862957161709568_usec function is implemented using a loop that calls a wait_1_75557863725914323419136_usec function 1 or 75557863725914323419136 times. The wait_1_75557863725914323419136_usec function is implemented using a loop that calls a wait_1_151115727451828646838272_usec function 1 or 151115727451828646838272 times. The wait_1_151115727451828646838272_usec function is implemented using a loop that calls a wait_1_302231454903657293676544_usec function 1 or 302231454903657293676544 times. The wait_1_302231454903657293676544_usec function is implemented using a loop that calls a wait_1_604462909807314587353088_usec function 1 or 604462909807314587353088 times. The wait_1_604462909807314587353088_usec function is implemented using a loop that calls a wait_1_1208925819614629174706176_usec function 1 or 1208925819614629174706176 times. The wait_1_1208925819614629174706176_usec function is implemented using a loop that calls a wait_1_2417851639229258349412352_usec function 1 or 2417851639229258349412352 times. The wait_1_2417851639229258349412352_usec function is implemented using a loop that calls a wait_1_4835703278458516698824704_usec function 1 or 4835703278458516698824704 times. The wait_1_4835703278458516698824704_usec function is implemented using a loop that calls a wait_1_9671406556917033397649408_usec function 1 or 9671406556917033397649408 times. The wait_1_9671406556917033397649408_usec function is implemented using a loop that calls a wait_1_19342813113834066795298816_usec function 1 or 19342813113834066795298816 times. The wait_1_19342813113834066795298816_usec function is implemented using a loop that calls a wait_1_38685626227668133590597632_usec function 1 or 38685626227668133590597632 times. The wait_1_38685626227668133590597632_usec function is implemented using a loop that calls a wait_1_77371252455336267181195264_usec function 1 or 77371252455336267181195264 times. The wait_1_77371252455336267181195264_usec function is implemented using a loop that calls a wait_1_154742504910672534362390528_usec function 1 or 154742504910672534362390528 times. The wait_1_154742504910672534362390528_usec function is implemented using a loop that calls a wait_1_309485009821345068724781056_usec function 1 or 309485009821345068724781056 times. The wait_1_309485009821345068724781056_usec function is implemented using a loop that calls a wait_1_618970019642690137449562112_usec function 1 or 618970019642690137449562112 times. The wait_1_618970019642690137449562112_usec function is implemented using a loop that calls a wait_1_1237940039285380274899124224_usec function 1 or 1237940039285380274899124224 times. The wait_1_1237940039285380274899124224_usec function is implemented using a loop that calls a wait_1_2475880078570760549798248448_usec function 1 or 2475880078570760549798248448 times. The wait_1_2475880078570760549798248448_usec function is implemented using a loop that calls a wait_1_4951760157141521099596496896_usec function 1 or 4951760157141521099596496896 times. The wait_1_4951760157141521099596496896_usec function is implemented using a loop that calls a wait_1_9903520314283042199192993792_usec function 1 or 9903520314283042199192993792 times. The wait_1_9903520314283042199192993792_usec function is implemented using a loop that calls a wait_1_19807040628566084398385987584_usec function 1 or 19807040628566084398385987584 times. The wait_1_19807040628566084398385987584_usec function is implemented using a loop that calls a wait_1_39614081257132168796771975168_usec function 1 or 39614081257132168796771975168 times. The wait_1_39614081257132168796771975168_usec function is implemented using a loop that calls a wait_1_79228162514264337593543950336_usec function 1 or 79228162514264337593543950336 times. The wait_1_79228162514264337593543950336_usec function is implemented using a loop that calls a wait_1_158456325028528675187087900672_usec function 1 or 158456325028528675187087900672 times. The wait_1_158456325028528675187087900672_usec function is implemented using a loop that calls a wait_1_316912650057057350374175801344_usec function 1 or 316912650057057350374175801344 times. The wait_1_316912650057057350374175801344_usec function is implemented using a loop that calls a wait_1_633825300114114700748351602688_usec function 1 or 633825300114114700748351602688 times. The wait_1_633825300114114700748351602688_usec function is implemented using a loop that calls a wait_1_1267650600228229401496703205376_usec function 1 or 1267650600228229401496703205376 times. The wait_1_1267650600228229401496703205376_usec function is implemented using a loop that calls a wait_1_2535301200456458802993406410752_usec function 1 or 2535301200456458802993406410752 times. The wait_1_2535301200456458802993406410752_usec function is implemented using a loop that calls a wait_1_5070602400912917605986812821504_usec function 1 or 5070602400912917605986812821504 times. The wait_1_5070602400912917605986812821504_usec function is implemented using a loop that calls a wait_1_10141204801825835211973625643008_usec function 1 or 10141204801825835211973625643008 times. The wait_1_10141204801825835211973625643008_usec function is implemented using a loop that calls a wait_1_20282409603651670423947251286016_usec function 1 or 20282409603651670423947251286016 times. The wait_1_20282409603651670423947251286016_usec function is implemented using a loop that calls a wait_1_40564819207303340847894502572032_usec function 1 or 40564819207303340847894502572032 times. The wait_1_40564819207303340847894502572032_usec function is implemented using a loop that calls a wait_1_81129638414606681695789005144064_usec function 1 or 81129638414606681695789005144064 times. The wait_1_81129638414606681695789005144064_usec function is implemented using a loop that calls a wait_1_162259276829213363391578010288128_usec function 1 or 162259276829213363391578010288128 times. The wait_1_162259276829213363391578010288128_usec function is implemented using a loop that calls a wait_1_324518553658426726783156020576256_usec function 1 or 324518553658426726783156020576256 times. The wait_1_324518553658426726783156020576256_usec function is implemented using a loop that calls a wait_1_649037107316853453566312041152512_usec function 1 or 649037107316853453566312041152512 times. The wait_1_649037107316853453566312041152512_usec function is implemented using a loop that calls a wait_1_1298074214633706907132624082305024_usec function 1 or 1298074214633706907132624082305024 times. The wait_1_1298074214633706907132624082305024_usec function is implemented using a loop that calls a wait_1_2596148429267413814265248164610048_usec function 1 or 2596148429267413814265248164610048 times. The wait_1_2596148429267413814265248164610048_usec function is implemented using a loop that calls a wait_1_5192296858534827628530496329220096_usec function 1 or 5192296858534827628530496329220096 times. The wait_1_5192296858534827628530496329220096_usec function is implemented using a loop that calls a wait_1_10384593717069655257060992658440192_usec function 1 or 10384593717069655257060992658440192 times. The wait_1_10384593717069655257060992658440192_usec function is implemented using a loop that calls a wait_1_20769187434139310514121985316880384_usec function 1 or 20769187434139310514121985316880384 times. The wait_1_20769187434139310514121985316880384_usec function is implemented using a loop that calls a wait_1_41538374868278621028243970633760768_usec function 1 or 41538374868278621028243970633760768 times. The wait_1_41538374868278621028243970633760768_usec function is implemented using a loop that calls a wait_1_83076749736557242056487941267521536_usec function 1 or 83076749736557242056487941267521536 times. The wait_1_83076749736557242056487941267521536_usec function is implemented using a loop that calls a wait_1_166153499473114484112975882535043072_usec function 1 or 166153499473114484112975882535043072 times. The wait_1_166153499473114484112975882535043072_usec function is implemented using a loop that calls a wait_1_332306998946228968225951765070086144_usec function 1 or 332306998946228968225951765070086144 times. The wait_1_332306998946228968225951765070086144_usec function is implemented using a loop that calls a wait_1_664613997892457936451903530140172288_usec function 1 or 664613997892457936451903530140172288 times. The wait_1_664613997892457936451903530140172288_usec function is implemented using a loop that calls a wait_1_1329227995784915872903807060280344576_usec function 1 or 1329227995784915872903807060280344576 times. The wait_1_1329227995784915872903807060280344576_usec function is implemented using a loop that calls a wait_1_2658455991569831745807614120560689152_usec function 1 or 2658455991569831745807614120560689152 times. The wait_1_2658455991569831745807614120560689152_usec function is implemented using a loop that calls a wait_1_5316911983139663491615228241121378304_usec function 1 or 5316911983139663491615228241121378304 times. The wait_1_5316911983139663491615228241121378304_usec function is implemented using a loop that calls a wait_1_10633823966279326983230456482242756608_usec function 1 or 10633823966279326983230456482242756608 times. The wait_1_10633823966279326983230456482242756608_usec function is implemented using a loop that calls a wait_1_21267647932558653966460912964485513216_usec function 1 or 21267647932558653966460912964485513216 times. The wait_1_21267647932558653966460912964485513216_usec function is implemented using a loop that calls a wait_1_42535295865117307932921825928971026432_usec function 1 or 42535295865117307932921825928971026432 times. The wait_1_42535295865117307932921825928971026432_usec function is implemented using a loop that calls a wait_1_85070591730234615865843651857942052864_usec function 1 or 85070591730234615865843651857942052864 times. The wait_1_85070591730234615865843651857942052864_usec function is implemented using a loop that calls a wait_1_170141183460469231731687303715884105728_usec function 1 or 170141183460469231731687303715884105728 times. The wait_1_170141183460469231731687303715884105728_usec function is implemented using a loop that calls a wait_1_340282366920938463463374607431768211456_usec function 1 or 340282366920938463463374607431768211456 times. The wait_1_340282366920938463463374607431768211456_usec function is implemented using a loop that calls a wait_1_680564733841876926926749214863536422912_usec function 1 or 680564733841876926926749214863536422912 times. The wait_1_680564733841876926926749214863536422912_usec function is implemented using a loop that calls a wait_1_1361129467683753853853498429727072845824_usec function 1 or 1361129467683753853853498429727072845824 times. The wait_1_1361129467683753853853498429727072845824_usec function is implemented using a loop that calls a wait_1_2722258935367507707706996859454145691648_usec function 1 or 2722258935367507707706996859454145691648 times. The wait_1_2722258935367507707706996859454145691648_usec function is implemented using a loop that calls a wait_1_54445178707350154154139937

χρονοκαθυστέρηση της υπορουτίνας wait_usec, που με είσοδο 125 είναι 1003 μsec, καθυστερεί συνολικά 1020 μsec. Επομένως με 2000 κλήσεις καθυστερεί $1020 \cdot 2000 = 2040000$ μsec ή 2040 msec ή 2,04 sec.

Ζήτημα 1.2 (Lab1_2.asm)

Ένα στιγμιότυπο από την πρώτη επανάληψη της εκτέλεσης του προγράμματος φαίνεται παρακάτω:



Ο συμπληρωμένος πίνακας:

A	B	C	D	F0	F1
0x55	0x43	0x22	0x02	0x57	0x77
0x57	0x46	0x26	0x07	0x56	0x76
0x59	0x49	0x2A	0x0C	0x59	0x7B
0x5B	0x4C	0x2E	0x11	0x4E	0x6E
0x5D	0x4F	0x32	0x16	0x4F	0x6F
0x5F	0x52	0x36	0x1B	0x56	0x76

Ζήτημα 1.3 (Lab1_3.asm)

Το αρχείο κώδικα μαζί με αναλυτικά σχόλια που επεξηγούν την λειτουργία του βρίσκεται στο συμπίεσμένο αρχείο που υποβλήθηκε. Η ορθή λειτουργία του επιβεβαιώνεται από το Runtime Watch της PORTD. Παρόλα αυτά ένα στιγμιότυπο εκτέλεσης με breakpoints μετά από κάθε εντολή *out PORTD, r22* φαίνεται παρακάτω:

```
1 .include "m328pdef.inc"
2
3 .def cnt = r20
4 .def temp = r21
5
6 reset:
7     ldi r24, low(RAMEND) ; Initialize Stack Pointer
8     out SPL, r24
9     ldi r24, high(RAMEND)
10    out SPH, r24
11    clr r22 ; r22 <- LED register
12
13 main:
14     ser temp ; Set temp register
15     out DDRO, temp ; PORTD is output
16     ldi r22, 0x01 ; Initialize r22 (LED) to 0x01 (LSB)
17     ldi cnt, 7 ; Initialize counter to 7
18     set ; Initialize T flag to 1 (first time led moves towards left)
19
20 left_wait:
21     ldi r24, low(500)
22     ldi r25, high(500)
23     rcall wait_msec
24     ldi r22, 0x01
25     out PORTD, r22 ; Show on PORTD
26     ldi r25, low(1000) ; Extra 1 sec delay when reaches LSB
27     rcall wait_msec
28     dec cnt
29
30 left:
31     set ; T flag = 1
32     ldi r24, low(500) ; 0.5 sec delay
33     ldi r25, high(500)
34     rcall wait_msec
35     clr ; Reset C flag, because changed from wait function
36
```

Name	Type	Address	Value	Binary
SREG	SFR	0x5F	0x40	01000000
C	SREG<0>		0x00	0
Z	SREG<1>		0x00	0
N	SREG<2>		0x00	0
V	SREG<3>		0x00	0
S	SREG<4>		0x00	0
H	SREG<5>		0x00	0
T	SREG<6>		0x01	1
I	SREG<7>		0x00	0
PORTD	SFR	0x2B	0x02	00000010

Παρατηρούμε ότι ο χρόνος παραμονής στα άκρα είναι 1,5 δευτερόλεπτα και η κάθε κίνηση γίνεται κάθε 0,5 δευτερόλεπτα. Επιπλέον φαίνεται και ένα στιγμιότυπο του T flag που ισούται με 1 αφού το βαγονέτο κινείται προς τα αριστερά.