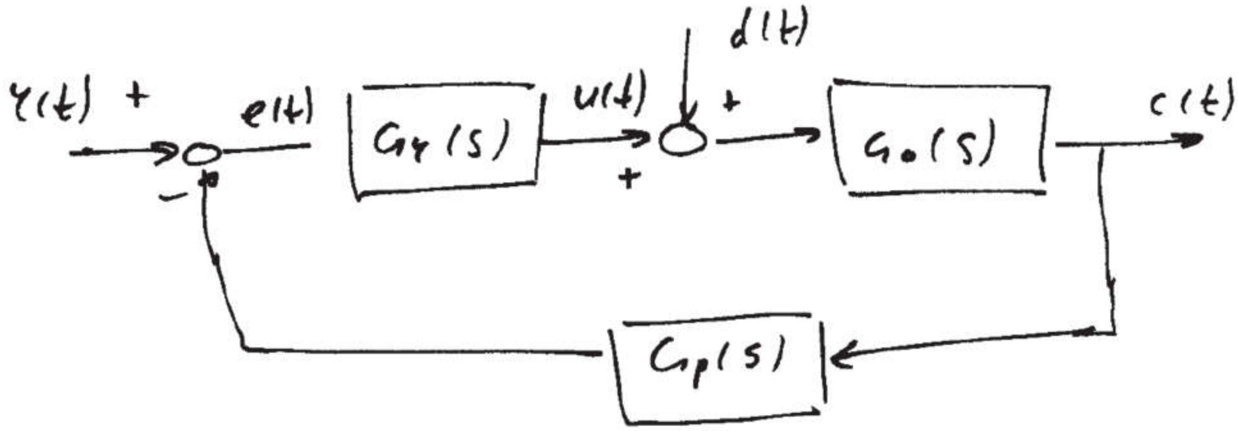
7. Algebra strukturnih blok dijagrama

7.1. Na slici je prikazan strukturni blok dijagram (SBD) klasičnog regulacionog sistema. Objasniti šta predstavlja svaki blok i naći karakteristične funkcije prenosa.



Rešenje:

$G_r(s)$ – regulator; $G_o(s)$ – objekat upravljanja; $G_p(s)$ – merno pretvarački element;

$R(s)$ – referentni signal; $C(s)$ – izlazni signal; $E(s)$ – signal greške;
$U(s)$ – upravljački signal; $D(s)$ – signal poremećaja;

$$C(s)=G_o(s)\left[U(s)+D(s)\right]\ ;\quad U(s)=G_r(s)E(s)\ ;\quad E(s)=R(s)-G_p(s)C(s)$$

$$C(s)=G_o(s)G_r(s)E(s)+G_o(s)D(s)=G_o(s)G_r(s)R(s)-G_o(s)G_r(s)G_p(s)C(s)+G_o(s)D(s)$$

$$C(s)\left[1+G_o(s)G_r(s)G_p(s)\right]=G_o(s)G_r(s)R(s)+G_o(s)D(s)$$

$$C(s)=\frac{G_o(s)G_r(s)}{1+G_o(s)G_r(s)G_p(s)}R(s)+\frac{G_o(s)}{1+G_o(s)G_r(s)G_p(s)}D(s)$$

$$C(s)=W_{sr}(s)R(s)+W_{sd}(s)D(s)\ ;\quad W_{sr}(s)=\frac{G_o(s)G_r(s)}{1+G_o(s)G_r(s)G_p(s)}\ ;\quad W_{sd}(s)=\frac{G_o(s)}{1+G_o(s)G_r(s)G_p(s)}$$

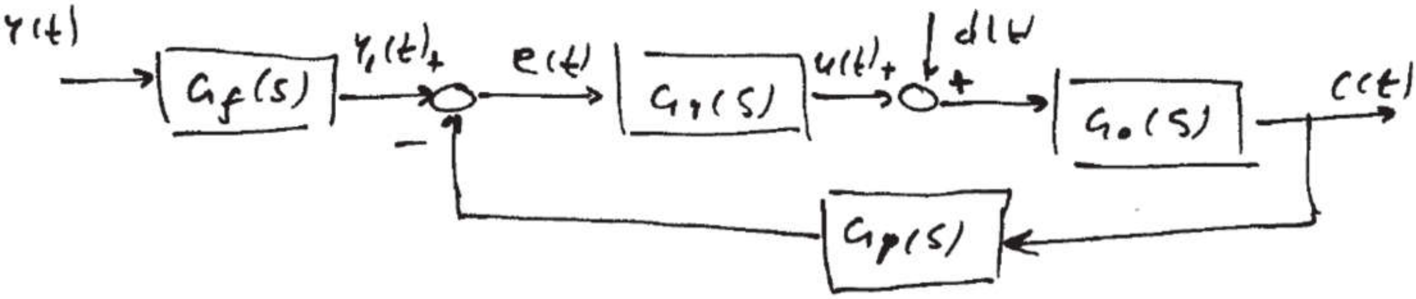
$$E(s)=R(s)-G_p(s)C(s)=R(s)-G_p(s)W_{sr}(s)R(s)-G_p(s)W_{sd}(s)D(s)$$

$$E(s)=\left[1-G_p(s)W_{sr}\right]R(s)-G_p(s)W_{sd}(s)D(s)$$

$$E(s)=\frac{1}{1+G_o(s)G_r(s)G_p(s)}R(s)-\frac{G_p(s)G_o(s)}{1+G_o(s)G_r(s)G_p(s)}D(s)$$

$$E(s)=E_R(s)+E_D(s)\ ;\quad E_R(s)=\frac{1}{1+G_o(s)G_r(s)G_p(s)}\ ;\quad E_D(s)=-\frac{G_p(s)G_o(s)}{1+G_o(s)G_r(s)G_p(s)}$$

7.2. Na slici je prikazan SBD klasičnog regulacionog sistema sa prefiltrom. Naći karakteristične funkcije prenosa.



Rešenje:

Prefilter $G_f(s)$ služi za tzv. meki start i koristi se u upravljanju elektromotornim pogonima. Npr. Pokretanje motora koji miruje ili naglo menjanje stanja.

Možemo iskoristiti jednačine iz prethodnog zadatka tako što ćemo zameniti $R(s)$ sa $R_1(s) = G_f(s)R(s)$.

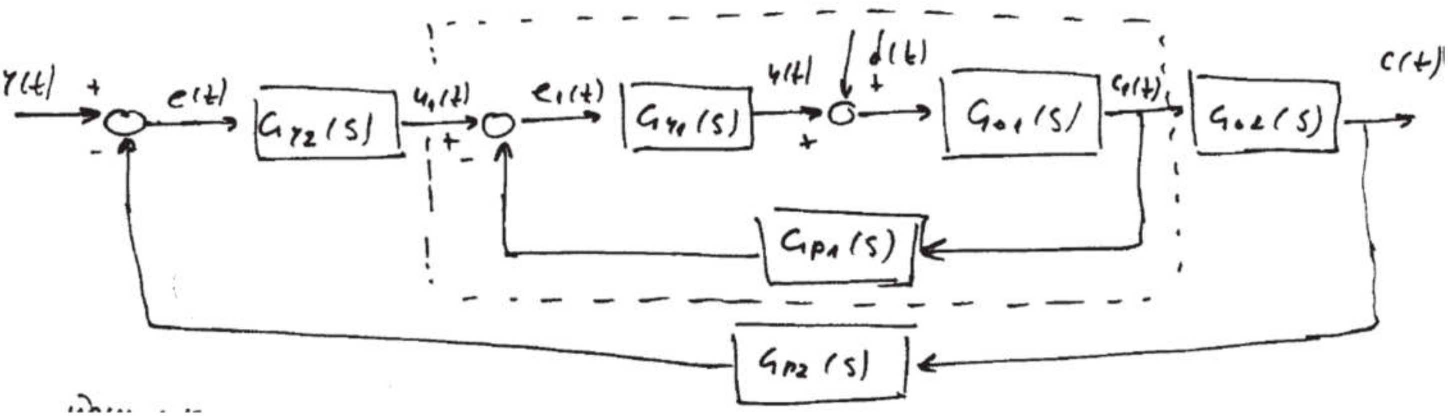
$$C(s) = W_{sr}(s)R_1(s) + W_{sd}(s)D(s) \; ; \quad R_1(s) = G_f(s)R(s)$$
$$C(s) = W_{sr}(s)G_f(s)R(s) + W_{sd}(s)D(s)$$

Prefilter ne utiče na uticaj poremećaja na sistem. Pre-filter takođe ne utiče ni na karakterističnu jednačinu.

$$E(s) = E_R(s)G_f(s) + E_D(s)$$

Prefiltrom usporavamo dinamiku sistema ali u isto vreme smanjujemo i preskok.

7.3. Na slici je prikazan SBD klasičnog regulacionog Sistema. Objasniti šta predstavlja svaki blok i odrediti karakteristične funkcije prenosa.

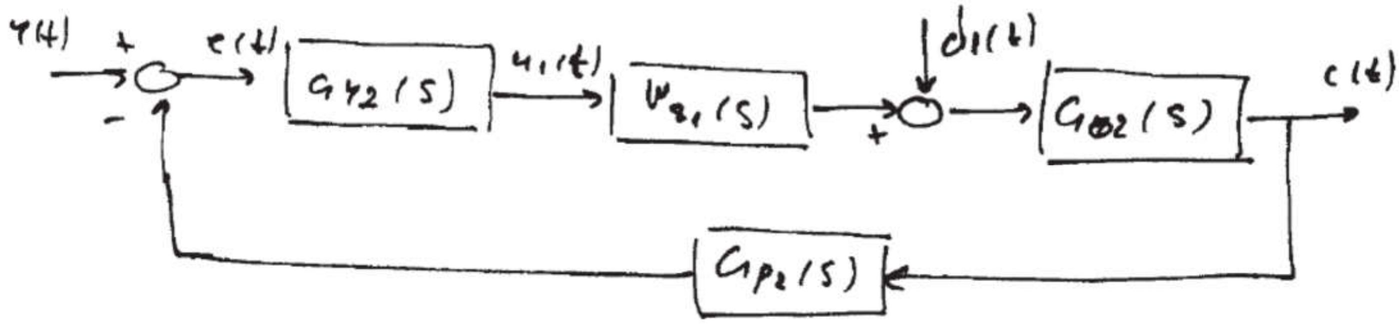


Rešenje:

Ovaj SBD nalazi primenu u regulaciji elektromotornih pogona.

$$C_1(s) = W_{s1}(s)U_1(s) + W_{sd1}(s)D(s) = W_{s1}(s)U_1(s) + D_1(s)$$

$$W_{s1}(s) = \frac{G_{o1}(s)G_{r1}(s)}{1 + G_{o1}(s)G_{r1}(s)G_{p1}(s)} \; ; \quad W_{sd1}(s) = \frac{G_{o1}(s)}{1 + G_{o1}(s)G_{r1}(s)G_{p1}(s)} \; ; \quad D_1(s) = W_{sd1}(s)D(s)$$

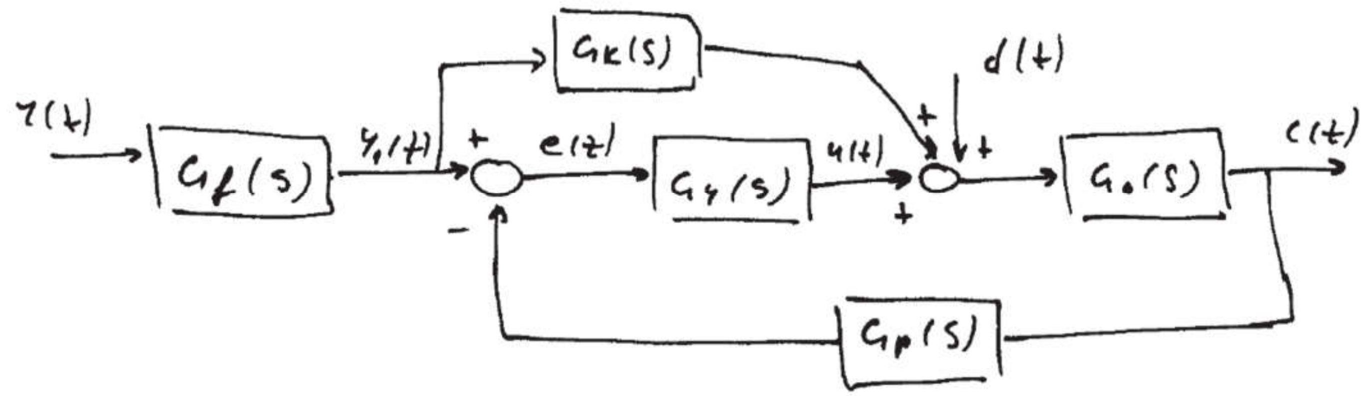


$$C(s)=\frac{G_{o2}(s)W_{s1}(s)G_{r2}(s)}{1+G_{o2}(s)W_{s1}(s)G_{r2}(s)G_{p2}(s)}R(s)+\frac{G_{o2}(s)}{1+G_{o2}(s)W_{s1}(s)G_{r2}(s)G_{p2}(s)}D_1(s)$$

$$C(s)=\frac{G_{o1}(s)G_{r1}(s)G_{o2}(s)G_{r2}(s)}{1+G_{o1}(s)G_{r1}(s)G_{p1}(s)+G_{o1}(s)G_{r1}(s)G_{o2}(s)G_{r2}(s)G_{p2}(s)}R(s)$$
$$+\frac{G_{o1}(s)G_{o2}(s)}{1+G_{o1}(s)G_{r1}(s)G_{p1}(s)+G_{o1}(s)G_{r1}(s)G_{o2}(s)G_{r2}(s)G_{p2}(s)}D(s)$$

$$E(s)=\frac{1+G_{o1}(s)G_{r1}(s)G_{p1}(s)}{1+G_{o1}(s)G_{r1}(s)G_{p1}(s)+G_{o1}(s)G_{r1}(s)G_{o2}(s)G_{r2}(s)G_{p2}(s)}R(s)$$
$$-\frac{G_{o1}(s)G_{o2}(s)}{1+G_{o1}(s)G_{r1}(s)G_{p1}(s)+G_{o1}(s)G_{r1}(s)G_{o2}(s)G_{r2}(s)G_{p2}(s)}D(s)$$

7.4. Na slici je prikazan SBD regulacionog sistema sa prefiltrom i feedforward prenosnom kompenzacijom. Naći karakteristične funkcije prenosa.



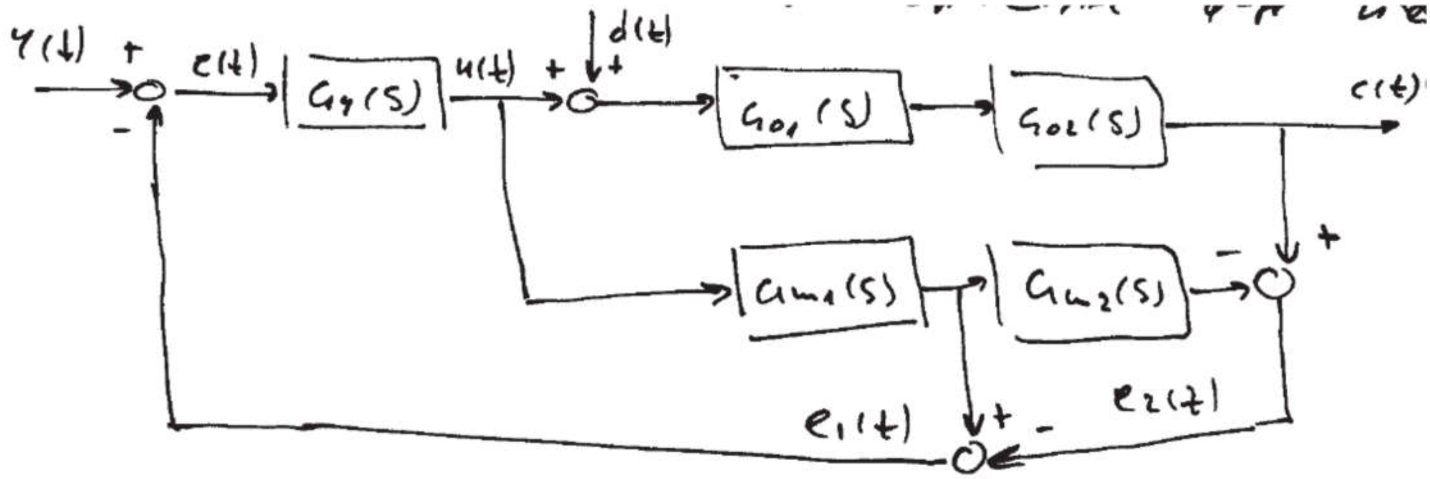
Rešenje:

$$C(s)=G_o(s)\left[D(s)+G_r(s)E(s)+G_k(s)G_f(s)R(s)\right]\;;\quad E(s)=G_f(s)R(s)-G_p(s)C(s)$$

$$C(s)=G_o(s)D(s)+G_o(s)G_r(s)G_f(s)R(s)-G_o(s)G_r(s)G_p(s)C(s)+G_o(s)G_k(s)G_f(s)R(s)$$
$$C(s)\left[1+G_o(s)G_r(s)G_p(s)\right]=G_o(s)G_f(s)\left[G_r(s)+G_k(s)\right]R(s)+G_o(s)D(s)$$
$$C(s)=\frac{G_o(s)G_f(s)\left[G_r(s)+G_k(s)\right]}{1+G_o(s)G_r(s)G_p(s)}R(s)+\frac{G_o(s)}{1+G_o(s)G_r(s)G_p(s)}D(s)$$

$$E(s)=\frac{G_f(s)\left[1-G_o(s)G_p(s)G_k(s)\right]}{1+G_o(s)G_r(s)G_p(s)}R(s)-\frac{G_p(s)G_o(s)}{1+G_o(s)G_r(s)G_p(s)}D(s)$$

7.5. Na slici je prikazan SBD klasičnog regulacionog sistema sa Smitovim prediktorom. Naći karakteristične funkcije prenosa.



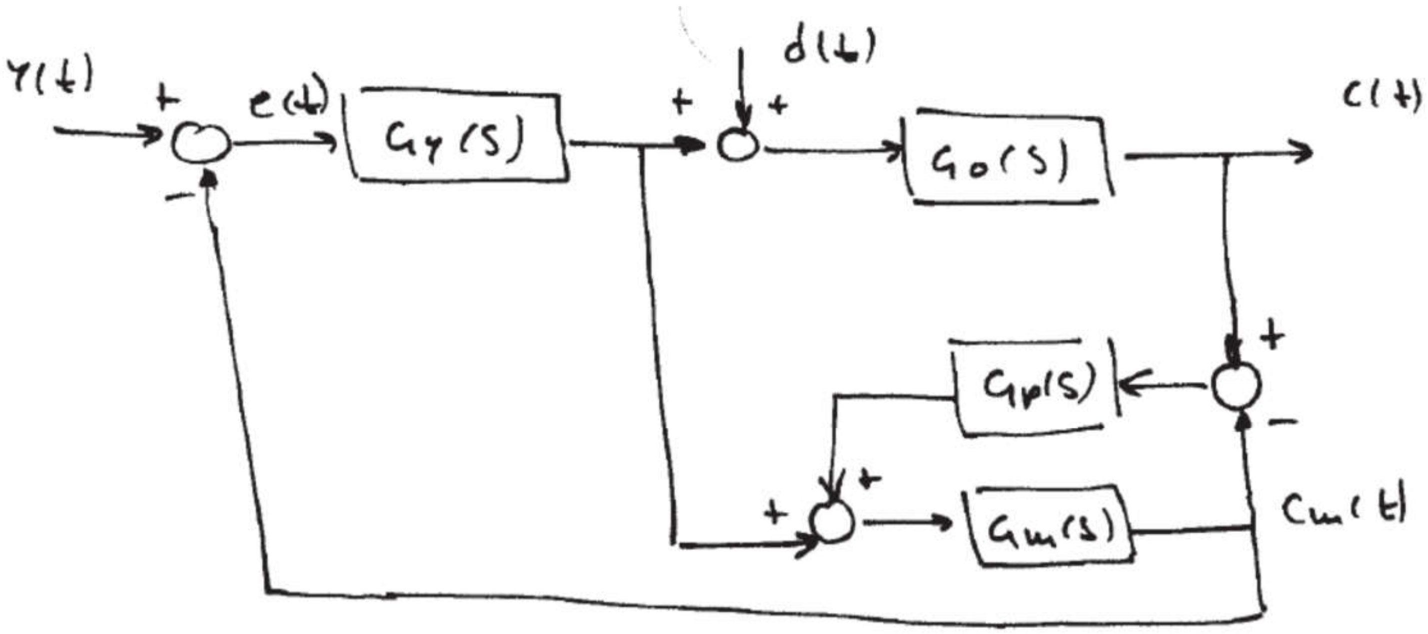
Rešenje:

Ovaj SBD se primenjuje kod sistema sa transportnim kašnjenjem.

$$E(s)=R(s)-E_1(s);\quad C(s)=G_{o1}(s)G_{o2}(s)D(s)+G_{o1}(s)G_{o2}(s)U(s);\quad \mathrm{U}(s)=G_r(s)E(s)$$
$$E_1(s)=G_{m1}(s)U(s)-E_2(s);\quad E_2(s)=C(s)-G_{m1}(s)G_{m2}(s)U(s)$$

$$C(s)=\frac{G_{o1}(s)G_{o2}(s)G_r(s)}{1+G_{m1}(s)G_r(s)+G_r(s)\left[G_{m1}(s)G_{m2}(s)-G_{o1}(s)G_{o2}(s)\right]}R(s)$$
$$+\frac{G_{o1}(s)G_{o2}(s)\left[1+G_{m1}(s)G_r(s)+G_{m1}(s)G_{m2}(s)G_r(s)\right]}{1+G_{m1}(s)G_r(s)+G_r(s)\left[G_{m1}(s)G_{m2}(s)-G_{o1}(s)G_{o2}(s)\right]}D(s)$$
$$E(s)=Domaći$$

7.6. Na slici je prikazan SBD regulacionog sistema sa opserverom. Naći karakteristične funkcije prenosa.



Rešenje:

$$C(s)=G_o(s)\left[D(s)+G_r(s)E(s)\right]\ ;\quad E(s)=R(s)-C_m(s)$$

$$C_m(s)=G_m(s)\left[G_p(s)\left(C(s)-C_m(s)\right)+G_r(s)E(s)\right]$$

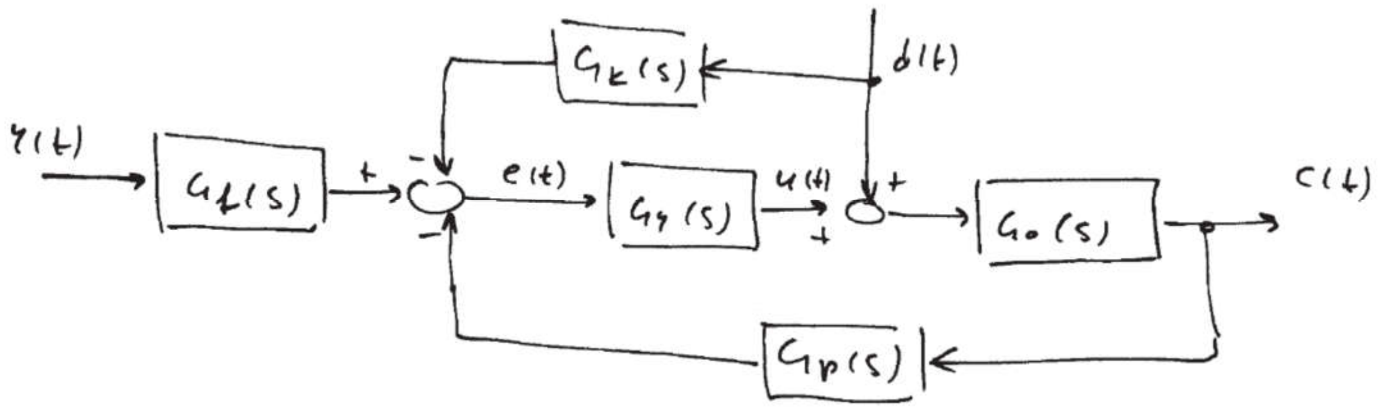
$$C_m(s)=\frac{G_m(s)G_p(s)}{1+G_m(s)G_p(s)}C(s)+\frac{G_m(s)G_r(s)}{1+G_m(s)G_p(s)}E(s)$$

$$E(s)=\frac{1+G_m(s)G_p(s)}{1+G_m(s)\left[G_p(s)+G_r(s)\right]}R(s)-\frac{G_m(s)G_p(s)}{1+G_m(s)\left[G_p(s)+G_r(s)\right]}C(s)$$

$$C(s)=\frac{G_o(s)G_r(s)\left[1+G_m(s)G_p(s)\right]}{1+G_m(s)\left[G_p(s)+G_r(s)+G_o(s)G_r(s)G_p(s)\right]}R(s)$$
$$+\frac{G_o(s)+G_o(s)G_m(s)\left[G_p(s)+G_r(s)\right]}{1+G_m(s)\left[G_p(s)+G_r(s)+G_o(s)G_r(s)G_p(s)\right]}D(s)$$

$$E(s)=\frac{1+G_m(s)G_p(s)}{1+G_m(s)\left[G_p(s)+G_r(s)+G_o(s)G_r(s)G_p(s)\right]}R(s)$$
$$-\frac{G_o(s)G_m(s)G_p(s)}{1+G_m(s)\left[G_p(s)+G_r(s)+G_o(s)G_r(s)G_p(s)\right]}D(s)$$

7.7. Na slici je prikazan SBD regulacionog sistema sa otklanjanjem poremećaja i prefiltrom. Naći karakteristične funkcije prenosa.



Rešenje:

$$C(s)=G_o(s)\left[D(s)+G_r(s)E(s)\right]\ ;\quad E(s)=G_f(s)R(s)-G_p(s)C(s)-G_k(s)D(s)$$

$$C(s)=G_o(s)D(s)+G_o(s)G_r(s)G_f(s)R(s)-G_o(s)G_r(s)G_p(s)C(s)-G_o(s)G_r(s)G_k(s)D(s)$$

$$C(s)\left[1+G_o(s)G_r(s)G_p(s)\right]=G_o(s)G_r(s)G_f(s)R(s)+G_o(s)\left[1-G_r(s)G_k(s)\right]D(s)$$

$$C(s)=\frac{G_o(s)G_r(s)G_f(s)}{1+G_o(s)G_r(s)G_p(s)}R(s)+\frac{G_o(s)\left[1-G_r(s)G_k(s)\right]}{1+G_o(s)G_r(s)G_p(s)}D(s)$$

$$E(s)=\frac{G_f(s)}{1+G_o(s)G_r(s)G_p(s)}R(s)-\frac{G_k(s)+G_p(s)G_o(s)}{1+G_o(s)G_r(s)G_p(s)}D(s)$$